GUAM'S REEFS AND BEACHES
PART II. TRANSECT STUDIES

Edited by

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UNIVERSITY OF GUAM MARINE LABORATORY

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Cover illustration: An abstraction of the transect line and quadrats through algae, corals and holothurians drawn by Leonor Lange-Moore.

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INTRODUCTION

by

Richard H. Randall

Background and Objectives

These reef transect studies are a continuation of the investigation of Guam's reefs and beaches initiated in May 1976, for the Guam Coastal Management Program. The objective of the first study was twofold, with the first to provide baseline information on Guam's coastal region by mapping the beaches, rocky shorelines, mangrove swamps, river estuaries, and reef-flat platforms, and the second to map the general distribution of corals, sea grasses, and sediments on the reef-flat platforms. These studies led to the publication of an "Atlas of Reefs and Beaches of Guam" by Randall and Eldredge (1976) with an appendix on "Mangroves and Estuaries" by Wilder (1977).

The present reef transect studies constitute the first part of a second phase of reef investigations which encompass more intensive regional studies. The overall objectives of the regional studies are to provide biological assessments on the reef-flat platforms in selected marine habitats and to evaluate the data and present them in a useable fashion. The data will be of value in characterizing and defining trends in physical, chemical, and biological conditions in the marine environment and to establish baseline conditions for determining water quality standards, identifying sources of pollution, and providing a basis for the classification or reclassification of inshore marine waters. The data will also be useful in establishing sound planning and management practices of these reef areas.

Baseline assessments of a biological nature are receiving increased attention with the promulgation of environmental protection standards and land-use rules and regulations. Such data are organism-dependent and can provide the most practical method to assess the impact of island development and pollution.

Baseline assessments should whenever possible be conducted over an extended period of time, such as an annual cycle, in order to characterize the diversity and stability of marine systems. Additionally, the assessment program should be carried out in a number of different environments. Locations which reflect the terrestrial contribution to the reef system near mouths of major rivers and estuaries and those which are affected by water escaping from the northern freshwater lens system should be studied. Additionally, areas which are presently or potentially subject to coastal development or pollution input from urban, industrial, and agricultural uses, as well as pristine areas should be included in the study.

Transect studies were conducted on the reef-flat platforms at five locations around Guam to cover the variety of environmental settings and present and potential coastal developmental areas as described above (Fig. 1). The five areas are: 1) Tumon Bay, which represents a relatively undisturbed area with moderate, and possibly increasing, coastal development along the northern limestone plateau-land that is not subject to surface run off except by springs and seeps from the freshwater lens system and a few storm drains (Fig. 2), 2) East Agana Bay, which represents an area already impacted by heavy coastal development and pollution that is subject to a limited amount of surface runoff from the Agana River at the southern part and seepage from the freshwater lens system along the northern part (Fig. 3), 3) Agat Bay, which represents an area of moderate to heavy coastal development and pollution that is subject to surface runoff from the adjacent volcanic mountain slopes along the southern part and some freshwater lens seepage along the northern part from the linestone plateau-land of Orote Peninsula (Fig. 4), 4) Fouha Bay, which represents a small reef and coastal embayment area subject to considerable amounts of freshwater runoff and sedimentation from the La Sa Fua River drainage basin in the volcanic mountain land of southwestern Guam (Fig. 5), and 5) Ylig Bay, which represents a large reef and coastal embayment area subject to heavy freshwater runoff and sedimentation from the Ylig River drainage basin in the volcanic mountain land of southeastern Guam (Fig. 6). Three transects were established across each of the reef-flat platforms at Tumon, Agana, and Agat Bays; and four to seven transects across the embayment reef-flat platforms at Fouha and Ylig Bays, respectively (Figs. 2-6).

Data collected on these transects consist of the quantitative distribution and community structure analyses of benthic organisms, including corals, algae, and other macroinvertebrates. The various sampling techniques and methods used to quantify the marine organisms are presented by each author in other parts of the report for each of the respective community groups.

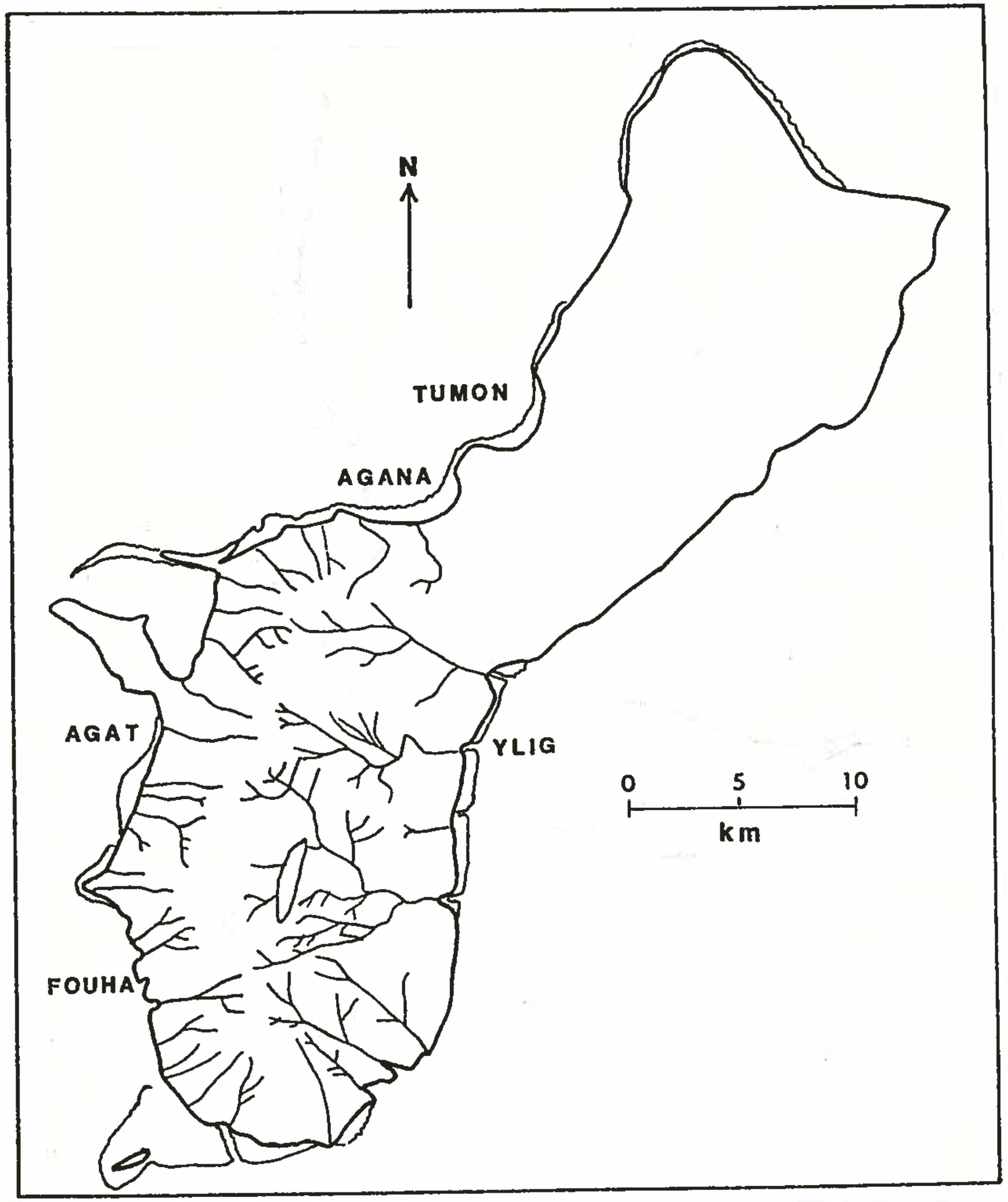

Fig. 1 . Map of Guam showing the five bays where transects were run.

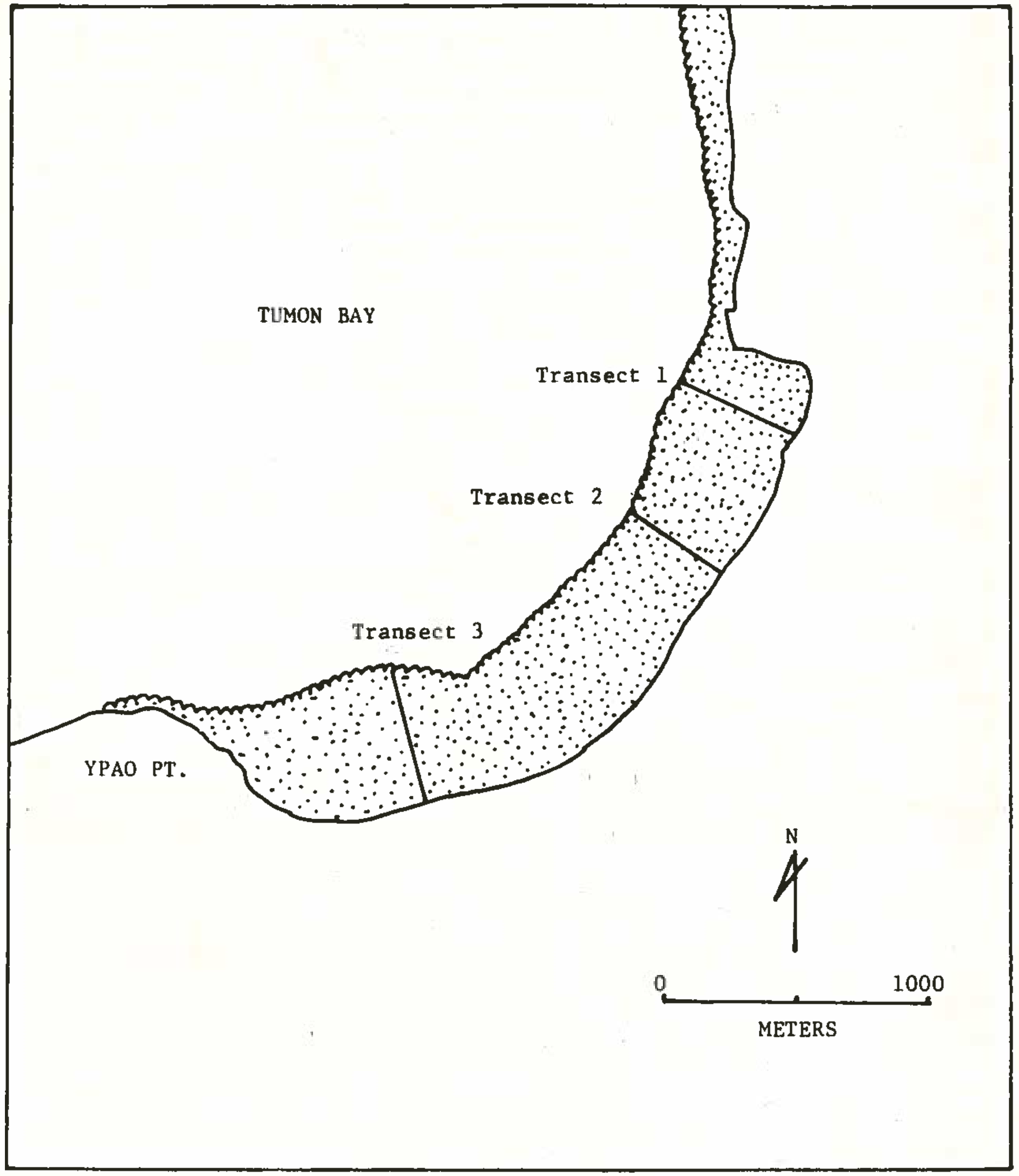

Fig. 2. Transect locations at Tumon Bay. Reef-flat platform is stippled.

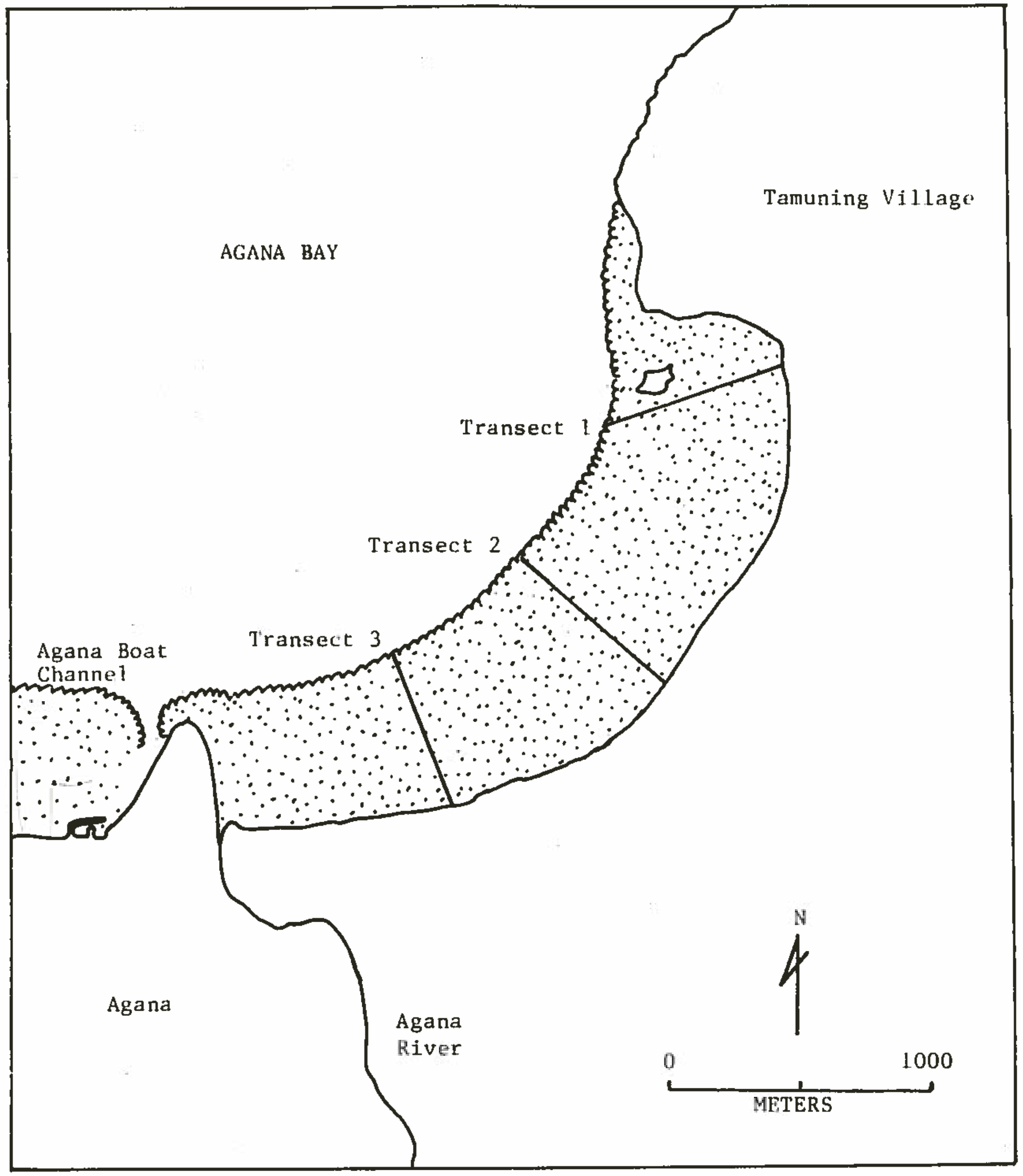

Fig. 3. Transect locations at Agana Bay. Reef-flat platform is stippled.

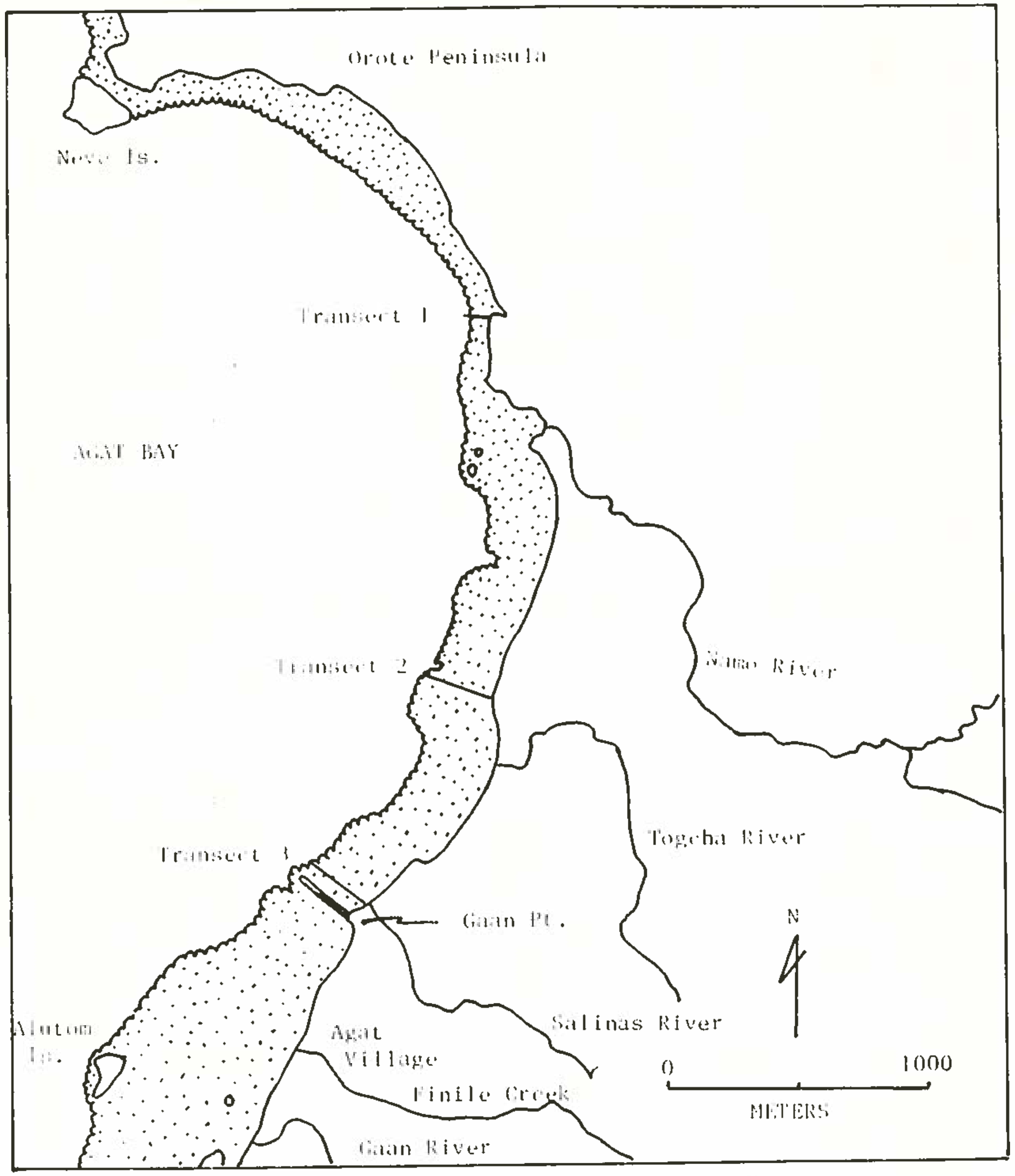

Fig. 4. Transect locations at Agat Bay. Reef-flat platform is stippled.

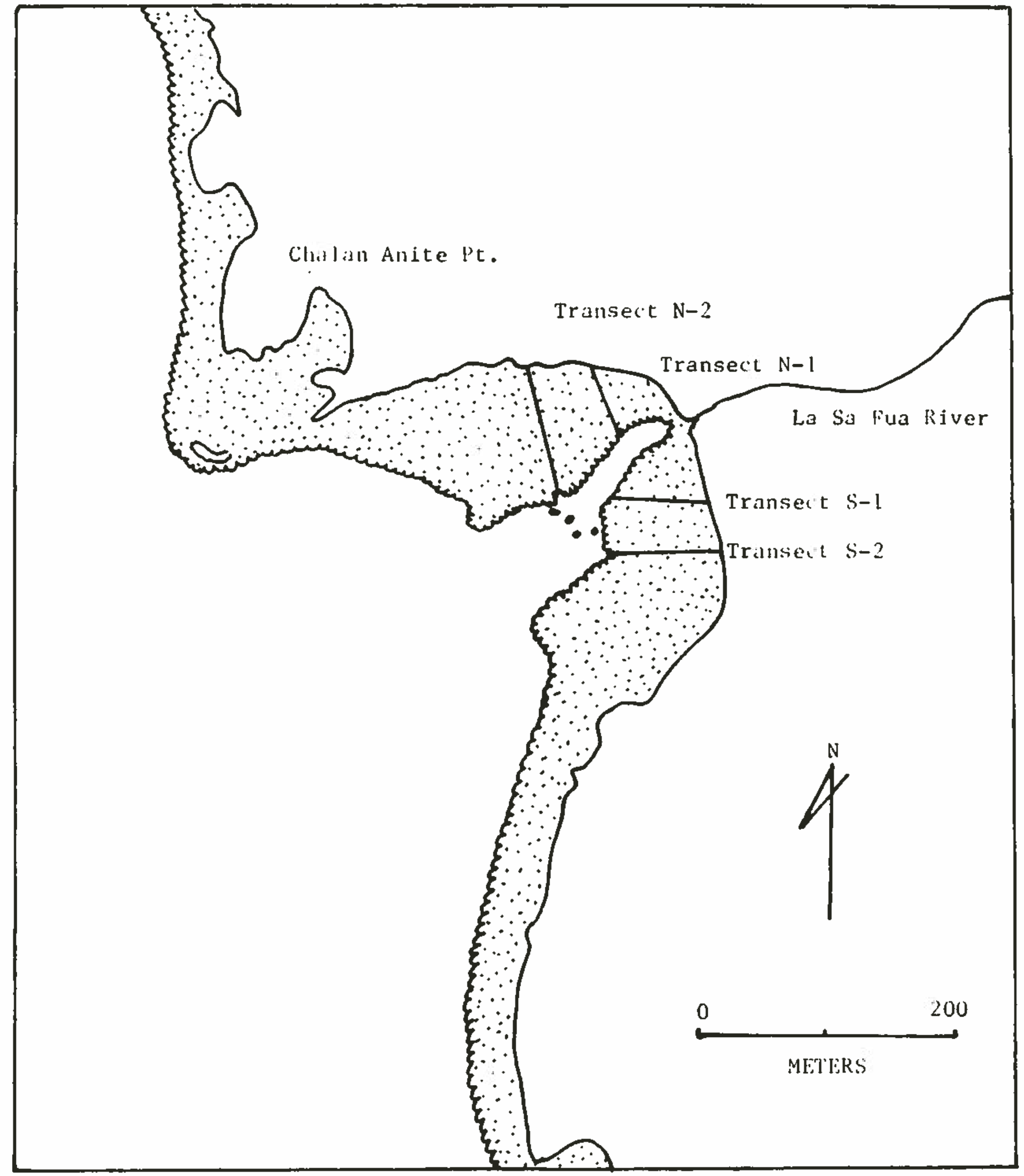

Fig. 5. Transect locations at Fouha Bay. Reef-flat platform is stippled.

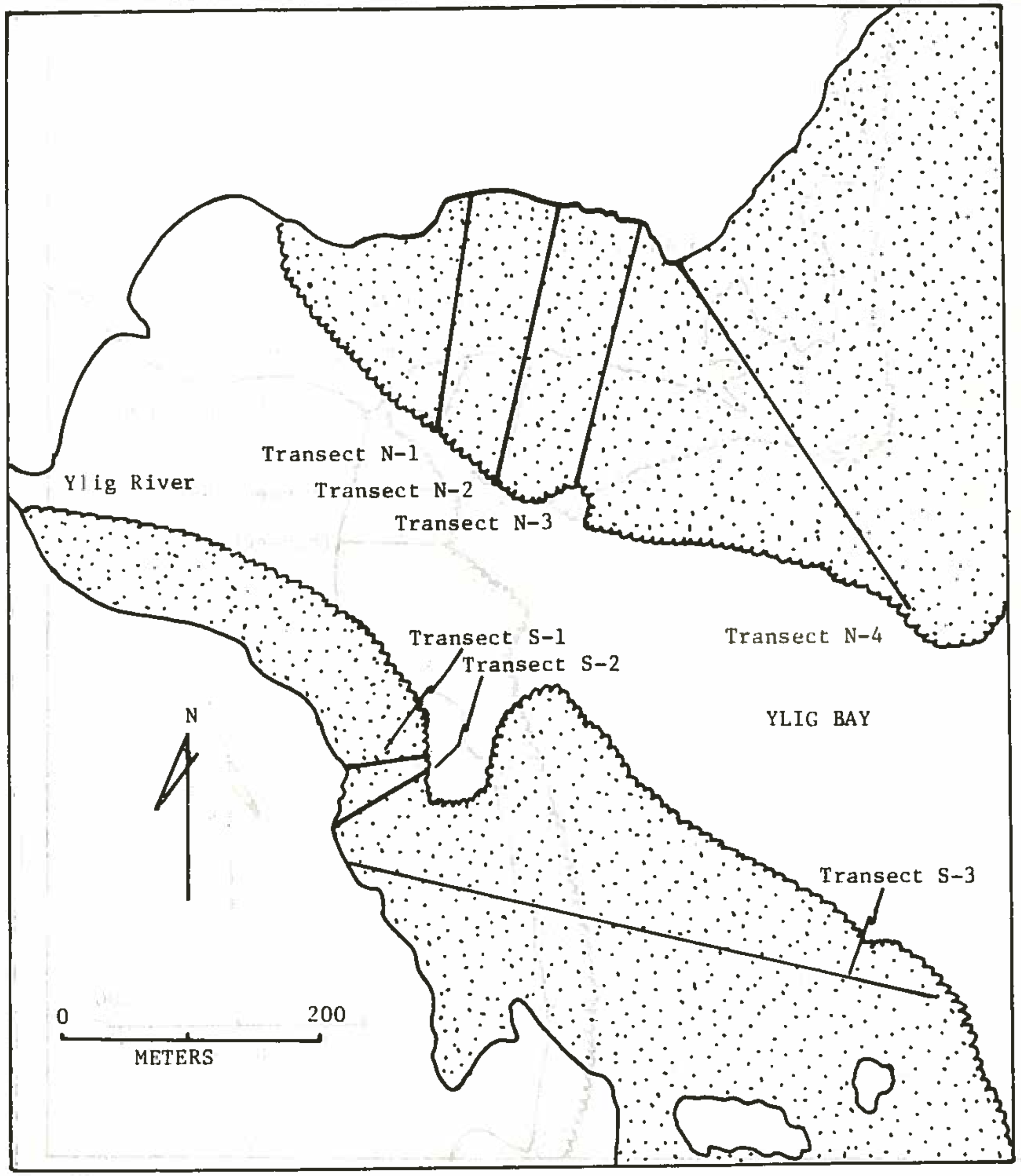

Fig. 6. Transect locations at Ylig Bay. Reef-flat platforms are stippled.

MARINE PLANTS

by

Roy T. Tsuda, Dennis R. Lassuy, and Steven E. Hedlund

Introduction

In the past, zonational and seasonal studies on the marine benthic plants of Guam have been restricted to the brown algae. Tsuda (1972) provides zonational and seasonal information on the two species of Sargassum on the reef flats of Guam, and concludes that the appearance of Sargassum cristaefolium (= S. duplicatum) coincides with the start of the dry season and that its disappearance is probably attributable to the onset of the dry season as well as to the exposure from the sun during low spring tides. In another paper on the seasonal aspects of the brown algae on Guam, Tsuda (1974) again states that the obvious factor influencing seasonality of brown algae on the reef flats "... is the desiccation of these species when exposed to prolonged low spring tides". The months during which low spring tides occur between 1000 and 1400 are May to August. It is during these months that the algae are exposed to the greatest intensity of the sun. The zonational patterns of selected species of brown algae are characterized for Pago Bay (Tsuda, 1977).

The objective of the marine plant phase of the overall reef flat study was to characterize the species composition during two different seasons within five bays under various environmental stress.

Methods

The sampling method used in this study consisted of quantifying the marine benthic plants along 12 transects in five bays at two different times of the year (Table 1). The periods of sampling coincided with the months when extreme low spring tides occurred on the reef flat (April to July, 1977) during the day and during the months when extreme low spring tides occurred at night (November to December, 1977; January, 1978). In this manner, the differences in the marine plant assemblages on the reef flat could be compared in terms of seasonality and information on their zonation from shore to reef margin could be obtained.

The benthic plant assemblages were analyzed by placing a small gridded quadrat (25 cm X 25 cm) at 1-m intervals along the length of the transect. The quadrat frame consisted of 25 squares and, thus, provided 16 interior points where the grid line intersected. Each species was recorded at every point at which it occurred. If no alga was found under the points, then whatever was present, e.g., sand, dead coral, live coral, was recorded. In some cases, the fine filamentous-like algae were impossible to identify in the field and were simply recorded as "turf". In other instances, the filaments were long enough to collect and specimens were brough back to the laboratory for identification.

Percent cover was obtained by dividing the number of points at which the species was recorded as a percent of the total number of points per 10-m segment or 10 quadrats, i.e., n/160 x 100 = percent cover.

Results and Discussion

Species Composition: A total of 75 species of marine benthic plants (Table 2) were quantified on the 12 transects in the five bays. The number of species within each Dividion is as follows - Cyanophyta (4 spp.), Chlorophyta (28 spp.), Phaeophyta (11 spp.), Rhodophyta (29 spp.), and Anthophyta (3 spp.). These species numbers represent 25%, 38%, 41%, and 100%, respectively, of the known species in each Division recognized in Guam.

When one examines the species assemblages quantified on the transects in each of the bays (Table 3), it becomes apparent that none of the bays have a homogeneous algal composition. The coefficient of community (Oosting, 1956) ranged from a low of 28% in Tumon Bay to a high of 72% in Fouha Bay. The lower coefficient of community values of Tumon and East Agana Bays can be partly explained by the use of three transects in the analyses, as opposed to only two transects for Agat, Fouha, and Ylig Bays. If the species assemblages of Transects 1 and 3 in Tumon Bay are analyzed, a slightly higher value of 38% is obtained as compared with the 28% obtained when three transects are analyzed. A much higher coefficient of community value of 68% is derived when only Transects 2 and 3 in East Agana Bay are considered.

Based on the above coefficient of community values, we cannot say that any one transect run in a single bay possesses the representative species assemblage for that bay. Thus, comparison of the five bays are based on all of the species quantified within a given bay.

Comparison of Species in the Five Bays: Of the 75 species quantified by the point-quadrat method, eleven species were common to all five bays (Table 4). In addition, only five of the 11 species were common to all 12 transects. The presence of *Microcoleus lyngbyaceus*, a ubiquitous blue-green alga, on all transects was not surprising. It is of interest to note that the other four species belonged to the Division Phaeophyta (brown algae) and that these same four species were also found on the transects in Pago Bay throughout the year (Tsuda, 1972, 1974).

If one considers as dominant only those species with 3% cover or greater on any one transect, we find the following numbers of species in each bay - Tumon (6 spp.), East Agana (4 spp.), Agat (11 spp.), Fouha (4 spp.), and Ylig (6 spp.). The species are listed in Table 5.

Zonation: The number of species and the percent cover of marine plants on each transect during the two sampling period are presented in Figures 1-9. There is a definite increase in species number and percent cover nearer the reef margin in the wider bays, i.e., Tumon Bay, East Agana Bay, and Agat Bay (Transect 2). This can be explained by the presence of the sandy substratum near shore which harbors fewer species. The sandy substrate is restricted to those species, especially the vascular plants and green algae, which possess modified attachment organs, e.g., creeping rhizomes as in *Halophila minor*, large sand-binding holdfasts, as in *Halimeda macroloba* and *Avrainvillea obscura*, and fibrous rhizoids as in *Enhalus acoroides*. The seagrass *Enhalus acoroides* was especially conspicuous on Transect 2 in Agat Bay. The May and December sampling revealed 25% and 26% cover on the inner half of the reef flat.

On the other hand, the number of species and the percent cover are more or less evenly distributed, from shore or inner reef flat to the reef margin in the narrower bays, i.e., Agat (Transect 1), Fouha, and Ylig, which possess reef rock as the major substrate.

Seasonality: Based on the histograms presented in Figs. 1-9, there seems to be little difference in the percent cover in seven of the 12 transects during the different sampling periods. On the other five transects (Transects 1 and 3 in Tumon Bay, Transects 1 and 2 in East Agana Bay, and Transect 1 in Agat Bay), there appears to be a higher percent cover of benthic plants during the months of November and December.

Cladophora fascicularis, a green alga, was the only species which occurred on three or more transects, and was found exclusively in the November and December samples. As seen on Table 2, there are several other species which were found only during one of the sample period, but these species are often quite rare (less than 1% cover).

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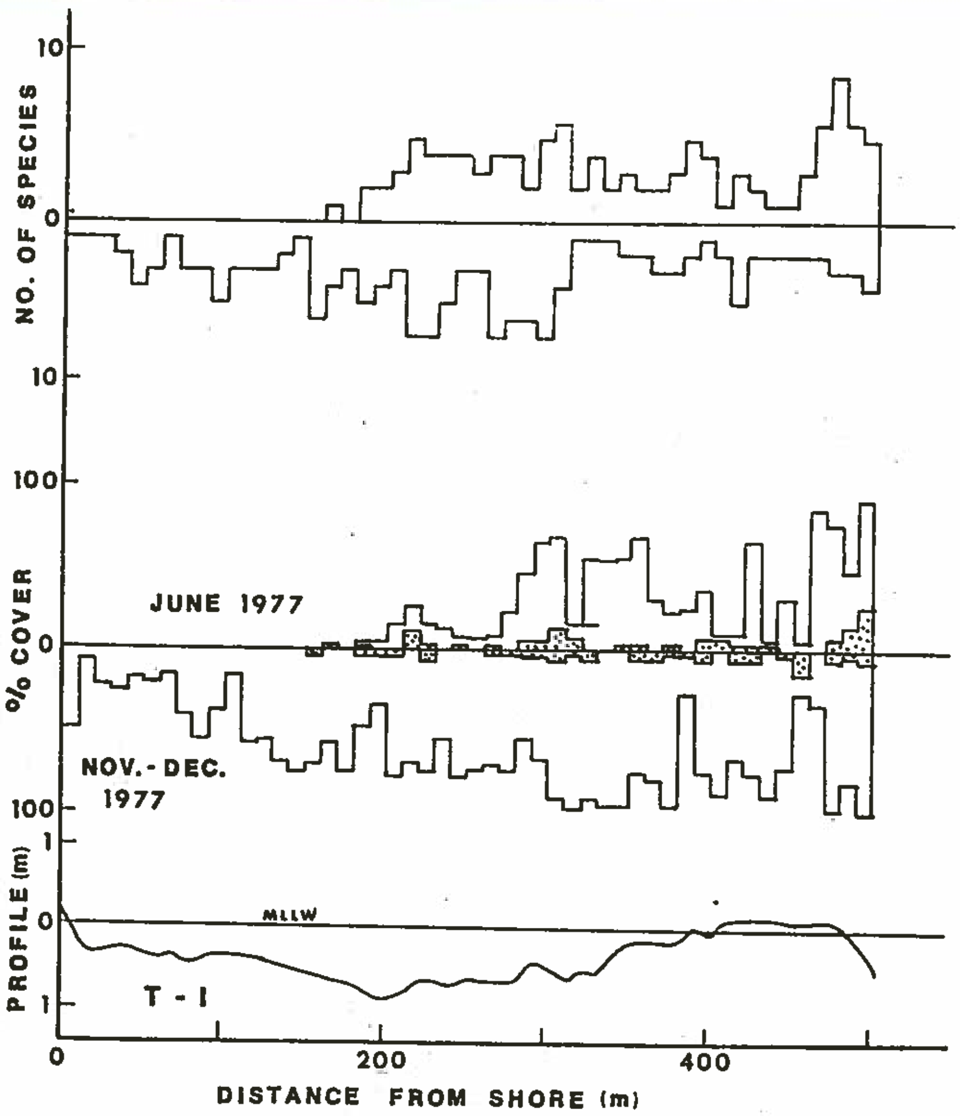

Fig. 1. Histograms showing the number of species and percent cover (stipled area represents coralline red algae) of marine plants quantified within 10-m intervals (.25 m wide) along Transect 1 (Tumon Bay) in June 1977 and November-December 1977. The water level is corrected to MLLW in relation to the reef profile.

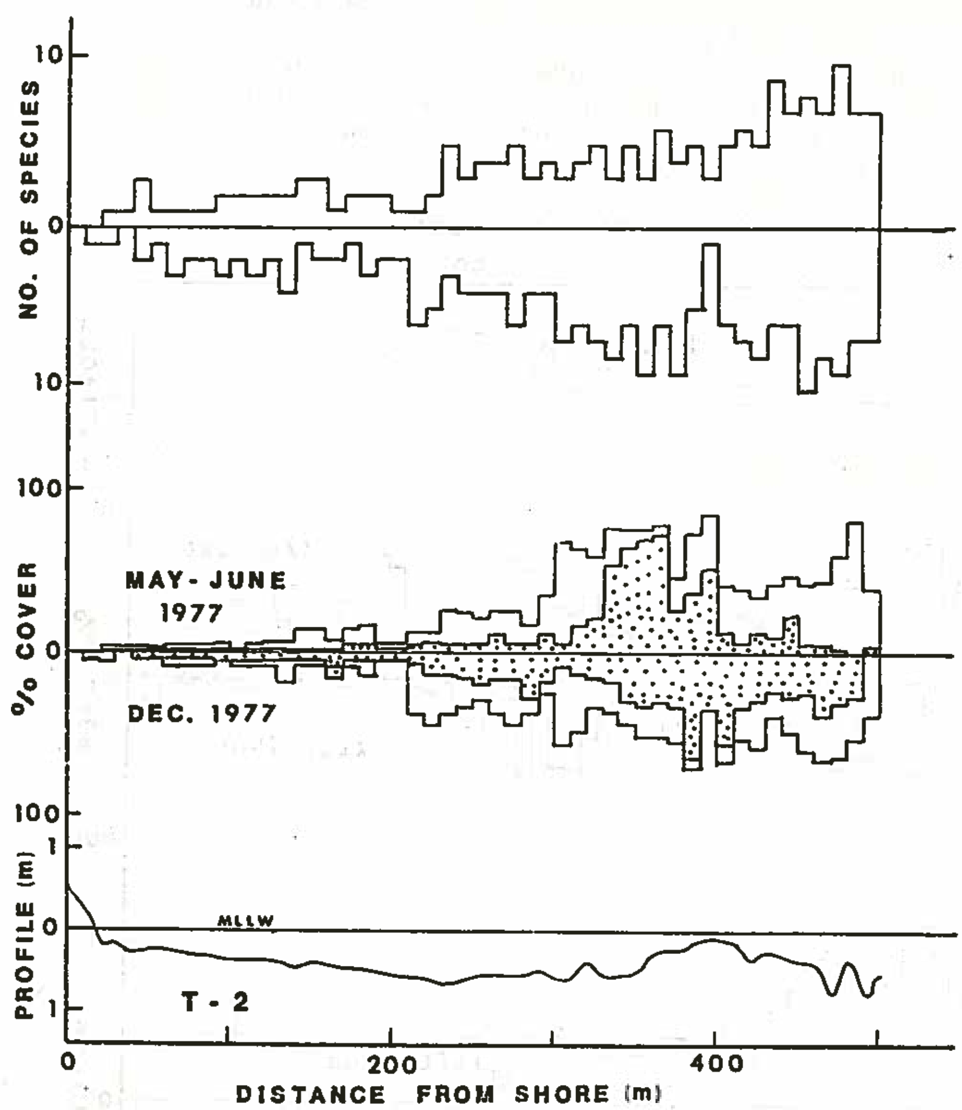

Fig. 2. Histograms showing the number of species and percent cover (stipled area represents coralline red algae) of marine plants quantified within 10-m intervals (.25 m wide) along Transect 2 (Tumon Bay) in May-June 1977 and December 1977. The water level is corrected to MLLW in relation to the reef profile.

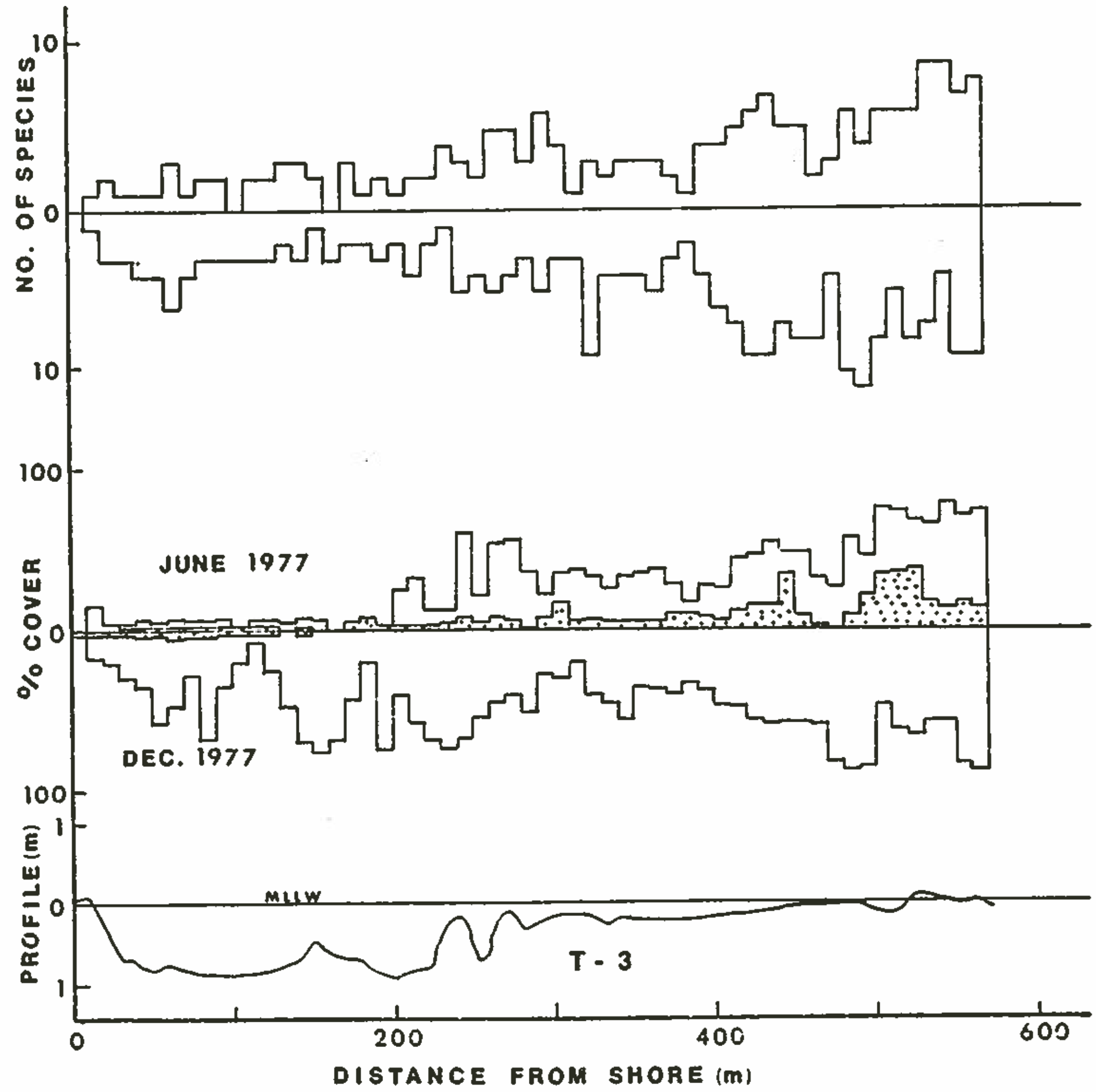

Fig. 3. Histograms showing the number of species and percent cover (stipled area represents coralline red algae) of marine plants quantified within 10-m intervals (.25 m wide) along Transect 3 (Tumon Bay) in June 1977 and December 1977. The water level is corrected to MLLW in relation to the reef profile.

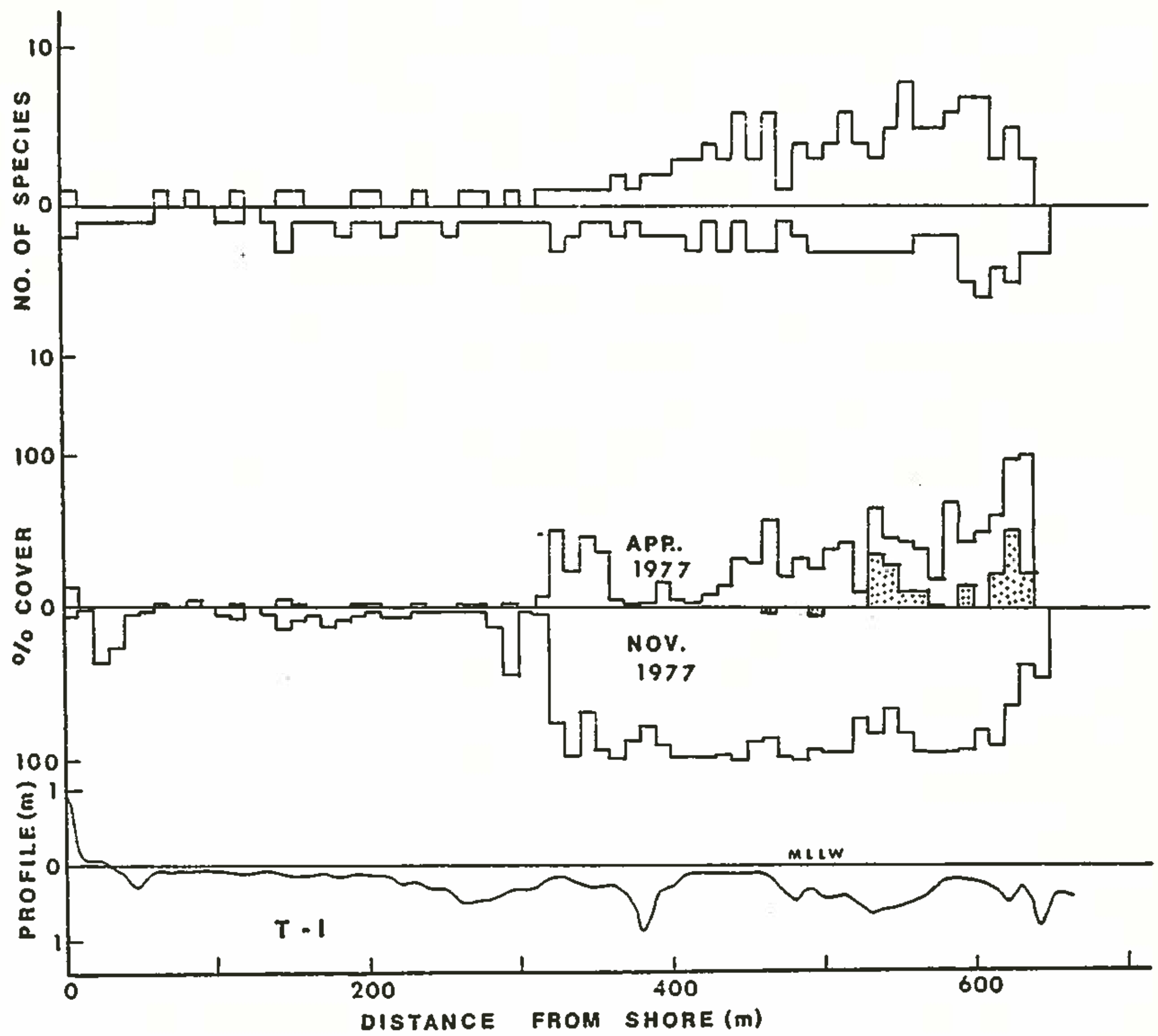

Fig. 4. Histograms showing the number of species and percent cover (stipled area represents coralline red algae) of marine plants quantified within 10-m intervals (.25 m wide) along Transect 1 (East Agana Bay) in April 1977 and November 1977. The water level is corrected to MLLW in relation to the reef profile.

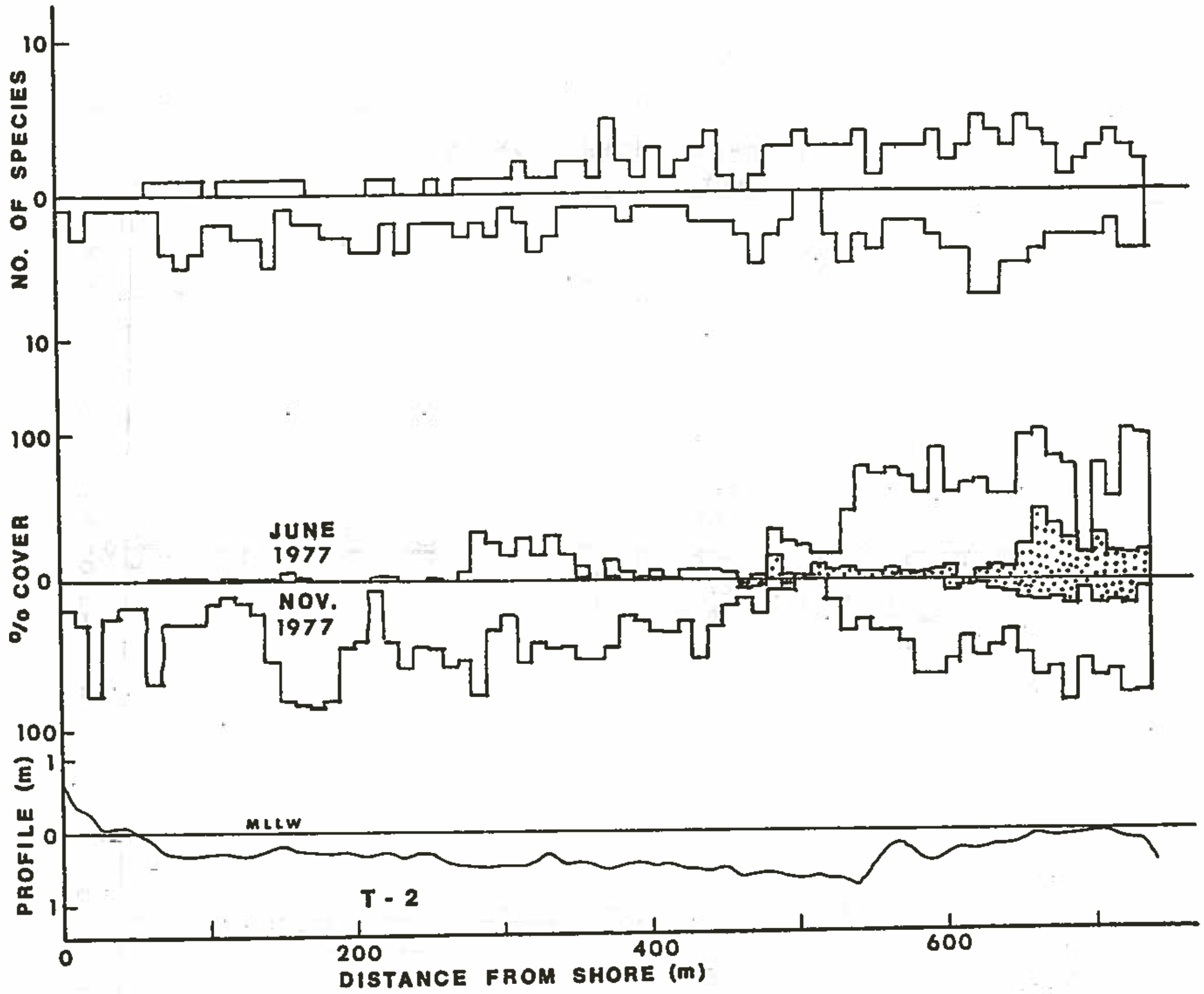

Fig. 5. Histograms showing the number of species and percent cover (stipled area represents coralline red algae) of marine plants quantified within 10-m intervals (.25 m wide) along Transect 2 (East Agana Bay) in June 1977 and November 1977. The water level is corrected to MLLW in relation to the reef profile.

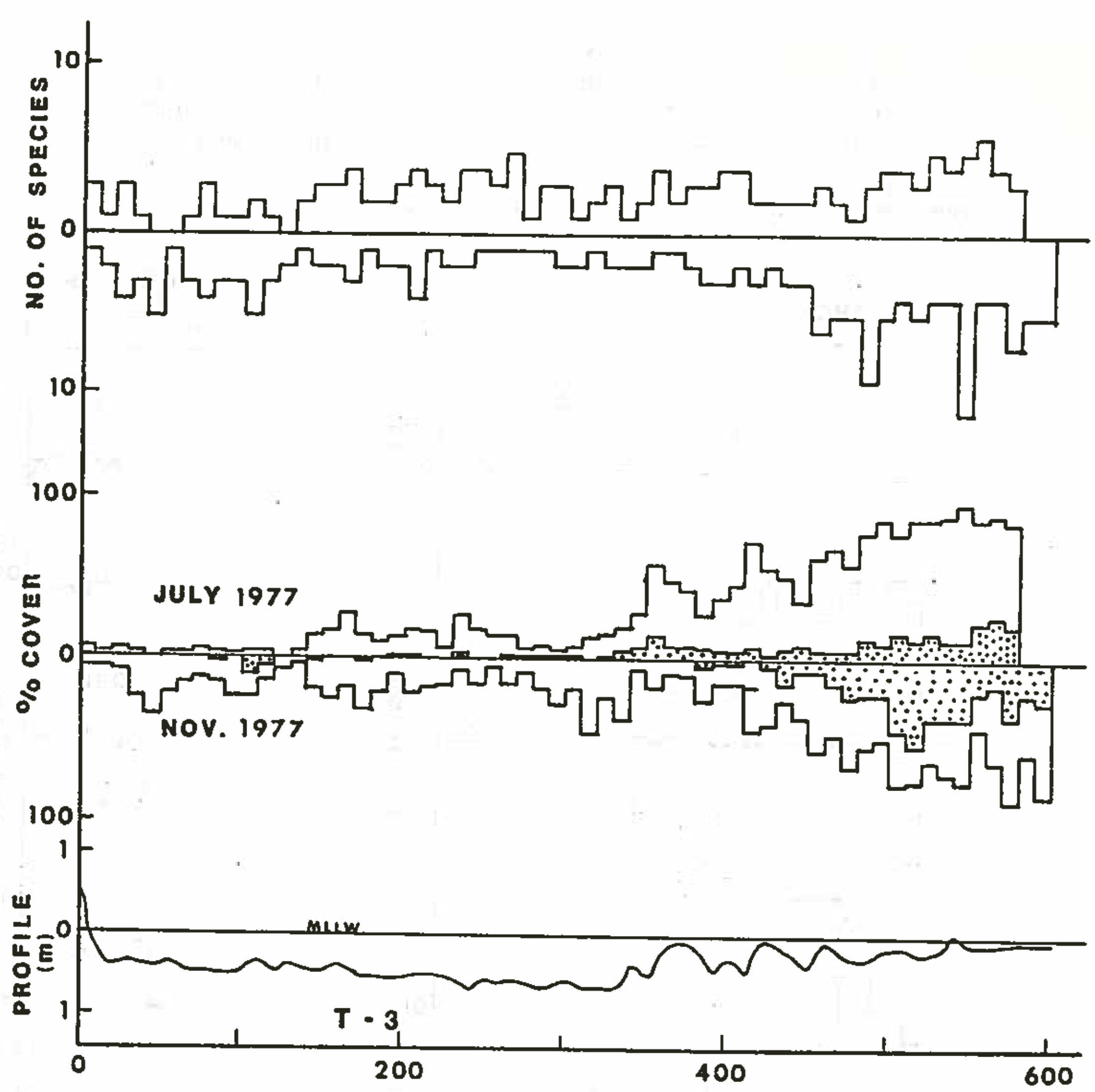

Fig. 6. Histograms showing the number of species and percent cover (stipled area represents coralline red algae) of marine plants quantified within 10-m intervals (.25 m wide) along Transect 3 (East Agana Bay) in July 1977 and November 1977. The water level is corrected to MLLW in relation to the reef profile.

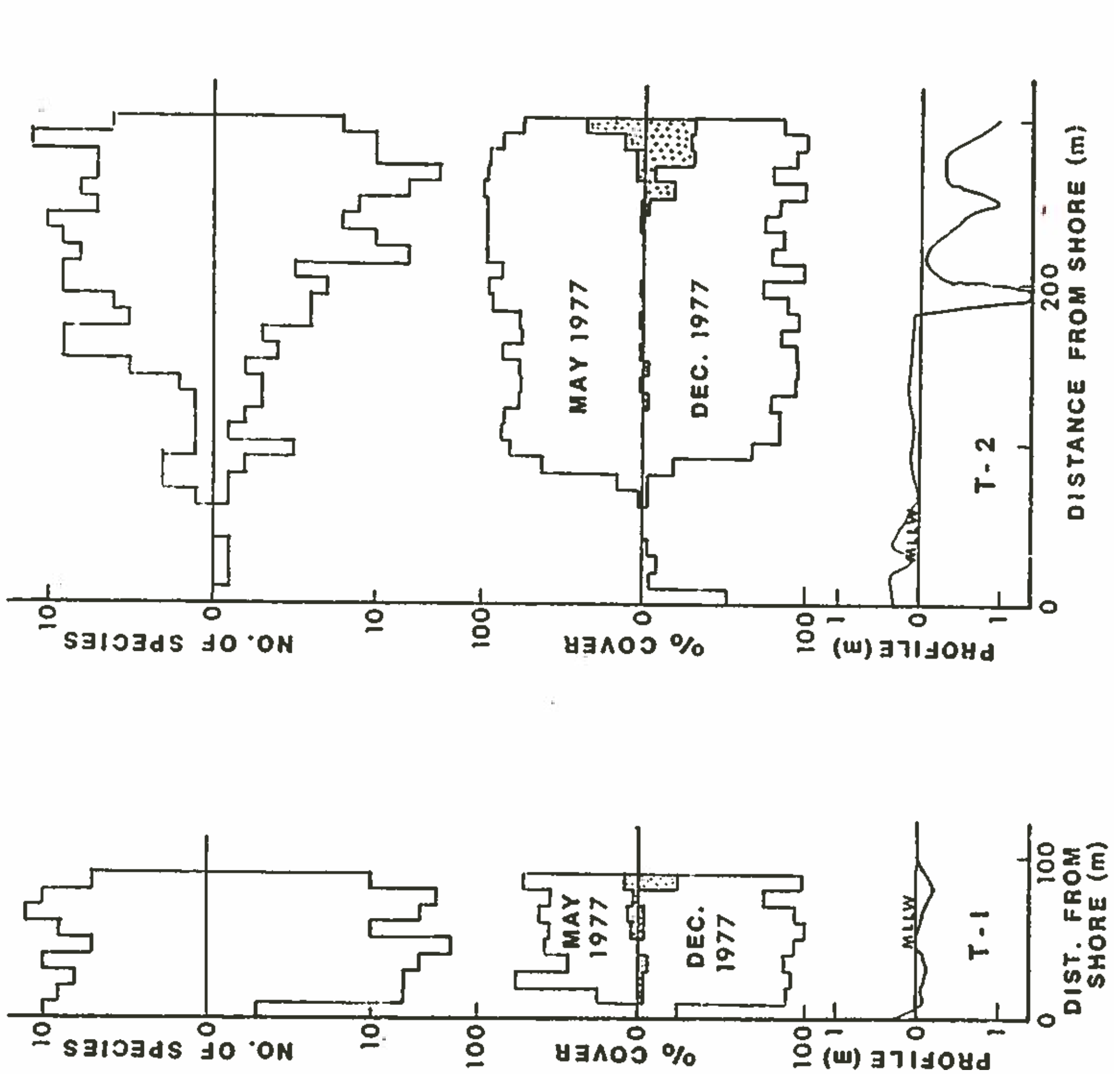

Fig. 7. Histograms showing the number of species and percent cover (stipled area represents coralline red algae) of marine plants quantified within 10-m intervals (.25 m wide) along Transects 1 and 2 (Agat Bay) in May 1977 and December 1977. The water level is corrected to MLLW in relation to the reef profile.

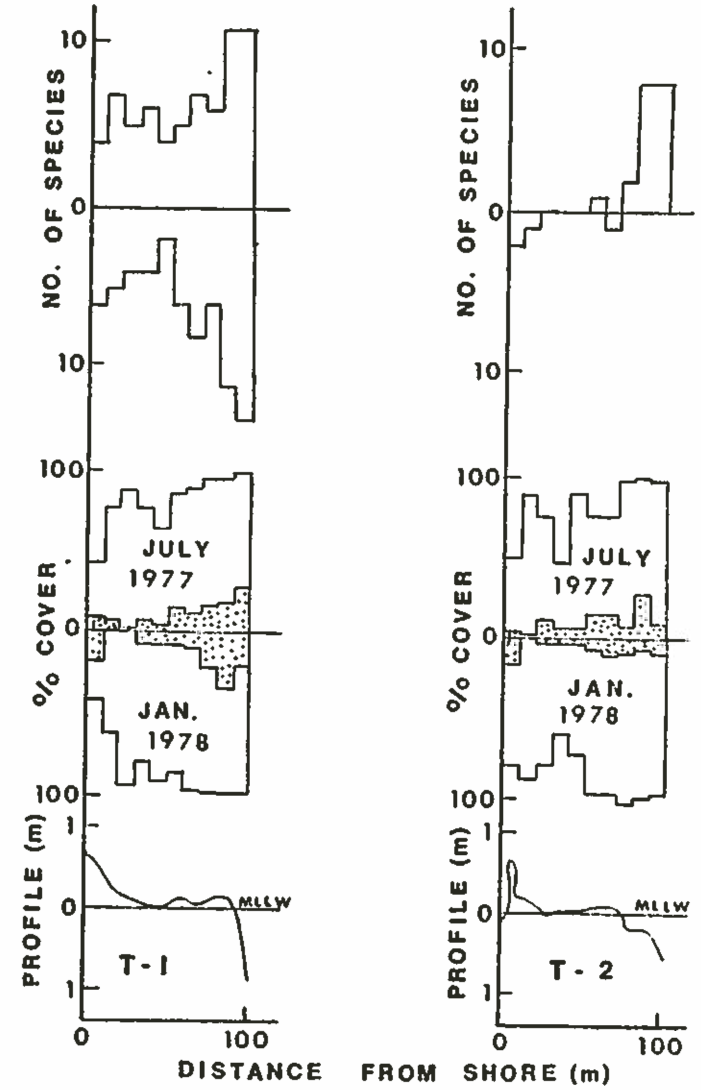

Fig. 8. Histograms showing the number of species and percent cover (stipled area represents coralline red algae) of marine plants quantified within 10-m intervals (.25 m wide) along Transects 1 and 2 (Fouha Bay) in July 1977 and January 1978. The water level is corrected to MLLW in relation to the reef profile.

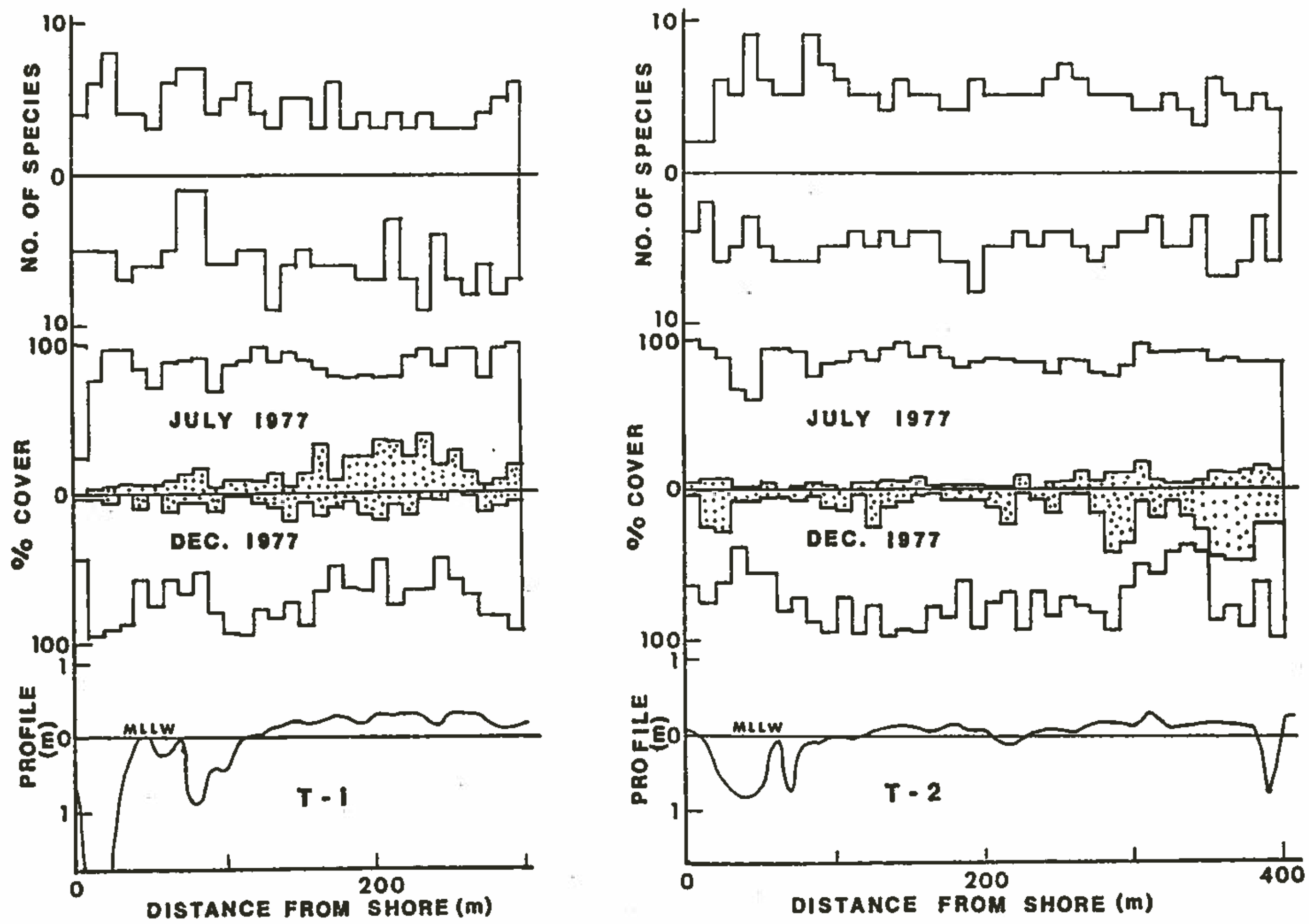

Fig. 9. Histograms showing the number of species and percent cover (stipled area represents coralline red algae) of marine plants quantified within 10-m intervals (.25 m wide) along Transects 1 and 2 (Ylig Bay) in July 1977 and December 1977. The water level is corrected to MLLW in relation to the reef profile.

Table 1. Location, length (m) and sampling dates of the 12 transects sampled for marine plants in Guam. See Fig. for location of each transect.

Bays and Transects	Location	Length (m)	Dates Sampled
TUMON BAY			
Transect 1	Off Guam Reef Hotel	500	June 20, 1977 Nov. 30; Dec. 4, 1977
Transect 2	Off Fujita Road	500	May 27, 31; June 2, 1977 Dec. 9, 10, 1977
Transect 3	Off Ipao Beach	570	June 8, 10, 1977 Dec. 5, 7, 8, 10, 1977
EAST AGANA BAY			
Transect 1	Alupang Cove	650	April 29, 1977 Nov. 16, 18, 1977
Transect 2	Off Storm Drainage	740	June 28, 1977 Nov. 21, 22, 1977
Transect 3	Off China Restaurant	600	July 19, 20, 1977 Nov. 22, 25, 28, 1977
AGAT BAY			
Transect 1	Off Rizal Beach	90	May 23, 1977 Dec. 15, 1977
Transect 2	Off Agat Cemetery	300	May 24, 1977 Dec. 15, 1977
FOUHA BAY			
Transect 1	North Side	100	July 27, 1977 Jan. 5, 1978
Transect 2	South Side	100	July 27, 1977 Jan. 5, 1978
YLIG BAY			
Transect 1	North Side	300	July 10,11, 1977 Dec. 13, 1977
Transect 2	South Side	400	July 10,11, 1977 Dec. 14, 1977

Table 2. Percent cover of marine plants based on 25 x 25 cm quadrat placed at meter interval along transect line. The values enclosed by parentheses represent percent cover values obtained during second sampling period.

Species	Tumon Bay			East Agana Bay			Agat Bay		Fouha Bay		Ylig Bay	
	1	2	3	1	2	3	1	2	1	2	1	2
	500	500	570	650	740	600	90	300	100	100	300	400
CYANOPHYTA												
Hormothamnion enteromorphoides Bornet & Flahault					<1	<1	(<1)		(<1)	<1(<1)	<1	
Microcoleus lyngbyaceus (Kutz.) Crouan	6(5)	<1(<1)	(2)	<1	<1(1)	<1	(<1)	<1(<1)	<1(<1)	12(1)	<1(<1)	<1
Schizothrix calcicola (Ag.) Gomont	<1(17)	<1(<1)	<1(16)	<1(40)	3(19)	< 1(10)		27	2(<1)	<1(<1)	2	<1(<1)
Schizothrix mexicana Gomont		(<1)	(<1)		<1(<1)	<1(<1)	(1)	(<1)	<1(<1)	(1)	<1(2)	<1(<1)
CHLOROPHYTA												
Acetabularia moebii Solms-Laubach			<1(<1)									<1
Avrainvillea lacerata Gepp		<1						<1				
Avrainvillea obscura J. Ag.				<1(<1)	<1(<1)	(<1)	<1	<1(<1)				<1
Boergesenia forbesii (Harv.) Feldmann												(<1)
Boodlea composita (Harv.) Brand	<1(<1)	(1)			<1(<1)	(<1)				(<1)	<1(<1)	<1
Bryopsis pennata Lamx.		<1(<1)		(1)								
Caulerpa cupressoides (West) C. Ag.		(<1)		<1			(1)	<1(<1)				
Caulerpa racemosa (Forsskal) J. Ag.		<1(<1)	<1(<1)	3	<1		5(8)	1(2)	<1(1)	<1(<1)		<1
Caulerpa serrulata (Forsskal) J. Ag.	<1			<1			(<1)					
Caulerpa sertularioides (Gmel.) Howe	(<1)	<1					(<1)					
Chlorodesmis fastigiata (C. Ag.) Ducker		<1								<1		
Cladophora fascicularis (Mertens) Kutz.	(1)				(<1)		(4)					
Cladophora sp.	<2										(<1)	
Cladophoropsis membranacea (Ag.) Boerg.			(1)				(1)					
Cladophoropsis sp.	<1											<1
Dictyosphaeria cavernosa (Forsskal) Boerg.	(<1)	<1(<1)	(<1)	<1(<1)		(<1)	<1				(<1)	(<1)
Dictyosphaeria versluysii Weber van Bosse		<1	<1	<1		<1	<1(<1)	<1(<1)	<1(<1)	<1(<1)		
Enteromorpha clathrata (Roth) Ag.	(3)	(<1)	(<1)	(2)	(4)	<1(<1)		(<1)				
Halimeda discoidea Decaisne							1(<1)	<1(<1)	(<1)	(<1)		
Halimeda incrassata (Ellis) Lamx.							(<1)	<1				
Halimeda macroloba Decaisne	<1(<1)			<1(<1)	<1(<1)	<1(<1)	<1(<1)	<1(<1)			<1	<1
Halimeda opuntia (L.) Lamx.	<1(1)	4(2)	2(<1)	<1(<1)	<1(<1)	<1(<1)	8(4)	3(3)			<1(<1)	3(1)
Neomeris annulata Dickie		(<1)		<1	<1(<1)	(<1)	(1)		<1	(<1)		
Rhizoclonium samoense Setchell		<1	<1				2	<1	(<1)			
Valonia aegagropila C. Ag.	<1											
Valonia fastigiata Harvey			<1	<1			<1				<1	(<1)

Table 2. Continued

Species	Tumon Bay			East Agana Bay			Agat Bay		Fouha Bay		Ylig Bay	
	1	2	3	1	2	3	1	2	1	2	1	2
	500	500	570	650	740	600	90	300	100	100	300	400
Valonia utricularis (Roth) C. Ag.									<1	<1		
Valonia ventricosa J. Ag.	(<1)	<1				(<1)	<1	<1(<1)			<1(<1)	
PHAEOPHYTA												
Dictyota bartayresii Lamx.		(<1)	<1(2)	<1	<1(1)	<1(<1)	4(2)	<1(<1)				
Dictyota friabilis Setch.				<1					<1(<1)	(<1)		
Feldmannia indica (Sonder) Womersley & Bailey	<1											<1
Hydroclathrus clathratus (C. Ag.) Howe				<1								<1
Lobophora variegata (Lamx.) Womersley	1	5	<1(<1)	<1(<1)	<1(<1)	<1(<1)	8(4)	<1(1)	1(<1)	<1	6(2)	2(<1)
Padina tenuis Bory	(<1)	(3)	<1(12)	4(<1)	<1(7)	2(<1)	5(8)	<1(<1)	<1(2)	<1(1)	3(9)	2(8)
Ralfsia pangoensis Setch.					(<1)				<1			
Sargassum cristaefolium C. Ag.			(<1)									
Sargassum polycystum C. Ag.	1(<1)	<1(<1)	<1(<1)	<1(<1)	<1	1(<1)	10(8)	<1(<1)	1	(<1)	5(22)	5(16)
Sphacelaria tribuloides Meneghini	(<1)	(<1)	(<1)		<1(<1)	(<1)	(1)	(<1)	(<1)	(<1)	<1(2)	(2)
Turbinaria ornata (Turner) J. Ag.	2(<1)	<1(<1)	7(7)	<1(<1)	1(<1)	<1(<1)	<1(<1)	<1(<1)	<1(<1)	<1(<1)	2(5)	2(5)
RHODOPHYTA												
Acanthophora spicifera (Vahl) Boerg.	(<1)	(<1)										
Actinotrichia fragilis (Forsskal) Boerg.							<1(<1)	<1(<1)	2(<1)	1(<1)	<1	
Amansia glomerulata C. Ag.							<1	2(1)	<1(5)	13(10)		
Amphiroa foliacea Lamx.							<1	(<1)	(1)	<1(<1)		
Amphiroa fragilissima (L.) Lamx.	<1	2(<1)	<1(<1)		(<1)	(<1)	<1(<1)	<1(5)	2	<1(2)	3(3)	
Ceramium sp.						<1						<1
Chondria polyrhiza Collins & Hervey								<1				
Dasyphila plumarioides Yendo		<1										
Galaxaura clavigera Kjellm.		<1		<1					(<1)			
Galaxaura fasciculata Kjellm.		<1(<1)					1(2)	1(<1)		<1		
Galaxaura fastigiata Decaisne									(<1)	(<1)		
Galaxaura oblongata (E.& S) Lamx.							<1(<1)	<1	<1	<1		
Gelidiella acerosa (Forsskal) Feldm. & Hamel		<1	1			(<1)	(2)	(<1)	(<1)	<1(2)	<1(<1)	<1(<1)

Table 2. Continued.

Species	Tumon Bay 1 500	Tumon Bay 2 500	Tumon Bay 3 570	East Agana Bay 1 650	East Agana Bay 2 740	East Agana Bay 3 600	Agat Bay 1 90	Agat Bay 2 300	Fouha Bay 1 100	Fouha Bay 2 100	Ylig Bay 1 300	Ylig Bay 2 400
<u>Gelidiopsis intricata</u> (Ag.) Vickers	2(<1)	<1(<1)	<1(<1)	(1)	(<1)	(<1)	<1	<1			(<1)	1(<1)
<u>Gelidium pusillum</u> (Stackh.) Le Jolis	(<1)	(<1)	(<1)				(1)		2	<1		
<u>Gracilaria arcuata</u> Zanard.	<1	<1(<1)								<1	(<1)	
<u>Gracilaria salicornia</u> (Mert.) Grev.				<1					<1(<1)	(<1)		(<1)
<u>Hypnea esperi</u> Bory	(2)	(<1)	(<1)	(<1)			(9)	(<1)		<1		
<u>Hypnea pannosa</u> J. Ag.	<1	<1			(<1)							
<u>Jania capillacea</u> Harv.		(1)	(<1)		<1	<1(<1)	(15)	(3)	5(3)	<1(5)	<1(<1)	(1)
<u>Laurencia cartilaginea</u> Yamada									<1	<1		
<u>Laurencia</u> sp.		<1						(<1)		<1		<1
<u>Mastophora</u> sp.									<1	<1(1)		
<u>Peyssonelia</u> sp.				<1(2)								
<u>Polysiphonia</u> spp.	1(<1)		<1(<1)	<1	<1	(1)		(1)				X
<u>Rhodymenia divaricata</u> Dawson			<1								<1	
<u>Rhodymenia</u> sp.							(<1)			<1(<1)		
<u>Spyridia filamentosa</u> (Wulf.) Harv.				<1								
<u>Tolypiocladia glomerulata</u>				2				2	(6)	<1(5)		
"crustose coralline"	3(2)	12(16)	3(<1)	3(<1)	2(2)	5(8)	3(3)	2(4)	13(11)	11(6)	14(8)	6(15)
ANTHOPHYTA												
<u>Enhalus acoroides</u> (L.f.) Royle								25(26)	2		<1(<1)	
<u>Halodule uninervis</u> (Forssk.) Ascher.				<1	(<1)							
<u>Halophila minor</u> (Zoll.) den Hartog			(<1)	<1	(<1)	(<1)						
TURF	7(27)	5(<1)	8(1)	0(<1)	14(4)	21(4)	0(0)	0(6)	49(52)	44(46)	49(18)	64(23)

Table 3. Comparison of species numbers present on each transect in each of the five bays. The coefficient of community is also presented based on the transects in each bay.

Bays	No. of Species Per Transect 1	2	3	Total No. of Species	No. of Species Common to Trans.	Coef. of Community
Tumon Bay	28	36	27	50	14	28%
East Agana Bay	31	26	26	43	15	35%
Agat Bay	38	36	-	46	29	63%
Fouha Bay	32	35	-	39	28	72%
Ylig Bay	24	27	-	35	16	46%

Table 4. List of species common to all bays and transects.

SPECIES COMMON TO ALL BAYS

Microcoleus lyngbyaceus
Schizothrix calcicola
Caulerpa racemosa
Lobophora variegata
Padina tenuis
Sphacelaria tribuloides
Sargassum polycystum
Turbinaria ornata
Amphiroa fragilissima
Gelidiella acerosa
Jania capillacea

SPECIES COMMON TO ALL TRANSECTS

Microcoleus lyngbyaceus
Lobophora variegata
Padina tenuis
Sargassum polycystum
Turbinaria ornata

Table 5. Algal species with 3% cover or greater on any one transect within each of the five bays. Species are derived from Table .

SPECIES	Tumon	East Agana	Agat	Fouha	Ylig
Cyanophyta					
Microcoleus lyngbyaceus	X			X	
Schizothrix calcicola	X	X	X		
Chlorophyta					
Caulerpa racemosa		X	X		
Cladophora fascicularis			X		
Enteromorpha clathrata	X	X			
Halimeda opuntia	X		X		X
Phaeophyta					
Dictyota bartayresii			X		
Lobophora variegata			X		X
Padina tenuis	X	X	X		X
Sargassum polycystum			X		X
Turbinaria ornata	X				X
Rhodophyta					
Amansia glomerata				X	
Amphiroa fragilissima			X		X
Hypnea esperi			X		
Jania capillacea			X	X	
Tolypiocladia glomerulata				X	

CORALS

by

Richard H. Randall

Introduction

Scleractinian corals are sessile organisms with potentially long life spans and distribution patterns that depend upon the particular environmental setting found from one habitat to another. Characteristic coral communities develop in response to these environmental settings, ranging from conditions completely unfavorable for corals to optimum conditions where corals are the dominant community. Corals are sensitive to many environmental variables - particularly suspended materials in the water column, sediment accumulation on the substrate upon which they are growing, sea water dilution from surface and groundwater discharge, temperature fluctuations, emersion during low tides, and various forms of pollution from thermal, storm drain, and sewage discharge. Because of the above characteristics, corals can be useful as indicator organisms which reflect the quality of the environment. Assessment of the present coral communities will establish baseline data from which changes in the quality of the environment can be determined or predicted. This data will be useful in establishing sound planning and management of these reef areas.

The principal objectives of this part of the transect studies are to determine the distribution and community structure of corals at the reef flat localities outlined in the introductory chapter.

Previous Studies

Zonation studies of corals on the reef-flat platforms within the present study sites have been conducted in the past at a number of locations in Tumon, Agana, and Agat Bays.

The first of these studies was made during a geological survey of the island from 1951 to 1954 (Tracey et al., 1964). During this survey the reefs around the island were described and four qualitative traverses were made across the fringing reefs, two of which were near Transect 3 in Tumon Bay and Transect 3 in Agana Bay, of this study. At Agana Bay, three reef flat zones were recognized. From the beach to the reef margin these zones were: 1) a sand zone where corals were small and widely scattered to absent, 2) a coral zone with scattered

Porites colonies in the outer part, abundant *Pavona* and *Acropora* patches in the middle part, and scattered *Acropora* patches in the inner part, and 3) an algal zone consisting of a truncated pavement which is exposed during low tides and lacking coral growth. At Tumon Bay, four reef-flat platform zones were recognized from the beach to the reef margin as follows: 1) a sand zone on which scattered patches of *Acropora* grew, 2) a coral zone covered by scattered *Porites* colonies on the outer part and *Acropora*, *Pavona*, and *Pocillopora* colonies on the inner part, 3) a boulder zone, and 4) an outer reef flat zone of reef rock covered with green algae on the outer part and scattered corals in small irregular pools on the inner part.

Reef physiography and coral distribution studies were conducted in Tumon Bay from studies made from 1966 to 1969 by Randall (1973). Quantitative coral zonation studies were conducted along six transects located in the northern third of Tumon Bay. Several of these transects were located near Transects 1 and 2 in the present study. The reef platform was divided into inner and outer reef flat zones. Forty-eight species of corals, covering 5.4 percent of the substrate, were recorded from the inner reef flat zone and 37 species, covering 14.9 percent of the substrate, were recorded from the outer reef flat zone. This coral zonation study is important in that it was made prior to the *Acanthaster planci* starfish infestation of Guam's reefs in 1969 and 1970 (Chesher, 1969).

Limited coral zonation studies were made in the vicinity of the present Transect 1 location in Tumon Bay by Jones and Randall (1972). In this study the reef-flat platform was divided into three zones as follows: 1) an inner reef flat zone mostly lacking coral growth on the inner part and with scattered corals (12 species and 0-5 percent substrate coverage), 2) a transition zone with much richer coral diversity (36 species and 2-39 percent substrate coverage) consisting mostly of *Acropora aspera* and *Acropora acuminata* thickets intermixed with small finely branched *Pocillopora damicornis* and *Psammocora contigua* colonies, and 3) an outer reef flat zone which is mostly exposed during low spring tides and lacking corals except where pools retain water.

Another limited reef study was conducted in Tumon Bay in the vicinity of the present Guam Hilton Hotel (Randall and Jones, 1973). This region is about 700 meters south of Transect 3 in the present study. The reef-flat platform was divided into three study sites as follows: 1) a proposed dredge site for a swimming area near the shore on the middle third of the reef-flat platform (10 species and 0.6 percent substrate coverage), 2) a downstream site located on the inner third of the reef-flat platform (5 species), and 3) a mid-bay site located on the middle part of the reef-flat platform, but farther out into the bay than the dredge site (22 species).

A fairly extensive coral zonation study was conducted in the northern part of Agana Bay (Randall and Eldredge, 1974). In this study 10 transects were established across a one-kilometer long section of the bay, which includes the location of Transect 1 in the present study. The reef-flat platform was divided into four zones as follows: 1) an intertidal sand and sea grass bed zone which lacks corals, 2) a sand zone with a few widely scattered corals (4 species), 3) a coral zone where corals are more abundant (14 species with coral density ranging from 0.49 to 1.97 per m^2 and percent of substrate coverage ranging from 0.19 to 2.75%), and 4) an outer reef flat zone which is mostly exposed during low spring tides where corals are absent except in holes or depressions which retain water (9 species).

Zonation studies of corals were made in Agat Bay (Randall, 1977), but most of the quantatative investigations were conducted in the deeper reef zones located seaward of the reef-flat platform. A total of 11 species of corals representing 8 genera were recorded from the reef-flat platform.

Methods

Coral communities were analyzed along the transects by using the point-centered or point-quarter technique (Cottam et al., 1953). The transects were established by placing a plastic surveyors tape along the bottom at the locations in Figures 1-5 in the introduction. Points were established at 5 meter intervals along the line. A line bisecting the sample point at right angles to the transect line established four quadrants around the point. The coral nearest the sample point in each quadrant was located and the specific name, diameter of the colony (or width and length measurement), and the distance from the center of the colony to the sample point was recorded. If no colony was observed within the maximum distance of 1 m from the sample point, the quadrant was recorded as having no colony with a diameter of zero and a sample point to colony distance of 1 m. Therefore, the unit area of the survey quadrant was 0.785 m^2.

From the point-quarter data the following calculations were used to estimate the population and community parameters:

$$\text{total density of all species} = \frac{\text{unit area}}{(\text{mean point-to colony distance})^2}$$

$$\text{relative density} = \frac{\text{individuals of a species}}{\text{total individuals of all species}} \times 100$$

$$\text{density} = \frac{\text{relative density of a species}}{100} \times \text{total density of all species}$$

$$\text{total percent coverage} = \text{total density of all species} \times \text{average coverage value for all species}$$

$$\text{percent coverage} = \text{density of a species} \times \text{average coverage value for the species}$$

$$\text{relative percent coverage} = \frac{\text{percent coverage for a species}}{\text{total coverage for all species}} \times 100$$

$$\text{frequency} = \frac{\text{number of points at which a species occurs}}{\text{total number of points}}$$

Colony size distribution data (n = number of data, $\bar{Y}$ = arithmetic mean, s = standard deviation, and w = size range) were also calculated from the point-quarter data.

The coral species encountered during the point-quarter analysis indicate the predominate and common species along the transects. The presence of uncommon and rare species, not encountered during the point-quarter analysis, were determined for each transect by making ten minute snorkel observations along each side of the transect line for each 100 meters of transect length. An overal list of species is compiled for each transect by combining those encountered during the point-quarter analysis and those from snorkel observations in Table 1. Because of the large number of transects (20) and the number of subzones discriminated for each transect (up to 5) it was not practical to compile a separate species list for each. To indicate species diversity within the subzones though, a separate table was compiled giving the total number of genera and species occurring in each (Table 2).

Quantitative data of the predominate and common species encountered from the point-quarter analysis are presented in Table 3. Size frequency distribution of colony diameters is given in Table 4 and colony growth form frequency distribution is presented in Table 5 for corals encountered during the point-quarter analysis.

Vertical profiles of each transect (Figs. 1-5) indicate the zones and subzones discriminated and the relative distribution of corals along the transects.

Results and Discussion

Zonation

One of the most noticable aspects of the coral communities studied is their unequal distribution across the fringing reef-flat platforms from the shoreline to the outer seaward edge. Although less noticeable, considerable community variation also occurs along the reef axis parallel to the shoreline. Vast areas are without corals at all, while other areas support communities ranging from a few widely scattered colonies and species to regions where the surface is dominated by a relatively rich diversity of species. Because of this variation in distribution it was necessary to divide the reef-flat platform into a number of zones and subzones in order to make a realistic quantitative assessment of the corals (Figs. 1-5). At most transect locations the reef-flat platform was divided into an inner and outer reef flat zone based upon the submergence and emergence of its various parts during low spring tides. At Transefts N-1, S-1, and S-2 in Fouha Bay, most of the entire reef-flat platform exposes during low spring tides and no such divisions were made (Fig. 4). At Tumon and Agana Bay transects, and all but Transects S-1 and S-2 at Ylig Bay, the outer reef flat zone is exposed during low spring tides while the major part of the inner reef flat zone is submerged forming a distinct moat of water (Figs. 1, 2 and 5). At all the Agat Bay and Fouha Bay transects and Ylig Bay Transects S-1 and S-2, the situation is reversed with the inner reef flat zone emergent and the outer reef flat zone submerged during low spring tides (Figs. 3, 4, and 5). On most of the wider reef transects the inner and outer reef flat zones are further divided into subzones based upon whether or not the substrate is composed mostly of reef rock pavement or unconsolidated deposits and upon the distribution and relative abundance of corals and sea grasses.

Coral Distribution

A combined total of 89 species of corals representing 30 genera were recorded from twenty reef flat transects at the five study sites (Table 1). Considerable variation occurred in species diversity, size distribution, frequency of occurrence, density, and percent of substrate coverage from one study site to another, between most transects within each study site, and among the various zones and subzones discriminated along the length of each individual transect Tables 1, 2, and 3).

Much of the regional variation found in the community structure of corals is attributable to the different parts of the reef-flat platform that are exposed and the depth of the water that is retained on the submerged parts during low spring tides (Figs. 1-5). Corals are unable to survive long periods of emergence, particularly when

low spring tides coincide with the drying effects of the mid-day sun, and are thus restricted to parts of the reef-flat platforms that retain water during such times. The few species of corals that were recorded (Tables 2 and 3) on the reef parts exposed during low spring tides (Figs. 1-5) were confined to small scattered holes that retained some water. Generally these corals consisted of small stunted colonies of _Porites lutea_, _Goniastrea retiformis_, and _Pocillopora damicornis_. On the shallow reef-flat platforms corals are restricted in their upward growth to a few contimeters above or below the mean lower low tide water level, and upon reaching this height can then grow only horizontally. Such growth restrictions explains the presence of the many flat-topped corals of massive or compact branching forms called microatolls and the truncated thickets of arborescent growth forms on the shallower parts of the reef-flat platforms. Certain acroporid and poritid species which possess a porous skeletal structure can generally withstand more exposure than other species as long as a significant portion of the colony remains submerged. These species can grow a few centimeters above the others and during low spring tides it is not uncommon to see the upper living parts of _Acropora aspera_, _Acropora acuminata_, and various _Porites_ species sticking out of the water.

Substrate composition is another important factor that influences coral species diversity and distribution across the reef-flat platforms. Most corals require a hard or relatively stable unconsolidated substrate to settle upon and successfully grow. Although coral planulae may settle on small grain-sized sediments, early growth is usually unsuccessful because of the unstable nature of such surfaces.

At Tumon and Agana Bays the inner reef flat zone retains water during low spring tides and is subdivided into an inner sand subzone where corals are mostly absent and the substrate consists of medium to coarse sand intermixed with small amounts of rubble; a middle scattered coral subzone where corals are widely separated or patchy in distribution and the substrate consists of coarse sand and rubble; and an outer coral subzone where corals are found in greatest abundance on the reef flat and the substrate consists mostly of reef rock pavement with a patchy veneer of coarse sand, rubble, and boulders at places. The outer reef flat zone is mostly exposed during low spring tides and at most transects is subdivided into an inner pavement and pool subzone consisting of an irregular reef rock pavement with scattered rubble and boulders and shallow depressions which contain a few small coral colonies. The outer pavement subzone is a relatively flat, wave washed, reef rock pavement that is mostly devoid of both sediments and corals (Table 2). At Transect 2 in Tumon Bay, no subdivisions are made on the outer reef flat zone because it is somewhat depressed and retains some water on its surface during low spring tides, which accounts for the high species diversity and moderate surface coverage of corals found there (Tables 2 and 3). A similar depressed outer reef flat zone is found on Transect 1 in Agana Bay, but here the zone is much narrower with fewer corals growing there.

Distribution of reef flat sediments at Agat Bay are somewhat similar to that found in Tumon and Agana Bays, except that the inner reef flat zones are emergent and support extensive sea grass beds at many places and the outer reef flat zones are covered by water during low spring tides. Corals are abundant and diverse on the nearly sediment free outer reef flat zones and mostly absent on the sandy inner reef flat zones (Fig. 3 and Tables 2 and 3).

At Fouha Bay the reef-flat platforms are mostly free of sand-sized sediments, pavement-like, narrow, mostly emergent during low spring tides, and for the most part lack corals except for a few small colonies growing in depressions and holes on the outer parts where they grade into Fouha Channel (Fig. 4 and Tables 1-3). After heavy rains the nearby La Sa Fua River brings silt and clay to reef-flat platforms which settle out forming a thin muddy coating on the substrate. The deposition of these fine-grained sediments plus the large amounts of fresh water which spreads out over the inner part of the bay during peak discharge is also detrimental to coral growth.

At Ylig Bay the reef-flat platforms are similar to those described for Fouha Bay, except that narrow inner reef flat moats are developed at Transects N-1, N-2, N-3, N-4, and S-3 (Fig. 5). The moat floor consists of an irregular reef rock pavement veneered with sand, rubble, and boulders in the low parts. Where sufficient water is retained at low tide a few corals grow on the barren reef rock areas and larger stable pieces of rubble and boulders (Tables 1 and 2). The reef-flat transects near the Ylig River mouth are subject sea water dilution and clay and silt deposits during periods of heavy rainfall which restricts coral development to a few small colonies in some of the deeper holes and depressions at the outer margin where it grades into the channel margin.

Distribution Patterns of Corals on the Reef Flat Platforms

Stylocoeniella armata is an inconspicuous species that forms small encrusting patches a few centimeters across in cryptic habitats. It was most abundant on the submerged outer reef flat zones at Tumon and Agat Bays.

The genus Psammocora is abundantly represented on the reef-flat platforms by P. contigua, P. stellata, and Psammocora Ramose sp. 1. These three species form ramose clusters with closely set branches that dominate local parts of the inner reef-flat platforms at Tumon and Agana Bays. Psammocora contigua and Psammocora Ramose sp. 1 are particularly abundant in the coral subzone and widely scattered to locally common on the unconsolidated substrates in the sand and scattered coral subzones. These ramose Psammocora species fragment easily during storms and the broken pieces are transported shoreward by wave action. Because of their much larger intial size, than newby settled planulae, these fragments have a greater chance of survival

which accounts partly for the colonies observed on the unconsolidated substrates of the sand and scattered coral subzones. Psammocora digitata was represented by a single columnar colony in the inner reef flat moat on Transect 1, at Tumon Bay. The remaining Psammocora species (Table 1) were uncommon and generally restricted to transects where the outer reef flat zone is submerged during low spring tides.

In the family Pocilloporidae, Stylophora mordax and Seriatopora hystrix were restricted to the deeper parts of the outer reef flat zones at Transect 3 in Agat Bay and Transect 2 in Tumon Bay respectively. Pocillopora damicornis was found at all five bays, but was most abundant in the inner reef flat moat subzones at Tumon and Agana Bays. Pocillopora damicornis is fairly successful at colonizing unconsolidated substrates by planulae settlement on larger stable pieces of rubble that are intermixed among the finer sand-sized sediments. Although Pocillopora danae and P. setchelli were found in all the bays except Agana, they are much less common than P. damicornis and generally restricted to the submerged outer reef-flat platform zones.

Although the family Acroporidae was the most diverse group represented on the reef-flat platforms (21 species), the only species found in abundance were Acropora aspera and Acropora acuminata. At places in the inner reef flat moats these two species form arborescent thickets up to 10 or more meters across. In 1972 a series of very low spring tides killed many of the arborescent Acropora thickets on the shallower parts of the reef-flat platforms. Acropora acumuniata was particularly sensitive to prolonged exposure during these low tides and now is abundant only at places in the coral and scattered coral subzones in Tumon Bay. The frequent dead Acropora thickets encountered during this survey indicate that the arborescent Acropora species were previously more widespread. Acropora formosa, another thicket-forming species, was found only on Transect 2 at Agat Bay in an isolated outer reef flat hole. Arborescent Acropora species are found in greatest abundance in the inner reef flat coral zone, but they also fragment easily during storms and small clumps and individuals become established on the unconsolidated sand and scattered coral subzones by wave transport. Although Montipora lobulata was found on all the transects in Tumon, Agana, and Agat Bays, none of the eight species of this genus are common or abundant. Astreopora myriophthalma was observed only on the outer submerged part of Transect 2 in Tumon Bay. The remaining Acropora and Montipora species listed in Table 3 are rare or uncommon on the reef-flat platforms, but are for the most part common species in the adjacent deeper water fore-reef habitats.

Of the eight Pavona species found on the reef-flat platforms (Table 3), all but Pavona (P.) Encrusting sp. 1 and Pavona Explanate sp. 1 are common to locally abundant in the inner reef flat coral subzones in Tumon, Agana, and Agat Bays. Golden brown colored colonies of Pavona divaricata, P. decussata, and Pavona Foliose sp. 1 are particularly abundant at many localities where the inner reef flat coral subzone grades into the outer reef flat zone.

In the family Poritidae, the two Goniopora species (Table 3) found on the reef-flat platforms are rare while the closely related Porites is the most diverse and widespread reef flat genus encountered. Porites lutea was the only species of coral encountered on all the transects at the five bays, and at some transects in Tumon and Agana Bays it was present in all the reef flat subzones. Small P. lutea colonies occasionally gain a refuge in size on the sandy floored inner reef flat subzones by planula settlement on scattered pieces of larger more stable rubble. Such colonies often develop into flat-topped microatolls a meter or more in diameter and are the only conspicuous relief features found on the sand floored inner reef flat subzones at Tumon and Agana Bays. Although colonies of P. lutea are found in the inner reef flat coral subzones, they do not compete as well with the other faster growing ramose and folaceous species found there, and the resulting colony size is generally smaller. Stunted nodular colonies of Porites lutea, growing in small holes that retain water, is the dominant species found in the harsh outer reef flat zones that expose during low tides (Table 3). Ramose clusters of Porites cocosensis are common to abundant in the inner reef flat coral subzones and uncommon to rare in the sand and scattered coral subzones at Tumon and Agana Bays. The remaining Porites species found on the reef-flat platforms are unevenly distributed and are uncommon to rare at most localities. Although the small pea-sized Stylaraea punctata colonies are difficult to observe, they are fairly common on pieces of rubble in the inner reef flat subzones at Tumon and Agana Bays.

With the exception of Goniastrea retiformis, which forms small colonies in the inner reef flat coral subzones and outer reef flat pools, the remaining coral species listed in Table 3 are either restricted to small local areas or are more widespread but uncommon to rare.

Coral Size Distribution

Average coral colony size ($\bar{Y}$), variance in size (s), and size range (w) are given in Table 3 for each overall zone and subzone discriminated on each transect and for each species that occurred within these divisions. For the overall zone and subzone divisions the average size ranged from 3.6 to 39.7 cm, variance in size from 0.0 to 27.6, and size range from 1 to 127 cm. Examination of the data reveals no significant patterns of similarity in the size distribution parameters between equivalent zones and subzones from one transect to another or between the zones and subzones within a given transect. The considerable amount of variance and the lack of discrete patterns in the colony size distribution parameters most likely stems from the large amount of variation found in community structure between equivalent zone and subzone divisions of the various transects and between the transects themselves (Table 3). If we take for example the coral

subzones at Tumon Bay (Table 3) and compare them, we find that the predominant species (highest frequency) at Transect 1 is Porites cocosensis ($\bar{Y}$ = 14.5 cm, s = 15.8, and w = 1-55 cm), at Transect 2 it is Psammocora Ramose sp. 1 ($\bar{Y}$ = 3.3 cm, s = 1.9, and w = 1-11 cm), and at Transect 3 it is Porites cocosensis ($\bar{Y}$ = 9.9 cm, s = 8.2, and w = 3-26 cm). Eventhough the same predominant species occurs at Transects 1 and 3, there is considerable difference between their size distribution statistics.

The frequency distribution of coral colony diameters given in Table 4 show that around half (42 to 53 percent range) of the sampled coral colonies from each bay falls within the 0-5 cm size range. The number of colonies that fall within the 0-10 cm size from each bay ranges from 65 to 92 percent and those within the 0-15 cm size range from 80 to 100 percent. Large corals are relatively uncommon, with only twelve being greater than 50 cm in diameter from a total sample of 1062 colonies from all the bays combined. All of these larger colonies were distributed in the scattered coral and coral subzones at Tumon, Agana, and Agat Bays. A coral community that has a population structure with a very large number of juvenile and small colonies sizes in relation to a very low number of intermediate and large sized colonies indicates that the reef-flat platforms are rather unpredictable environments where coral recruitment and mortality are high.

Colony size of individual species ranged from juvenile Pocillopora damicornis and adult Stylaraea punctata colonies less than a centimeter in diameter to flat-topped microatolls of Porites lutea, Porites cocosensis, and Porites annae up to 127 centimeters across. In the scattered coral and coral subzones Acropora aspera and Acropora acuminata colonies sometimes formed contiguous thickets up to ten or more meters across, but such masses are generally composed of an aggregation of smaller colonies less than 50 centimeters in diameter. In shallow water many of these large Acropora thickets are living only at the peripheral margin with the central portion being mostly dead from repeated exposure during low spring tides.

Coral Growth Form Distribution

The frequency distribution of coral colony growth forms given in Table 5 shows that the cespitose form was most abundant at all the bays (35 to 75 percent range) except Ylig. The high number of cespitose forms, in relation to other forms, is probably related to the fact that this growth form includes the finely divided Psammocora and Porites cocosensis species that produce many new colonies by mechanical fragmentation. Arborescent branching colonies of Acropora aspera and A. acuminata and foliose Pavona species also undugo mechanical fragmentation which may account for them being the next most abundant growth form at Tumon and Agana Bays (9 to 19 percent range). Corymbose growth forms are restricted to uncommon to rare Acropora species that were found on transects where the outer reef flat zone is depressed and submergent during low spring tides. Massive growth forms are mostly represented by Porites species which are more frequently found as small nodular colonies in the outer reef flat zones and as larger subhemispherical forms and microatolls in the inner reef flat zones. Encrusting growth forms are mostly uncommon (ranging from 3 to 20 percent at Tumon, Agana, and Agat Bays) and are represented for the most part by Montipora species, Porites superfusa, Porites (S.) vaughani, Pavona (P.) venosa, and Stylocoeniella armata. The remaining growth forms listed in Table 5 are uncommon to rare or absent on the reef-flat platforms.

Other Factors Effecting Coral Distribution

Sea water dilution and sedimentation from river and stream discharge occurs at the southern part of Agana Bay and at Agat, Fouha, and Ylig Bays. There appears to be little effect, in regard to coral distribution, from the Agana River discharge at the southern end of Agana Bay. Although coral growth is for the most part inhibited because of reef flat exposure during low spring tides at Fouha Bay, the effect of fresh water and sediments during peak discharge of the La Sa Fua River is certainly a contributing factor for the near absence of corals at Transects N-1 and S-1 nearest the river mouth where corals could possibly be more abundant in holes and depressions that retain water. Heavy peak discharge of the Ylig River is also a contributing factor for the absence of corals at Transect S-1 in Ylig Bay, but at Transect N-1, low tide exposure appears to more inhibitive as Pocillopora damicornis colonies are fairly common in the inner reef flat moat.

Freshwater discharge from storm drains and the freshwater lens system does not seem to effect coral distribution at Tumon, Agana, and Agat Bays. This type of freshwater discharge is for the most part restricted to the intertidal shoreline where coral growth is absent because of exposure during low tides and the presence of fine-grained unconsolidated sediments. By the time freshwater from storm drains and the lens system spreads outward to reef flat areas occupied by corals there is sufficient mixing with sea water to raise the salinity to near-normal reef flat levels. Although some sediments are carried to the reef flat by storm drains, accumulation is generally restricted to the nearshore regions where corals are normally absent.

Elevated water temperature to lethal or sublethal levels also effects the distribution of reef flat corals. When sufficient water circulation is maintained by wave transport over the reef margin onto the reef-flat platform there is little increase in the water temperature. Sublethal and lethal temperatures generally occur during low spring tides when water circulation by wave transport over the reef margin is drastically reduced or absent because of exposure of the outer reef flat zone. During low spring tides the temperature of the water trapped in the inner reef flat moat and small pools and depressions on the exposed outer reef flat can be elevated to levels that inhibit coral growth altogether in some locations or reduce the diversity to a

few species in other areas. Elevated temperature effects are greatest in the small pools and depressions on the exposed outer reef flat zone and least in the deeper and larger water mass of the inner reef flat moat. Reef-flat platforms with submerged outer reef flat zones are least affected because water circulation is maintained to a greater extent with the water mass at the reef margin. The most diverse coral community found during this study was on the submerged outer reef flat zone at Transect 2 in Tumon Bay, where 59 species were recorded.

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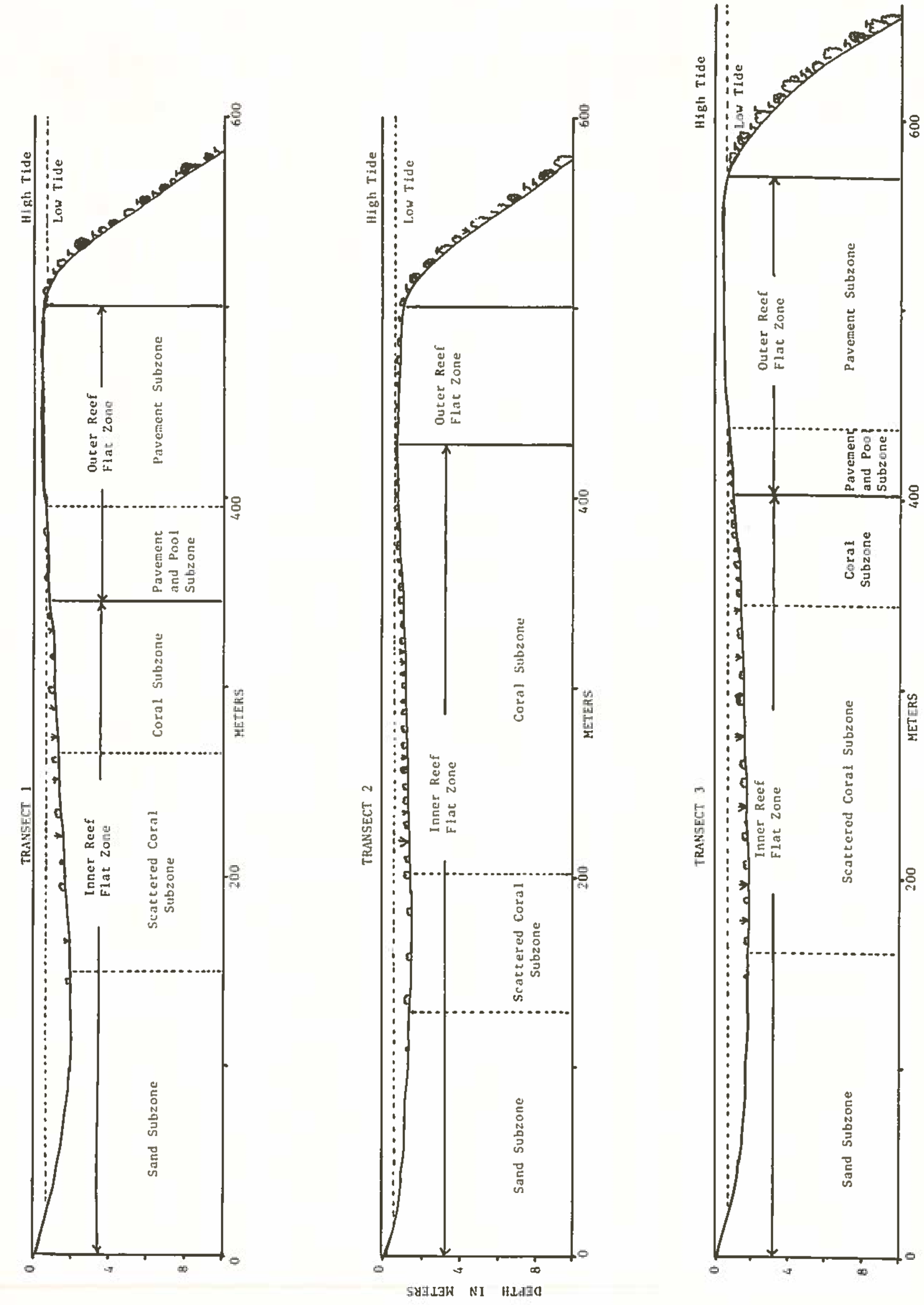

Fig. 1. Vertical profiles of Transects 1, 2, and 3 at Tumon Bay showing reef zones and subzones and the general distribution of corals. Solid vertical lines indicate reef flat zone boundaries and vertical dotted lines indicate subzone divisions. Vertical exaggeration X 10.

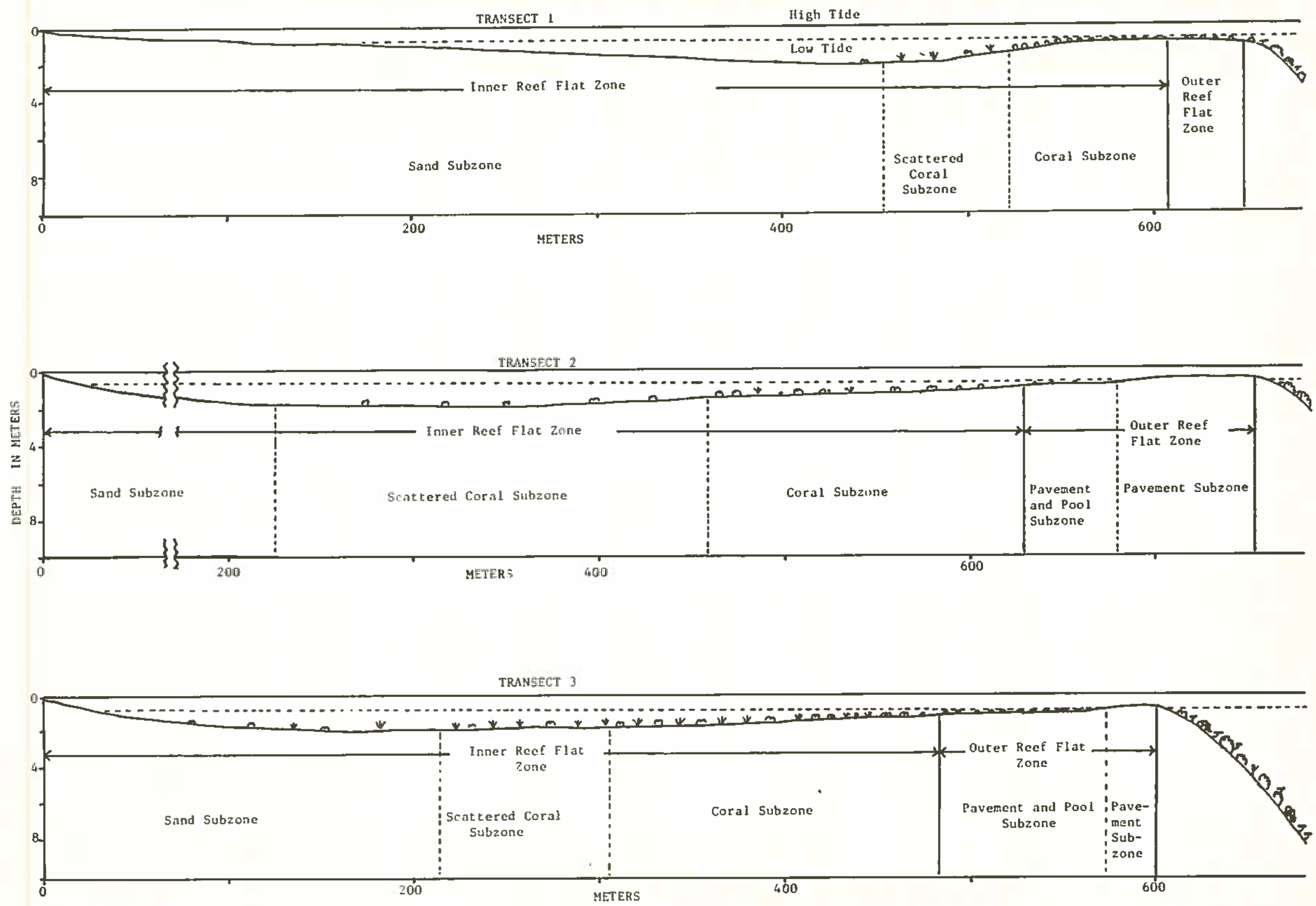

Fig. 2. Vertical profiles of Transects 1, 2, and 3 at Agana Bay showing reef zones and subzones and the general distribution of corals. Solid vertical lines indicate reef zone boundaries and vertical dotted lines indicate subzone divisions. Vertical exaggeration X 10.

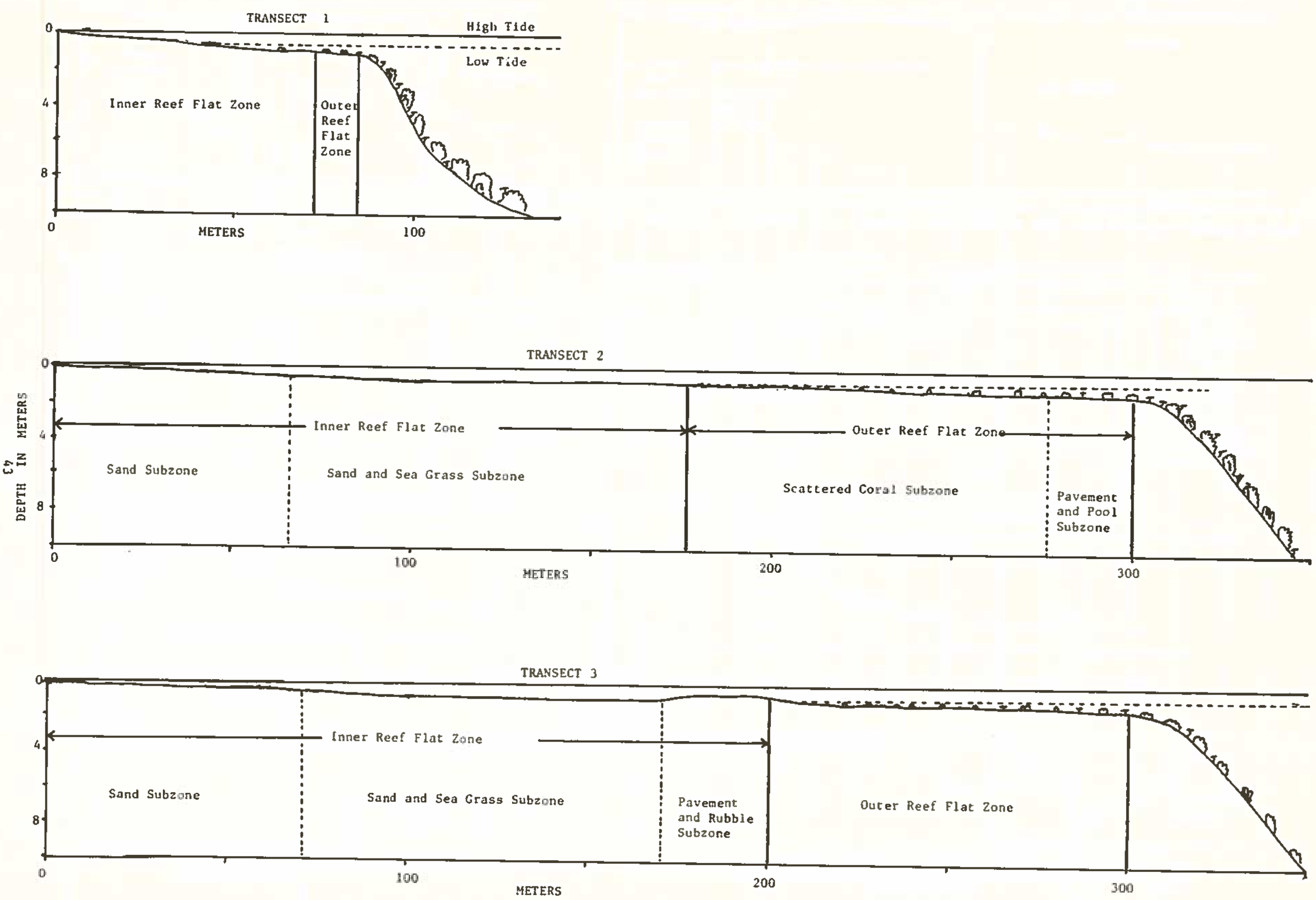

Fig. 3. Vertical profiles of Transects 1, 2, and 3 at Agat Bay showing reef zones and subzones and the general distribution of corals. Solid vertical lines indicate reef flat zone boundaries and vertical dotted lines indicate subzones. Vertical exaggeration X 5.

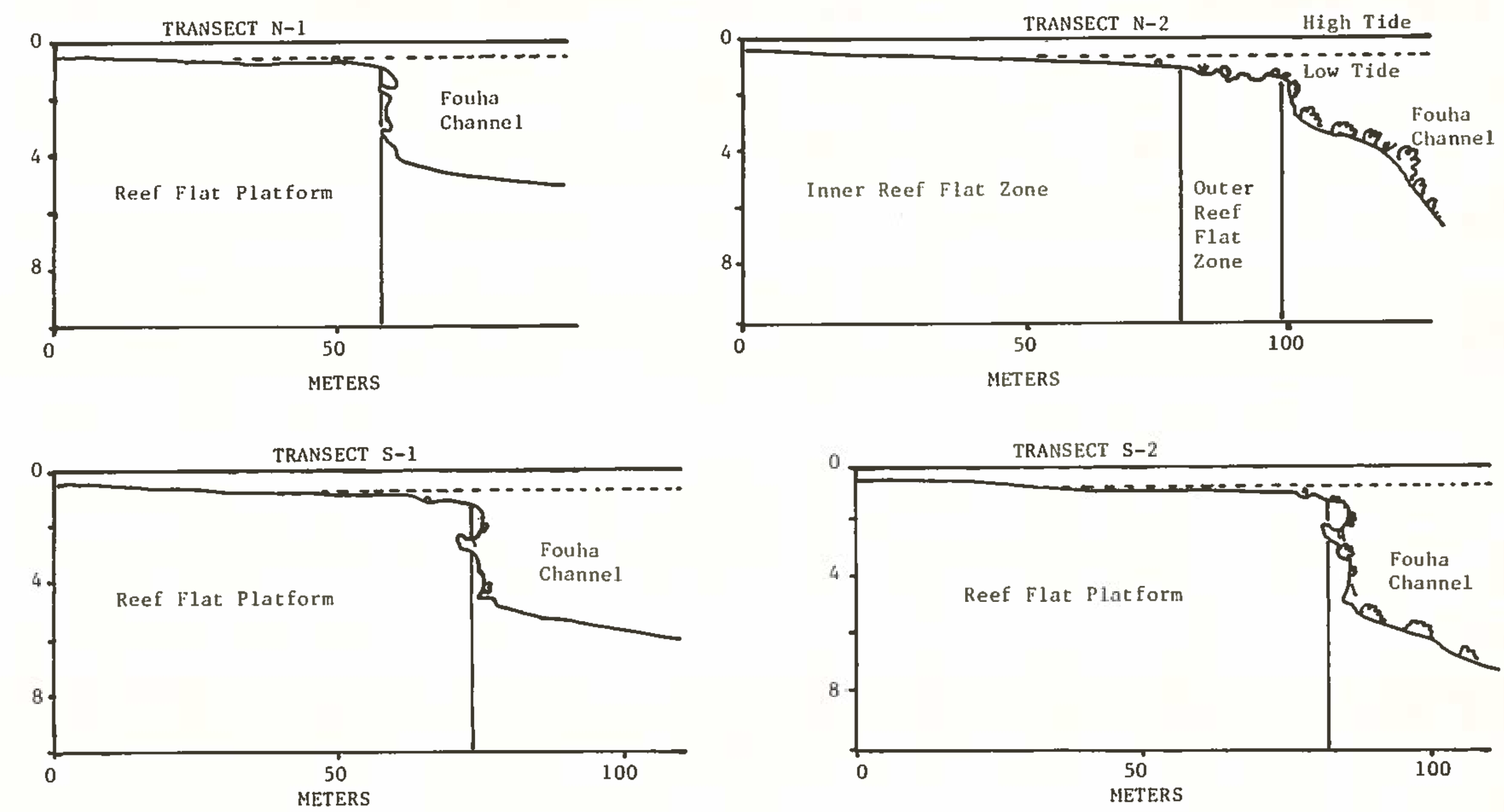

Fig. 4. Vertical profiles of Transects N-1, N-2, S-1, and S-2 at Fouha Bay showing reef zones and the general distribution of corals. At N-1, S-1, and S-2 the reef-flat platforms were not subdivided into zones. Vertical exaggeration X 5.

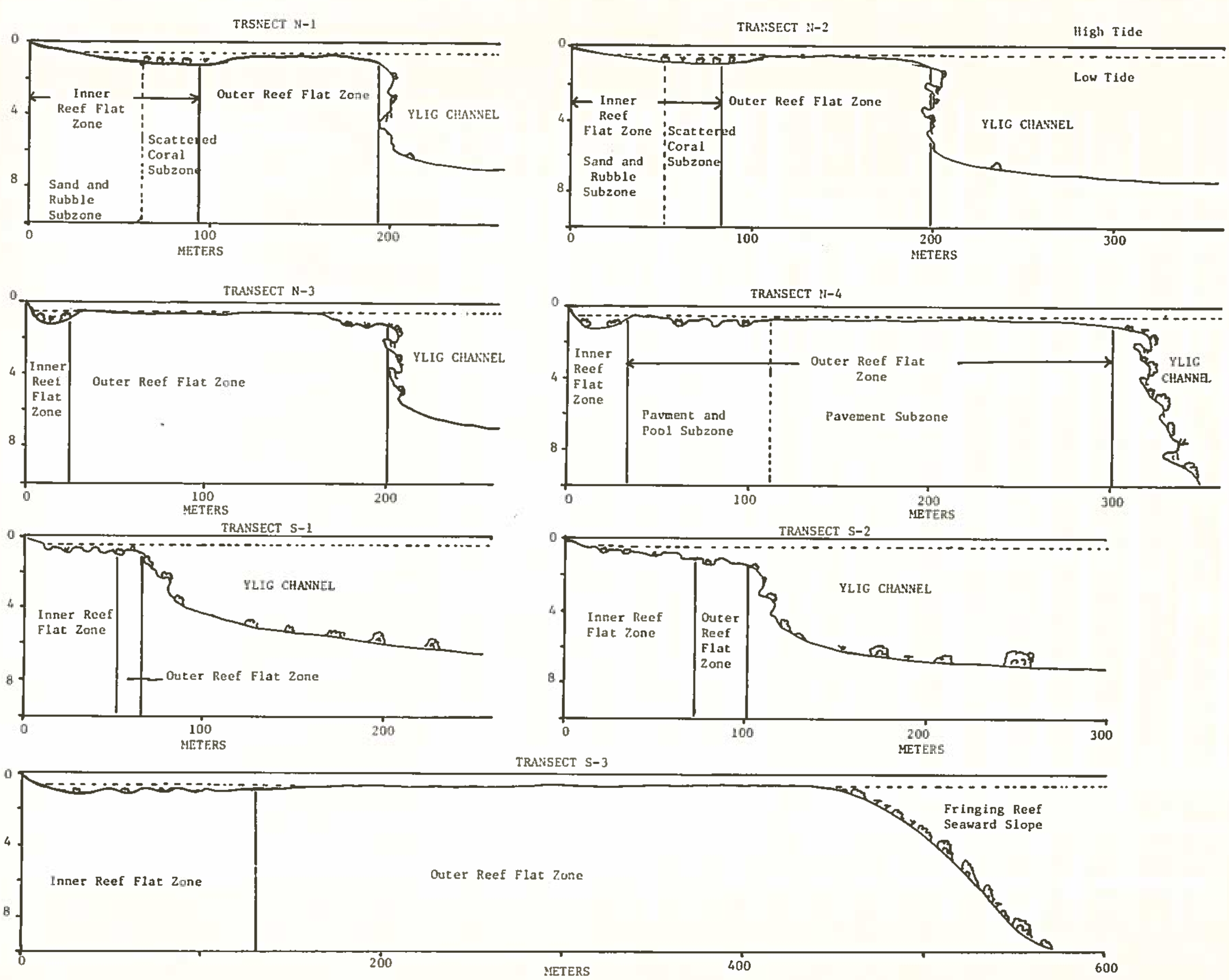

Fig. 5. Vertical profiles of Transects N-1 through N-4 and S-1 through S-3 at Ylig Bay showing reef zones and subzones and the general distribution of corals. Solid vertial lines indicate reef flat zone boundaries and dotted vertical lines indicate subzone divisions. Vertical exaggeration X 10.

Table 1. Species list of corals by transects for Tumon, Agana, Agat, Fouha, and Ylig Bays. List includes corals recorded on the transects and those observed within a 10 meter band on each side of the transects.

	TUMON BAY			AGANA BAY			AGAT BAY			FOUHA BAY				YLIG BAY						
	1	2	3	1	2	3	1	2	3	N-1	N-2	S-1	S-2	N-1	N-2	N-3	N-4	S-1	S-2	S-3
CLASS - ANTHOZOA																				
ORDER - SCLERACTINIA																				
SUBORDER - ASTROCOENIINA																				
FAMILY - ASTROCOENIIDAE																				
Stylocoeniella armada (Ehrenberg)		X						X	X											
FAMILY - THAMNASTERIIDAE																				
Psammocora contigua (Esper)	X	X	X	X	X	X		X			X				X	X	X			X
Psammocora digitata Milne-Edwards and Haime	X																			
Psammocora stellata Verrill	X	X	X		X	X														
Psammocora (Plesioseris) haimeana Milne-Edwards and Haime								X	X											
Psammocora nierstraszi van der Horst								X												
Psammocora (Nodulose sp. 1)		X				X														
Psammocora (Ramose sp. 1)	X	X	X		X	X		X			X							X	X	
Psammocora (Encrusting sp. 1)									X											
FAMILY - POCILLOPORIDAE																				
Stylophora mordax (Dana)									X											
Seriatopora hystrix Dana		X																		
Pocillopora damicornis (Linnaeus)	X	X	X	X	X	X	X	X	X		X			X	X	X	X	X	X	X
Pocillopora danae Verrill		X					X	X	X		X				X			X		
Pocillopora setchelli Hoffmeister		X					X	X	X		X				X					
FAMILY - ACROPORIDAE																				
Acropora acuminata Verrill	X	X																		
Acropora aspera (Dana)	X		X	X	X	X		X												
Acropora formosa (Dana)								X												
Acropora humilis (Dana)		X					X		X											
Acropora hystrix (Brook)		X																		
Acropora irregularis (Brook)		X							X											
Acropora nana (Studer)		X																		
Acropora nasuta (Dana)		X	X	X			X		X		X									
Acropora squarrosa (Ehrenberg)		X																		
Acropora surculosa (Dana)		X				X			X											

Table 1. continued

	TUMON BAY			AGANA BAY			AGAT BAY			FOUHA BAY				YLIG BAY						
	1	2	3	1	2	3	1	2	3	N-1	N-2	S-1	S-2	N-1	N-2	N-3	N-4	S-1	S-2	S-3
Acropora valida (Dana)		X																		
Acropora wardii Verrill						X	X				X									
Astreopora myriophthalma (Lamarck)		X																		
Montipora acanthella Bernard	X																			
Montipora hoffmeisteri Wells		X							X										X	
Montipora lobulata Bernard	X	X	X	X	X	X	X	X	X											X
Montipora verrilli Vaughan		X				X	X		X											
Montipora (Tuberculate sp. 1)		X						X	X											
Montipora (Tuberculate sp. 2)		X						X	X		X									
Montipora (Papillate sp. 1)		X	X		X			X	X									X		
Montipora (Papillate sp. 2)		X				X			X											
SUBORDER - FUNGIINA																				
FAMILY - AGARICIIDAE																				
Pavona decussata Dana		X	X		X	X		X							X					
Pavona divaricata (Lamarck)	X	X	X	X	X	X														
Pavona varians Verrill	X	X							X											
Pavona (Polyastra) obtusata (Quelch)	X	X	X			X	X	X	X									X		
Pavona (Polyastra) venosa Ehrenberg	X	X				X		X											X	
Pavona (Polyastra) (Encrusting sp. 1)		X							X											
Pavona (Explanate sp. 1)		X																		
Pavona (Foliose sp. 1)	X	X	X		X	X														
FAMILY - PORITIDAE																				
Goniopora arbuscula Umbgrove		X																		
Goniopora tenuidens (Quelch)		X																		
Porites andrewsi Vaughan		X																X		X
Porites annae Crossland	X	X	X	X		X		X												
Porites australiensis Vaughan		X					X													
Porites cocosensis Wells	X	X	X	X	X	X														
Porites lichen Dana		X							X											
Porites lobata Dana		X							X		X							X	X	
Porites lutea Milne-Edwards and Haime	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Porites murrayensis Vaughan		X							X											
Porites superfusa Gardiner		X																		

Table 1. continued

	TUMON BAY 1	2	3	AGANA BAY 1	2	3	AGAT BAY 1	2	3	FOUHA BAY N-1	N-2	S-1	S-2	YLIG BAY N-1	N-2	N-3	N-4	S-1	S-2	S-3
<u>Porites</u> (Massive sp. 1)	X	X																		
<u>Porites</u> (Nodular sp. 1)			X																	
<u>Porites</u> (<u>Synaraea</u>) <u>convexa</u> Verrill									X											
<u>Porites</u> (<u>Synaraea</u>) <u>iwayamaensis</u> Eguchi		X							X											
<u>Porites</u> (<u>Synaraea</u>) <u>vaughani</u> Crossland		X						X												
<u>Stylaraea</u> <u>punctata</u> Klunzinger	X	X	X	X	X	X														
SUBORDER - FAVIINA																				
FAMILY - FAVIIDAE																				
<u>Favia</u> <u>favus</u> (Forskaal)		X						X												
<u>Favia</u> <u>matthai</u> Vaughan							X		X											
<u>Favia</u> <u>pallida</u> (Dana)		X			X	X	X		X										X	
<u>Favia</u> <u>stelligera</u> (Dana)		X							X											
<u>Favites</u> <u>abdita</u> (Ellis and Solander)			X																	
<u>Favites</u> <u>virens</u> (Dana)		X																		
<u>Goniastrea</u> <u>edwardsi</u> Chevalier	X	X									X								X	
<u>Goniastrea</u> <u>pectinata</u> (Ehrenberg)			X																	
<u>Goniastrea</u> <u>retiformis</u> (Lamarck)	X	X	X	X		X	X		X		X							X	X	
<u>Platygyra</u> <u>daedalea</u> (Ellis and Solander)	X						X		X											
<u>Platygyra</u> <u>pini</u> Chevalier		X					X		X											
<u>Leptoria</u> <u>phrygia</u> (Ellis and Solander)		X							X		X									
<u>Hydnophora</u> <u>microconos</u> (Lamarck)			X																	
<u>Montastrea</u> <u>curta</u> (Dana)									X											
<u>Diploastrea</u> <u>heliopora</u> (Lamarck)		X																		
<u>Leptastrea</u> <u>bottae</u> (Milne-Edwards and Haime)	X	X	X		X															
<u>Leptastrea</u> <u>purpurea</u> (Dana)	X	X	X	X	X	X	X	X	X											
<u>Cyphastrea</u> <u>serailia</u> (Forskaal)		X						X												
FAMILY - OCULINIDAE																				
<u>Galaxea</u> <u>fascicularis</u> (Linnaeus)		X						X			X									
FAMILY - MUSSIDAE																				
<u>Lobophyllia</u> <u>corymbosa</u> (Forskaal)			X						X											
<u>Lobophyllia</u> <u>hemprichii</u> (Ehrenberg)		X																		
<u>Acanthastrea</u> <u>echinata</u> (Dana)		X							X											

Table 1. continued

	TUMON BAY 1	2	3	AGANA BAY 1	2	3	AGAT BAY 1	2	3	FOUHA BAY N-1	N-2	S-1	S-2	YLIG BAY N-1	N-2	N-3	N-4	S-1	S-2	S-3
SUBORDER - CARYOFHYLLIINA																				
FAMILY - CARYOPHYLLIIDAE																				
<u>Polycyathus</u> <u>verrilli</u> Duncan		X					X													
<u>Euphyllia</u> <u>glabrescens</u> (Chamisso and Eysenhardt)	X																			
ORDER - COENOTHECALIA																				
FAMILY - HELIOPHORIDAE																				
<u>Heliopora</u> <u>coerulea</u> (Pallas)	X	X			X				X											
CLASS - HYDROZOA																				
ORDER - MILLEPORINA																				
FAMILY - MILLEPORIDAE																				
<u>Millepora</u> <u>dichotoma</u> Forskaal											X									
<u>Millepora</u> <u>foveolata</u> (Crossland)		X	X	X	X	X		X										X	X	
<u>Millepora</u> <u>platyphylla</u> Hemprich and Ehrenberg		X					X		X		X									
ORDER - STYLASTERINA																				
FAMILY - STYLASTERIDAE																				
<u>Distichopora</u> sp. 1		X																		
TOTAL GENERA FOR EACH TRANSECT	12	26	13	10	11	11	11	12	18	1	9	1	1	2	4	3	3	8	8	4
TOTAL SPECIES FOR EACH TRANSECT	26	69	25	13	18	24	19	25	40	1	16	1	1	2	6	3	3	11	10	5
TOTAL GENERA FOR EACH BAY		27			12			19			9						8			
TOTAL SPECIES FOR EACH BAY		79			28			55			16						19			

Table 2. Number of coral genera and species occurring on the transect zones and subzones at Tumon, Agana, Agat, Fouha, and Ylig Bays. The number of genera and species includes corals recorded on the transects and those observed within a 10 meter band on each side of the transects. A single asterisk (*) indicates a reef zone that was not divided into subzones and a double asterisk (**) indicates a reef-flat platform that was not divided into either zones or subzones.

ZONES AND SUBZONES	GENERA	SPECIES
TUMON BAY 1		
Inner Reef Flat Zone		
Sand Subzone	1	1
Scattered Coral Subzone	8	11
Coral Subzone	11	23
Outer Reef Flat Zone		
Pavement and Pool Subzone	6	7
Pavement Subzone	2	2
TUMON BAY 2		
Inner Reef Flat Zone		
Sand Subzone	3	5
Scattered Coral Subzone	4	8
Coral Subzone	12	23
Outer Reef Flat Zone*	22	59
TUMON BAY 3		
Inner Reef Flat Zone		
Sand Subzone	1	1
Scattered Coral Subzone	7	11
Coral Subzone	11	20
Outer Reef Flat Zone		
Pavement and Pool Subzone	4	4
Pavement Subzone	2	2
AGANA BAY 1		
Inner Reef Flat Zone		
Sand Subzone	1	1
Scattered Coral Subzone	7	9
Coral Subzone	4	5
Outer Reef Flat Zone*	5	5
AGANA BAY 2		
Inner Reef Flat Zone		
Sand Subzone	1	1
Scattered Coral Subzone	5	6
Coral Subzone	10	16
Outer Reef Flat Zone		
Pavement and Pool Subzone	4	4
Pavement Subzone	1	1
AGANA BAY 3		
Inner Reef Flat Zone		
Sand Subzone	6	8
Scattered Coral Subzone	5	6
Coral Subzone	8	20
Outer Reef Flat Zone		
Pavement and Pool Subzone	6	9
Pavement Subzone	2	2
AGAT BAY 1		
Inner Reef Flat Zone*	1	2
Outer Reef Flat Zone*	10	18
AGAT BAY 2		
Inner Reef Flat Zone		
Sand Subzone	0	0
Sand and Sea Grass Subzone	1	1
Outer Reef Flat Zone		
Scattered Coral Subzone	5	6
Pavement and Pool Subzone	9	22
AGAT BAY 3		
Inner Reef Flat Zone		
Sand Subzone	0	0
Sand and Sea Grass Subzone	1	1
Pavement and Rubble Subzone	1	1
Outer Reef Flat Zone*	18	40
FOUHA BAY N-1		
Reef-Flat Platform**	1	1
FOUHA BAY N-2		
Inner Reef Flat Zone*	1	1
Outer Reef Flat Zone*	9	16
FOUHA BAY S-1		
Reef-Flat Platform**	1	1
FOUHA BAY S-2		
Reef-Flat Platform**	1	1

Table 2. continued

ZONES AND SUBZONES	GENERA	SPECIES
YLIG BAY N-1		
Inner Reef Flat Zone		
Sand and Rubble Subzone	0	0
Scattered Coral Subzone	2	2
Outer Reef Flat Zone*	2	2
YLIG BAY N-2		
Inner Reef Flat Zone		
Sand and Rubble Subzone	1	1
Scattered Coral Subzone	4	6
Outer Reef Flat Zone*	1	1
YLIG BAY N-3		
Inner Reef Flat Zone*	3	3
Outer Reef Flat Zone*	1	1
YLIG BAY N-4		
Inner Reef Flat Zone*	3	3
Outer Reef Flat Zone		
Pavement and Pool Subzone	1	1
Pavement Subzone	1	1
YLIG BAY S-1		
Inner Reef Flat Zone*	3	3
Outer Reef Flat Zone*	7	10
YLIG BAY S-2		
Inner Reef Flat Zone*	4	4
Outer Reef Flat Zone*	7	8
YLIG BAY S-3		
Inner Reef Flat Zone*	4	5
Outer Reef Flat Zone*	2	2

Table 3. Coral size distribution, frequency, density and relative density, and percent and relative percent of substrate coverage at Tumon, Agana, Agat, Fouha, and Ylig Bays. Species are listed in order of the sum of their relative density and percent coverage values.

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
Tumon Bay - Transect 1									
Inner Reef Flat Zone									
Sand subzone 0-147 meters									
(No Corals Encountered)									
Scattered Coral Subzone 147-262 meters									
Acropora aspera	19	13.9	8.6	5-34	.21	.129	46.3	.303	75.7
Pocillopora damicornis	15	4.7	3.0	1-11	.12	.102	36.7	.024	6.0
Acropora acuminata	2	22.5	7.8	17-28	.02	.014	4.9	.058	14.5
Porites cocosensis	3	8.7	2.1	7-11	.03	.020	7.3	.012	3.0
Psammocora contigua	1	6.0	-	-	.01	.007	2.4	.002	.5
Psammocora (Ramose sp. 1)	1	4.0	-	-	.01	.007	2.4	.001	.3
TOTALS	41	11.2	9.6	1-28	.40	.279	100.0	.400	100.0
Coral Subzone 262-342 meters									
Porites cocosensis	23	14.5	15.8	1-55	.36	.619	50.0	2.173	89.1
Pocillopora damicornis	7	4.0	2.0	1-7	.11	.188	15.3	.029	1.2
Acropora aspera	4	6.3	2.1	4-8	.06	.108	8.7	.036	1.5
Psammocora (Ramose sp. 1)	3	5.0	2.0	3-7	.05	.080	6.6	.018	.7
Porites annae	2	6.5	0.7	6-7	.03	.053	4.3	.017	.7
Porites (Massive sp. 1)	2	5.5	0.7	5-6	.03	.053	4.3	.013	.5
Porites lutea	1	19.0	-	-	.02	.027	2.2	.077	3.2
Pavona divaricata	1	13.0	-	-	.02	.027	2.2	.036	1.5
Leptastrea bottae	1	12.0	-	-	.02	.027	2.2	.031	1.3
Psammocora contigua	1	4.0	-	-	.02	.027	2.2	.004	.2
Psammocora stellata	1	3.0	-	-	.02	.027	2.2	.002	.1
TOTALS	46	11.1	12.7	1-55	.74	1.236	100.0	2.436	100.0

Table 3. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
Outer Reef Flat Zone									
Pavement and Pool Subzone 342-392 meters									
Porites lutea	4	7.0	0.8	6-8	.10	.021	57.1	.008	33.3
Psammocora (Ramose sp. 1)	2	11.5	0.7	11-12	.05	.010	28.6	.010	41.7
Pocillopora damicornis	1	12.0	-	-	.03	.005	14.3	.006	25.0
TOTALS	7	9.0	2.6	6-12	.18	.036	100.0	.024	100.0
Pavement Subzone 392-500 meters									
(No Corals Encountered)									
TUMON BAY - TRANSECT 2									
Inner Reef Flat Zone									
Sand Subzone 0-127 meters									
(No Corals Encountered)									
Scattered Coral Subzone 127-202 meters									
Psammocora stellata	6	5.3	2.7	3-10	.10	.019	60.0	.006	14.0
Porites (Massive sp. 1)	1	37.0	-	-	.02	.003	10.0	.032	74.4
Psammocora (Ramose sp. 1)	2	7.5	3.5	5-10	.03	.007	20.0	.004	9.3
Porites cocosensis	1	3.0	-	-	.02	.003	10.0	<.001	2.3
TOTALS	10	8.3	10.4	3-37	.17	.032	100.0	.043	100.0

Table 3. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
Coral Subzone 202-427 meters									
Psammocora (Ramose sp. 1)	80	3.3	1.9	1-11	.44	6.14	46.1	.67	7.3
Pavona decussata	26	13.8	11.2	2-46	.14	1.99	15.0	4.69	52.1
Psammocora contigua	23	4.3	1.9	1-9	.13	1.77	13.3	.30	3.3
Porites (Massive sp. 1)	1	57.0	-	-	.01	.08	.6	2.04	22.5
Pocillopora damicornis	18	4.5	3.1	1-11	.10	1.38	10.4	.29	3.2
Psammocora stellata	17	5.6	2.5	2-12	.09	1.30	9.8	.37	4.1
Pavona divaricata	3	14.0	10.0	4-24	.02	.23	1.7	.48	5.3
Montipora lobulata	1	13.0	-	-	.01	.08	.6	.10	1.1
Heliopora coerulea	1	10.0	-	-	.01	.08	.6	.03	.3
Pavona (P.) obtusata	1	8.0	-	-	.01	.08	.6	.03	.3
Pocillopora setchelli	1	6.0	-	-	.01	.08	.6	.02	.2
Porites cocosensis	1	2.0	-	-	.01	.08	.6	<.01	<.1
TOTALS	173	6.1	7.4	1-57	.98	13.28	100.0	9.02	100.0
Outer Reef Flat Zone 427-500 meters									
Pocillopora damicornis	21	3.4	2.6	1-9	.35	2.53	35.0	.37	7.0
Psammocora contigua	14	9.1	7.1	3-30	.23	1.69	23.2	1.72	32.5
Pavona decussata	4	8.0	5.0	4-15	.06	.48	6.7	.31	5.9
Millepora platyphylla	2	19.0	22.6	3-35	.03	.24	3.3	1.16	22.0
Stylocoeniella armata	7	3.4	0.5	3-4	.11	.85	11.6	.08	1.5
Pocillopora setchelli	4	7.8	4.0	3-12	.07	.48	6.7	.27	5.1
Acropora acuminata	1	10.0	-	-	.02	.12	1.7	.09	1.7
Psammocora stellata	1	2.0	-	-	.02	.12	1.7	<.01	.2
Psammocora (Ramose sp. 1)	1	5.0	-	-	.02	.12	1.7	.02	.4
Goniastrea retiformis	2	17.5	0.7	17.18	.03	.24	3.3	.58	11.0
Montipora verrilli	1	19.0	-	-	.02	.12	1.7	.34	6.4
Heliopora coerulea	1	18.0	-	-	.02	.12	1.7	.31	5.9
Porites (S.) vaughani	1	5.0	-	-	.02	.12	1.7	.02	.4
TOTALS	60	7.0	6.7	1-35	1.00	7.23	100.0	5.28	100.0

Table 3. continued

TUMON BAY - TRANSECT 3	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
Inner Reef Flat Zone									
Sand Subzone 0-162 meters									
(No Corals Encountered)									
Scattered Coral Subzone 162-347 meters									
Porites cocosensis	12	16.8	35.5	1-127	.08	.72	23.1	8.08	84.3
Pocillopora damicornis	23	3.8	2.6	1-9	.16	1.38	44.3	.22	2.3
Acropora aspera	12	13.1	7.1	3-27	.08	.72	23.1	1.23	12.8
Acropora acuminata	2	4.0	1.4	3-5	.01	.12	3.8	.02	.2
Leptastrea purpurea	2	2.5	0.7	2-3	.01	.12	3.8	.01	.1
Psammocora contigua	1	8.0	-	-	.01	.06	1.9	.03	.3
TOTALS	52	9.0	17.8	1-127	.35	3.12	100.0	9.59	100.0
Coral Subzone 347-402 meters									
Pavona decussata	8	19.6	18.0	2-55	.18	.68	20.0	3.96	38.1
Porites lutea	8	24.3	13.1	4-50	.18	.68	20.0	3.95	38.1
Porites cocosensis	15	9.9	8.2	3-26	.34	1.28	37.5	1.61	15.5
Psammocora contigua	4	9.3	8.2	2-21	.09	.34	10.0	.36	3.5
Pavona divaricata	2	14.5	12.0	6-23	.05	.17	5.0	.38	3.7
Pavona (P.) obtusata	1	12.0	-	-	.02	.09	2.5	.10	1.0
Porites annae	1	4.0	-	-	.02	.09	2.5	.01	.1
Pocillopora damicornis	1	2.0	-	-	.02	.09	2.5	<.01	<.1
TOTALS	40	14.6	12.9	2-55	.90	3.42	100.0	10.37	100.0

Table 3. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
Outer Reef Flat Zone									
Pavement and Pool Subzone 402-437 meters									
Porites lutea	12	6.8	3.4	4-14	.42	.32	92.3	.13	92.9
Pocillopora damicornis	1	3.0	-	-	.04	.03	7.7	.01	7.1
TOTALS	13	6.5	3.4	4-14	.46	.35	100.0	.14	100.0
Pavement Subzone 437-570 meters									
Porites lutea	4	8.0	2.9	5-11	.04	.001	100.0	<.001	100.0
TOTALS	4	8.0	2.9	5-11	.04	.001	100.0	<.001	100.0
AGANA BAY - TRANSECT 1									
Inner Reef Flat Zone									
Sand Subzone 0-457 meters									
(No Corals Encountered)									
Scattered Coral Subzone 457-522 meters									
Pocillopora damicornis	9	6.4	3.1	3-12	.17	.062	64.4	.025	65.8
Leptastrea purpurea	3	4.3	2.3	3-7	.06	.210	21.4	.004	10.5
Psammocora contigua	1	11.0	-	-	.02	.007	7.1	.006	15.8
Acropora aspera	1	8.0	-	-	.02	.007	7.1	.003	7.9
TOTALS	14	6.4	3.1	3-12	.27	.286	100.0	.038	100.0
Coral Subzone 552-607 meters									
Pocillopora damicornis	50	4.0	2.4	1-11	.74	5.15	75.8	.78	83.9
Leptastrea purpurea	16	3.1	1.3	1-6	.24	1.65	24.2	.15	16.1
TOTALS	66	3.6	2.2	1-11	.98	6.80	100.0	.93	100.0

Table 3. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
Outer Reef Flat Zone 607-645 meters									
Pocillopora damicornis	5	6.4	2.5	4-10	.16	.050	62.5	.018	19.8
Leptastrea purpurea	2	3.0	1.4	2-4	.06	.020	25.0	.002	2.2
Porites lutea	1	30.0	-	-	.03	.010	12.5	.071	78.0
TOTALS	8	8.5	9.0	2-30	.25	.080	100.0	.091	100.0
AGANA BAY - TRANSECT 2									
Inner Reef Flat Zone									
Sand Subzone 0-222 meters									
(No Corals Encountered)									
Scattered Coral Subzone 222-457 meters									
Pocillopora damicornis	9	5.4	3.4	2-11	.05	.003	90.0	<.001	81.8
Porites lutea	1	1.2	-	-	.01	<.001	10.0	<.001	18.2
TOTALS	10	6.1	3.8	2-11	.06	.004	100.0	<.002	100.0
Coral Subzone 457-627 meters									
Pocillopora damicornis	86	3.9	3.3	1-7	.63	1.37	79.6	.28	17.0
Porites lutea	13	20.1	17.6	3-60	.10	.21	12.0	1.14	59.1
Psammocora contigua	5	8.8	6.1	3-18	.04	.07	4.6	.06	3.6
Pavona divaricata	1	27.0	-	-	<.01	.02	.9	.11	6.7
Porites cocosensis	1	17.0	-	-	<.01	.02	.9	.04	2.4
Leptastrea bottae	1	8.0	-	-	<.01	.02	.9	<.01	.6
Leptastrea purpurea	1	4.0	-	-	<.01	.02	.9	<.01	.6
TOTALS	108	6.4	8.8	1-60	.78	1.73	100.0	1.63	100.0

Table 3. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
Outer Reef Flat Zone									
Pavement and Pool Subzone 627-677 meters									
Porites lutea	4	11.8	3.4	7-15	.10	.017	66.7	.019	95.0
Psammocora contigua	1	3.0	-	-	.03	.004	16.7	<.001	3.5
Pocillopora damicornis	1	1.0	-	-	.03	.004	16.7	<.001	1.5
TOTALS	6	8.5	5.7	1-15	.16	.025	100.0	.021	100.0
Pavement Subzone 677-750 meters									
(No Corals Encountered)									
AGANA BAY - TRANSECT 3									
Inner Reef Flat Zone									
Sand Subzone 0-217 meters									
Acropora aspera	7	9.6	8.1	3-22	.04	.05	50.1	.060	42.3
Porites lutea	4	2.0	1.2	1-3	.02	.03	28.6	<.001	.2
Pocillopora damicornis	1	38.0	-	-	.01	.01	7.1	.080	57.1
Pavona decussata	1	3.0	-	-	.01	.01	7.1	<.001	.2
Psammocora contigua	1	3.0	-	-	.01	.01	7.1	<.001	.2
TOTALS	14	8.5	10.8	1-38	.09	.11	100.0	.143	100.0
Scattered Coral Subzone 217-306 meters									
Acropora aspera	16	19.9	10.6	4-42	.22	.14	80.0	.540	94.7
Pocillopora damicornis	2	12.0	2.8	10-14	.03	.02	10.0	.020	3.5
Psammocora contigua	1	79.0	-	-	.01	<.01	5.0	<.010	1.8
Leptastrea purpurea	1	1.0	-	-	.01	<.01	5.0	<.001	-
TOTALS	20	17.7	10.7	1-79	.27	.17	100.0	.571	100.0

Table 3. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
Coral Subzone 306-482 meters									
Pavona decussata	23	24.7	13.9	2-54	.16	.67	17.6	4.20	32.7
Acropora aspera	54	15.9	15.9	1-60	.39	1.57	41.2	6.10	47.4
Pocillopora damicornis	31	8.9	7.0	1-33	.22	.90	23.7	.90	7.0
Pavona divaricata	15	14.7	12.3	3-45	.11	.44	11.5	1.20	9.4
Porites lutea	3	11.7	13.3	3-27	.02	.09	2.3	.20	1.6
Pavona (P.) obtusata	2	23.0	1.4	22-24	.01	.06	1.5	.20	1.6
Leptastrea purpurea	2	2.0	0.0	3-3	.01	.06	1.5	<.01	.1
Psammocora contigua	1	8.0	-	-	.01	.03	.7	.02	.2
TOTALS	131	15.5	13.9	1-60	.93	3.82	100.0	12.83	100.0
Outer Reef Flat Zone									
Pavement and Pool Subzone 482-572 meters									
Porites lutea	29	8.1	5.7	1-21	.40	.90	48.4	.68	42.5
Pavona divaricata	10	9.0	10.2	1-31	.14	.31	16.6	.43	26.8
Pavona decussata	5	12.0	8.0	4-22	.07	.15	8.3	.23	14.4
Psammocora contigua	6	4.7	1.8	3-8	.08	.19	10.0	.04	2.5
Porites annae	5	8.6	3.7	4-14	.07	.15	8.3	.10	6.3
Pavona (P.) obtusata	4	10.5	2.6	7-13	.06	.12	6.7	.11	6.9
Goniastrea retiformis	1	7.0	-	-	.01	.03	1.7	.01	.6
TOTALS	60	8.4	6.3	1-31	.83	1.85	100.0	1.60	100.0
Pavement Subzone 572-600 meters									
Porites lutea	5	7.0	1.6	5-9	.21	.05	100.0	.02	100.0
TOTALS	5	7.0	1.6	5-9	.21	.05	100.0	.02	100.0

Table 3. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
AGAT BAY - TRANSECT 1									
Inner Reef Flat Zone 0-72 meters									
Pocillopora damicornis	2	8.0	5.7	4-12	.03	<.001	100.0	.001	100.0
TOTALS	2	8.0	5.7	4-12	.03	.001	100.0	.001	100.0
Outer Reef Flat Zone 72-85 meters									
Goniastrea retiformis	3	5.0	3.6	2-9	.25	2.65	25.0	.71	32.7
Leptastrea purpurea	3	3.7	.6	3-4	.25	2.65	25.0	.29	13.4
Pocillopora damicornis	2	2.5	.7	2-3	.18	1.78	16.8	.09	4.1
Porites lutea	1	8.0	-	-	.08	.88	8.3	.44	20.3
Pocillopora danae	1	7.0	-	-	.08	.88	8.3	.33	15.2
Platygyra pini	1	6.0	-	-	.08	.88	8.3	.25	11.5
Pocillopora setchelli	1	3.0	-	-	.08	.88	8.3	.06	2.8
TOTALS	12	4.6	2.4	2-9	1.00	10.60	100.0	2.17	100.0
AGAT BAY - TRANSECT 2									
Inner Reef Flat Zone Sand Subzone 0-67 meters									
(No Corals Encountered)									
Sea Grass Subzone 67-177 meters									
(No Corals Encountered)									

Table 3. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
Outer Reef Flat Zone Scattered Coral Subzone 177-277 meters									
Pocillopora damicornis	19	3.7	5.1	1-19	.24	.095	73.2	.045	14.1
Porites lutea	4	36.3	23.4	15-58	.05	.020	15.4	.271	84.7
Psammocora contigua	1	8.0	-	-	.01	.005	3.8	.003	.9
Porites annae	1	5.0	-	-	.01	.005	3.8	.001	<.3
Polycyathus verrilli	1	1.0	-	-	.01	.005	3.8	<.001	<.1
TOTALS	26	10.3	14.6	1-58	.32	.130	100.0	.320	100.0
Pavement and Pool Subzone 277-300 meters									
Pocillopora damicornis	6	3.7	2.8	1-9	.30	1.29	33.1	.21	14.0
Pavona (P.) obtusata	2	12.5	0.7	12-13	.10	.43	11.1	.53	35.5
Psammocora (Ramose sp. 1)	1	13.0	-	-	.05	.22	5.6	.29	19.4
Pocillopora setchelli	2	4.0	0.0	4-4	.10	.43	11.1	.06	4.0
Psammocora contigua	2	3.5	2.1	3-5	.10	.43	11.1	.05	3.3
Psammocora nierstraszi	1	10.0	-	-	.05	.22	5.6	.17	11.3
Galaxea fascicularis	1	8.0	-	-	.05	.22	5.6	.11	7.2
Pocillopora danae	1	4.0	-	-	.05	.22	5.6	.03	2.0
Porites (S.) vaughani	1	4.0	-	-	.05	.22	5.6	.03	2.0
Porites annae	1	3.0	-	-	.05	.22	5.6	.02	1.3
TOTALS	18	5.8	3.9	1-13	.90	3.90	100.0	1.50	100.0
AGAT BAY - TRANSECT 3									
Inner Reef Flat Zone Sand Subzone 0-72 meters									
(No Corals Encountered)									
Sand and Sea Grass Subzone 72-172 meters									
(No Corals Encountered)									

Table 4. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
Pavement and Rubble Subzone 172-202 meters									
(No Corals Encountered)									
Outer Reef Flat Zone 202-300 meters									
Pocillopora damicornis	19	8.2	5.1	1-16	.24	.368	35.8	.262	28.8
Stylophora mordax	1	16.0	-	-	.01	.019	1.9	.039	4.3
Porites lutea	5	21.4	12.9	7-39	.06	.097	9.4	.337	36.9
Stylocoeniella armata	12	3.7	2.0	1-7	.15	.231	22.5	.030	3.3
Pocillopora setchelli	3	8.6	6.4	4-16	.04	.059	5.7	.047	5.1
Psammocora (Encrusting sp. 1)	1	19.0	-	-	.01	.019	1.9	.055	6.0
Goniastrea retiformis	3	6.3	6.7	2-14	.04	.059	5.7	.032	3.5
Porites (S.) iwaymaensis	1	7.0	-	-	.01	.019	1.9	.008	.9
Psammocora (P.) haimeana	2	6.5	3.5	4-9	.03	.039	3.8	.015	1.6
Acropora surculosa	3	5.0	1.7	3-6	.04	.059	5.7	.012	1.3
Heliopora coerulea	2	14.0	8.5	8-20	.03	.039	3.8	.071	7.8
Pocillopora danae	1	5.0	-	-	.01	.019	1.9	.005	.5
TOTALS	53	8.2	6.7	1-39	.67	1.027	100.0	.913	100.00
FOUHA BAY - TRANSECT N-1									
Reef-Flat Platform 0-61 meters									
(No Corals Encountered)									
FOUHA BAY - TRANSECT N-2									
Inner Reef Flat Zone 0-77 meters									
(No Corals Encountered)									

Table 3. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
Outer Reef Flat Zone 77-95 meters									
Psammocora contigua	6	6.6	2.1	4-9	.38	1.20	50.0	.38	41.3
Leptoria phrygia	1	13.6	-	-	.06	.20	8.3	.31	33.6
Pocillopora setchelli	2	5.5	3.5	3-8	.13	.40	16.8	.11	12.0
Porites lutea	1	8.0	-	-	.06	.20	8.3	.10	10.9
Millepora dichotoma	1	3.0	-	-	.06	.20	8.3	.01	1.1
Pocillopora danae	1	3.0	-	-	.06	.20	8.3	.01	1.1
TOTALS	12	6.6	3.1	3-13.6	.75	2.40	100.0	.92	100.0
FOUHA BAY - TRANSECT S-1									
Reef-Flat Platform 0-75 meters									
(No Corals Encountered)									
FOUHA BAY - TRANSECT S-2									
Reef-Flat Plaftorm 0-85 meters									
(No Corals Encountered)									
YLIG BAY - TRANSECT N-1									
Inner Reef Flat Zone Sand and Rubble Subzone 0-62 meters									
(No Corals Encountered)									
Scattered Coral Subzone 62-97 meters									
Pocillopora damicornis	17	4.6	3.7	1-13	.61	.647	100.0	.148	100.0
TOTALS	17	4.6	3.7	1-13	.61	.647	100.0	.148	100.0
Outer Reef Flat Zone 97-187 meters									
(No Corals Encountered)									

Table 3. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
YLIG BAY - TRANSECT N-2									
Inner Reef Flat Zone Sand and Rubble Subzone 0-47 meters									
(No Corals Encountered)									
Scattered Coral Subzone 47-82 meters									
<u>Porites lutea</u>	2	58.0	50.9	22-94	.07	.042	16.7	1.533	89.5
<u>Pavona decussata</u>	5	10.6	3.4	6-14	.18	.105	41.7	.101	5.9
<u>Pocillopora damicornis</u>	4	6.0	6.4	4-15	.04	.084	33.3	.072	4.2
<u>Psammocora contigua</u>	1	6.0	-	-	.04	.021	8.3	.006	.4
TOTALS	12	17.7	24.6	4-94	.33	.252	100.0	1.712	100.0
Outer Reef Flat Zone 82-200 meters									
(No Corals Encountered)									
YLIG BAY - TRANSECT N-3									
Inner Reef Flat Zone 0-22 meters									
<u>Pocillopora damicornis</u>	3	8.0	2.6	5-10	.19	.043	100.0	.023	100.0
TOTALS	3	8.0	2.6	5-10	.19	.043	100.0	.023	100.0
Outer Reef Flat Zone 22-200 meters									
(No Corals Encountered)									
YLIG BAY - TRANSECT N-4									
Inner Reef Flat Zone 0-32 meters									
<u>Porites lutea</u>	2	29.5	27.6	10-49	.08	.008	100.0	.079	100.0
TOTALS	2	29.5	27.6	10-49	.08	.008	100.0	.079	100.0

Table 3. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
Outer Reef Flat Zone Pavement and Pool Subzone 32-112 meters									
<u>Porites lutea</u>	2	19.0	8.5	13-25	.03	.001	100.0	.003	100.0
TOTALS	2	19.0	8.5	13-25	.03	.001	100.0	.003	100.0
Pavement Subzone 112-300 meters									
(No Corals Encountered)									
YLIG BAY - TRANSECT S-1									
Inner Reef Flat Zone 0-47 meters									
(No Corals Encountered)									
Outer Reef Flat Zone 47-60 meters									
<u>Porites lutea</u>	1	14.0	-	-	.02	.001	50.0	.002	75.0
<u>Goniastrea retiformis</u>	1	8.0	-	-	.02	.001	50.0	.001	25.0
TOTALS	2	11.0	4.2	8-14	.04	.002	100.0	.003	100.0
YLIG BAY - TRANSECT S-2									
Inner Reef Flat Zone 0-72 meters									
<u>Pocillopora damicornis</u>	7	3.1	1.1	2-5	.11	.020	63.6	.002	5.1
<u>Porites lutea</u>	1	35.0	-	-	.02	.003	9.1	.029	74.4
<u>Psammocora</u> (Ramose sp. 1)	3	8.7	9.0	3-19	.05	.009	27.3	.008	20.5
TOTALS	11	7.5	10.3	2-35	.18	.032	100.0	.039	100.0
Outer Reef Flat Zone 72-100 meters									
<u>Porites lutea</u>	2	10.0	0.0	10-10	.08	.007	100.0	.006	100.0
TOTALS	2	10.0	0.0	10-10	.08	.007	100.0	.006	100.0

Table 3. continued

	Size Distribution of Colony Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover
YLIG BAY - TRANSECT S-3									
Inner Reef Flat Zone 0-127 meters									
Porites lutea	2	39.7	3.8	37-42	.02	<.001	100.0	.012	100.0
TOTALS	2	39.7	3.8	37-42	.02	<.001	100.0	.012	100.0
Outer Reef Flat Zone 127-435 meters									
(No Corals Encountered)									

Table 4. Frequency distribution of coral colony diameters recorded on the transects at Tumon, Agana, Agat, Fouha, and Ylig Bays.

TUMON BAY	TRANSECT 1					TRANSECT 2				TRANSECT 3					
REEF ZONES	INNER REEF FLAT			OUTER REEF FLAT		INNER REEF FLAT			OUTER REEF FLAT	INNER REEF FLAT			OUTER REEF FLAT		TOTAL
REEF SUBZONES	Sand	Scattered Coral	Coral	Pavement and Pool	Pavement	Sand	Scattered Coral	Coral	Pavement and Pool	Sand	Scattered Coral	Coral	Pavement and Pool	Pavement	
Size Range (cm)															
0 - 5		13	22				5	113	34		29	12	7	1	236
5 - 10		12	13	4			3	38	16		11	9	4	3	113
10 - 15		7	3	3				11	3		6	3	2		38
15 - 20		5	4				1	4	5		2	2			23
20 - 25		1						2			1	8			12
25 - 30		1						2	1		2	2			8
30 - 35		2							1			2			5
35 - 40			1				1								2
40 - 45			1					1							2
45 - 50			1					1				1			3
50 - 55			1									1			2
55 - 60								1							1
Over - 60											1				1
TOTAL	0	41	46	7	0	0	10	173	60	0	52	40	13	4	446

Table 4. continued

AGANA BAY	TRANSECT 1				TRANSECT 2					TRANSECT 3					
REEF ZONES	INNER REEF FLAT			OUTER REEF FLAT	INNER REEF FLAT			OUTER REEF FLAT		INNER REEF FLAT			OUTER REEF FLAT		TOTAL
SUBZONES	Sand	Scattered Coral	Coral	Pavement and Pool	Sand	Scattered Coral	Coral	Pavement and Pool	Pavement	Sand	Scattered Coral	Coral	Pavement and Pool	Pavement	
Size Range (cm)															
0 - 5		7	54	5		5	72	2		10	3	40	24	1	223
5 - 10		5	11	2		2	17	1			3	18	21	4	84
10 - 15		2	1			3	9	3		2	4	18	7		49
15 - 20							5				3	19	3		30
20 - 25										1	2	7	4		14
25 - 30				1			2				2	13			18
30 - 35											1	2	1		4
35 - 40							1			1	1	2			5
40 - 45							1				1	5			7
45 - 50												3			3
50 - 55												3			3
55 - 60							1					1			2
60 - 65															0
TOTAL	0	14	66	8	0	10	108	6	0	14	20	131	60	5	442

Table 4. continued

AGAT BAY	TRANSECT 1		TRANSECT 2				TRANSECT 3				
REEF ZONES	INNER REEF FLAT	OUTER REEF FLAT	INNTER REEF FLAT		OUTER REEF FLAT		INNER REEF FLAT			OUTER REEF FLAT	
SUBZONES	Not Subdivided	Not Subdivided	Sand	Sand and Sea Grass	Scattered Coral	Pavement and Pool	Sand	Sand and Sea Grass	Pavement and Rubble	Not Subdivided	TOTAL
Size Range (cm)											
0 - 5	1	8			14	12				21	56
5 - 10		4			6	3				17	30
10 - 15	1				1	3				7	12
15 - 20					3					6	9
20 - 25										1	1
25 - 30											0
30 - 35											0
35 - 40										1	1
40 - 45											0
45 - 50											0
50 - 55					1						1
55 - 60					1						1
60 - 65											0
TOTAL	2	12	0	0	26	18	0	0	0	53	111

Table 4. continued

FOUHA BAY	TRANSECT N-1	TRANSECT N-2		TRANSECT S-1	TRANSECT S-2	
REEF ZONE	REEF FLAT PLATFORM	INNER REEF FLAT	OUTER REEF FLAT	REEF FLAT PLATFORM	REEF FLAT PLATFORM	
SUBZONES	Reef Flat Not Subdivided into Zones or Subzones	Not Subdivided	Not Subdivided	Reef Flat Not Subdivided into Zones or Subzones	Reef Flat Not Subdivided into Zones or Subzones	TOTAL
Size Range (cm)						
0 - 5			5			5
5 - 10			6			6
10 - 15			1			1
15 - 20						0
TOTAL	0	0	12	0	0	12

Table 4. continued

YLIG BAY	TRANSECT N-1			TRANSECT N-2			TRANSECT N-3		TRANSECT N-4			TRANSECT S-1		TRANSECT S-2		TRANSECT S-3		
REEF ZONES	INNER REEF FLAT		OUTER REEF FLAT	INNER REEF FLAT		OUTER REEF FLAT	INNER REEF FLAT	OUTER REEF FLAT	INNER REEF FLAT	OUTER REEF FLAT		INNER REEF FLAT	OUTER REEF FLAT	INNER REEF FLAT	OUTER REEF FLAT	INNER REEF FLAT	OUTER REEF FLAT	
SUBZONES	Sand and Rubble	Scattered Coral	Not Subdivided	Sand and Rubble	Scattered Coral	Not Subdivided	Not Subdivided	Not Subdivided	Not Subdivided	Pavement and Pool	Pavement	Not Subdivided	Not Subdivided	Not Subdivided	Not Subdivided	Not Subdivided	Not Subdivided	TOTAL
Size Range (cm)																		
0 - 5		13			2		1		1						9			25
5 - 10		1			3		2						1					8
10 - 15		3			5					1			1					10
15 - 20															1			1
20 - 25					1					1								2
25 - 30																		0
30 - 35															1			1
35 - 40																1		1
40 - 45																1		1
45 - 50									1									1
Over 50					1													1
TOTAL	0	17	0	0	12	0	3	0	2	2	0	0	2	0	11	2	0	51

Table 5. Frequency distribution of coral colony growth forms recorded on the transects at Tumon, Agana, Agat, Fouha, and Ylig Bays.

TUMON BAY	TRANSECT 1					TRANSECT 2				TRANSECT 3					
REEF ZONES	INNER REEF FLAT			OUTER REEF FLAT		INNER REEF FLAT			OUTER REEF FLAT	INNER REEF FLAT			OUTER REEF FLAT		
REEF SUBZONES	Sand	Scattered Coral	Coral	Pavement and Pool	Pavement	Sand	Scattered Coral	Coral	Pavement and Pool	Sand	Scattered Coral	Coral	Pavement and Pool	Pavement	TOTAL
COLONY FORMS															
Arborescent		21	4						1		14				40
Cespitose		20	35	3			9	140	41		36	20	1		305
Corymbose															0
Massive			3	4			1	1	2			8	12	4	35
Encrusting			1					2	9		2	1			15
Columnar			2					1				1			4
Explanate Plates															0
Foliose			1					29	4			10			44
Flabellate Plates									3						3
Free (Fungiids)															0
Phaceloid															0
TOTALS	0	41	46	7	0	0	10	173	60	0	52	40	13	4	446

Table 5. continued

AGANA BAY	TRANSECT 1				TRANSECT 2					TRANSECT 3					
REEF ZONES	INNER REEF FLAT			OUTER REEF FLAT	INNER REEF FLAT			OUTER REEF FLAT		INNER REEF FLAT			OUTER REEF FLAT		
REEF SUBZONES	Sand	Scattered Coral	Coral	Pavement and Pool	Sand	Scattered Coral	Coral	Pavement and Pool	Pavement	Sand	Scattered Coral	Coral	Pavement and Pool	Pavement	TOTAL
COLONY FORMS															
Arborescent		1								7	16	23			47
Cespitose		10	50	5		9	92	2		5	3	32	6		214
Corymbose															0
Massive				1		1	13	4		1		3	30	5	58
Encrusting		3	10	2			2				1	2			26
Columnar												2	9		11
Explanate Plates															0
Foliose							1			1		69	15		86
Flabellate Plates															0
Free (Fungiids)															0
Phaceloid															0
TOTALS	0	14	66	8	0	10	108	6	0	14	20	131	60	5	442

Table 5. continued

AGAT BAY	TRANSECT 1		TRANSECT 2				TRANSECT 3				
REEF ZONES	INNER REEF FLAT	OUTER REEF FLAT	INNER REEF FLAT		OUTER REEF FLAT		INNER REEF FLAT			OUTER REEF FLAT	
SUBZONES	Not Subdivided	Not Subdivided	Sand	Sand and Sea Grass	Scattered Coral	Pavement and Pool	Sand	Sand and Sea Grass	Pavement and Rubble	Not Subdivided	TOTAL
COLONY FORM											
Arborescent											0
Cespitose	2	4			20	12				24	62
Corymbose										3	3
Massive		5			4					8	17
Encrusting		3				4				15	22
Columnar					1	1				1	3
Explanate Plates											0
Foliose											0
Flabellate Plates										2	2
Free (Fungiids)											0
Phaceloid						1					1
Solitary					1						1
TOTALS	2	12	0	0	26	18	0	0	0	53	111

Table 5. continued

FOUHA BAY	TRANSECT N-1	TRANSECT N-2		TRANSECT S-1	TRANSECT S-2	
REEF ZONES	REEF FLAT PLATFORM	INNER REEF FLAT	OUTER REEF FLAT	REEF FLAT PLATFORM	REEF FLAT PLATFORM	
SUBZONES	Reef Flat Not Subdivided into Zones or Subzones	Not Subdivided	Not Subdivided	Reef Flat Not Subdivided into Zones or Subzones	Reef Flat Not Subdivided into Zones or Subzones	TOTAL
COLONY FORMS						
Arborescent			1			1
Cespitose			9			9
Corymbose						0
Massive			2			2
Encrusting						0
Columnar						0
Explanate Plates						0
Foliose						0
Flabellate Plantes						0
Free (Fungiids)						0
Phaceloid						0
TOTAL	0	0	12	0	0	12

Table 5. continued

YLIG BAY	TRANSECT N-1			TRANSECT N-2			TRANSECT N-3		TRANSECT N-4			TRANSECT S-1		TRANSECT S-2		TRANSECT S-3		
REEF ZONES	INNER REEF FLAT		OUTER REEF FLAT	INNER REEF FLAT		OUTER REEF FLAT	INNTER REEF FLAT	OUTER REEF FLAT	INNER REEF FLAT	OUTER REEF FLAT		INNER REEF FLAT	OUTER REEF FLAT	INNER REEF FLAT	OUTER REEF FLAT	INNER REEF FLAT	OUTER REEF FLAT	
SUBZONES	Sand and Rubble	Scattered Coral	Not Subdivided	Sand and Rubble	Scattered Coral	Not Subdivided	Not Subdivided	Not Subdivided	Not Subdivided	Pavement and Pool	Pavement	Not Subdivided	Not Subdivided	Not Subdivided	Not Subdivided	Not Subdivided	Not Subdivided	TOTAL
COLONY FORM																		
Arborescent																		0
Cespitose					5		3								10			18
Corymbose																		0
Massive		17			2				2	2			2		1	2		28
Encrusting																		0
Columnar																		0
Explanate Plates																		0
Foliose					5													5
Flabellate Plates																		0
Free (Fungids)																		0
Phaceloid																		0
TOTALS	0	17	0	0	12	0	3	0	2	2	0	0	2	0	11	2	0	51

OTHER MACROINVERTEBRATES

by

Charles Birkeland

Introduction

There is a tremendous diversity of invertebrates such as gastropods and polychaetes on the reef flats of Guam (cf. Roth 1976, Kohn and White 1977), but the holothurians are by far the most prevalent group of large macroinvertebrates in terms of biomass. The holothurians are predominant to the extent that most of our attention will be directed towards this group. Holothurians (also called "trepang", "beche-de-mer", and "sea cucumbers") are a popular food to Europeans, Japanese, and other peoples. The prevalence of holothurians on reef flats throughout the tropical Pacific (Bakus 1968) indicates that their feeding activity of transporting sediments through their stomachs might be of general importance to the ecology of the reef flat communities. Information on the distribution and abundances of holothurians is of value to resource management programs and ecological investigations because of their potential importance as food and possibly also as a major factor influencing the structure of reef flat communities.

Methods

The population densities of macroinvertebrates were quantified by counting the number of invertebrates within one meter of the transect along its length. The counts were made as the observer swam along the transect, holding the meter stick perpendicular to the transect line with one end of the meter stick touching the line. The data were grouped and tallied in terms of ten-meter intervals along one side of the transect line. The animals were then counted in similar ten-meter rectangular quadrants along the other side of the transect line. This process was repeated along the entire lenghts of the transects and the data were recorded separately for the different zones. Care was taken to look under rocks, in crevices and among coral heads along the transect.

Results

The frequencies and abundances of macroinvertebrates along three transects (north, middle, and south) in each of Tumon Bay, Agana Bay, and Agat Bay are given in Tables 1, 2, and 3, respectively. Twelve species of holothurians were found along the transects in Tumon Bay and eleven species were found along the transects in Agana Bay. Despite the number of species present, well over half (often over 90%) of the holothurians along all transects on the inner reef flat were of the species *Holothuria atra* (Table 4). *Holothuria atra* was very prevalent, having an average abundance in the general order of magnitude of one per square meter throughout both bays (Table 5).

There were generally more holothurians in Tumon Bay than in Agana Bay, in terms of both abundances and numbers of species (Table 5). Other than that, there were no clear or consistent patterns of differences in abundances or diversities that emerged from comparisons between Tumon Bay and Agana Bay or from comparisons between the north, middle, and south transects in each of the bays. *H. atra* generally became more predominant as one moved towards shore on the inner reef flat in both bays and the number of species of holothurians were generally greatest in the coral zone of the inner reef flat of both bays (Tables 4 and 5).

Holothurians were far less abundant and diverse in Agat Bay (Table 3) than in Tumon Bay or Agana Bay (Table 5). However, echinoids appeared to be relatively more prevalent in Agat Bay.

The reef flat at Fouha Bay was largely exposed to desiccation on low spring tides. Because of this, few holothurians and other macroinvertebrates were found along the transects and those few that were seen were in tide pools. Therefore there were too few data obtained along the transects to be summarized in tabular form so they will be stated as follows. Two transects were taken on the north side of the bay. The first was 100 m long and in the 200m^2 area surveyed, only three *Holothuria leucospilota* and one *Actinopyga mauritiana* were found. The second transect was 61 m long and only a single *Trochus niloticus* was found. The first transect along the south shore of the bay was 85 m long. A total of five *Holothuria atra*, twelve *H. leucospilota*, and one *Echinothrix diadema* were found along this transect. No macroinvertebrates were found along the entire second transect from the south shore of the bay.

The reef flat at Ylig Bay was similar to that at Fouha Bay in that there were few macroinvertebrates on the reef flat because of severe desiccation during low spring tides. Holothurians were found mainly in the tide pools. Eight transects were taken in Ylig Bay, four on the north side and four on the south side. The data are presented in Table 6.

In order to obtain representative weight measurements of holothurians for biomass estimates, ten *Holothuria atra* and seven *H. leucospilota* were collected from Pago Bay and net weights (damp-dry weights) were measured in the laboratory on a triple-beam balance. *Holothuria atra* averaged 245 ± 111 gms ($\bar{Y} \pm s$) and *H. leucospilota* averaged 437 ± 99 gms.

Discussion

The data obtained during this study allow us to make a reasonably accurate estimate of the total abundance of holothurians in each of the bays. The total area sampled for holothurians in Tumon Bay was 3140 m^2 and in Agana Bay the total area was 3990m^2. The average population densities for holothurians in each of the reef flat zones in each of the bays are given in Table 5. To obtain an average population density for each of the entire bays, we take an average of the population densities of each of the zones after thay have been weighted for the proportions of the total transect lenghts which fell in each of the zones. These calculations give us a mean population density of holothurians in Tumon Bay of 15.58 per 10 m^2. The total area of the Tumon Bay reef flat is about 1.4 km^2. Therefore, there is a total population of over three million holothurians in Tumon Bay. If we take the average wet weight of *H. atra* from Pago Bay (245 gms) as an estimated average holothurian wet weight, then the average wet weight biomass would be 3.87 kg per 10 m^2. This figure would give us an estimated wet weight standing crop biomass for Tumon Bay of 7.5×10^5 kgs (or 824 tons).

The same series of calculations indicate that the population densities are generally about half as great in Agana Bay. The mean population density of holothurians in Agana Bay is about 7.9 per 10 m^2. If we adjusted the area of Agana Bay to 1.4 km^2 for comparison with Tumon Bay, then the total population would be over 1.5 million and the estimated wet weight standing crop would be 3.8×10^5 kgs (or 418 tons).

These estimates might be of possible future use in calculating appropriate figures concerned with the removal of holothurians for utilization as food or for experimental manipulations. However, it is not likely that the holothurians will be removed for food on a large scale on Guam because they are not especially popular as food on Guam and because the abundant species are not the species most acceptable for harvesting. Larger species of the genera *Thelenota* and *Stichopus* are more readily processed for meat than are the smaller *Holothuria*.

On the other hand, there is a real need for an experimental investigation of the influence of holothurians on the reef flat system. The general importance of the investigation to basic science is indicated by the predominence and abundance of holothurians on the reef flats throughout the Indo-West Pacific region. The importance of this suggested study to the applied science of marine resource management is indicated by the possibility of their future removal from some areas for utilization as food or "to enhance the environment for tourists". Even if these actions are inadvisable from an economic standpoint, it does not preclude the possibility of their basis for man's activities. So an understanding of the functional role of holothurians in the ecosystem is of importance.

Despite the quantity of literature on the ecology of holothurians (cf. Bakus 1973 for a review), all of the conclusions to date concerning the importance of holothurians in the community are speculative. That holothurians are relatively unimportant may be argued on the basis that 1) they do not significantly alter the grain size of sediments that pass through their guts (Bonham and Held 1963), 2) that they are toxic and serve as prey for very few predators (Bakus 1968, Bakus and Green 1968), and 3) their main source of nutrition is organic matter and microorganisms in the sediment (Bakus 1973) so they do not serve a major role as predators. However, without experimental evidence from field studies, it is too early to dismiss the importance of holothurians in marine communities. There might be second order effects on the benthic community from the turning over, mixing, and transportation of sediments. There may be second order effects on the community from the digestion of bacteria, other microorganisms, and organic matter in the sediments. There is the possibility of an influence on recruitment of benthic macroinvertebrates from digestion of both the recruits as the sediment is consumed and from the alteration of the nature of the substratum through the feeding activities. The distribution and abundance of other deposit-feeding macroinvertebrates might be stongly affected by the predominant holothurians. The importance of these second order interactions on the functioning of the benthic community can only be assessed with field experiments.

Holothurians are abundant in bays such as Tumon and Agana in which the reef flat has an extensive moat component. Holothurians are scarce in bays such as Fouha and Ylig in which nearly all of the reef flat is exposed to severe desiccation during low spring tides.

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Table 1. Macroinvertebrates found along three transects in Tumon Bay [N=(1) north, M=(2) middle, S=(3) south]. The frequency (f) is the number of 10 m2 quadrats in which the species or genus was observed (the numerator) over the total number of 10 m2 quadrats examined (the denominator). The means and standard deviations are of the numbers of individuals per 10 m2 quadrat. The "+" means the species was observed near, but not on, the transects. There was no pavement subzone on the outer reef flat along the Middle Transect.

Reef Area / Reef Subarea / Statistic		TUMON BAY: Sand (f)	Sand $\bar{Y} \pm s$	INNER REEF FLAT Scattered Coral (f)	Scattered Coral $\bar{Y} \pm s$	Coral (f)	Coral $\bar{Y} \pm s$	OUTER REEF FLAT Pavement and Pool (f)	Pavement and Pool $\bar{Y} \pm s$	Pavement (f)	Pavement $\bar{Y} \pm s$
TAXA	Transect										
Gastropoda											
Trochus niloticus	N							(4/10)	.5 ± .7	(2/20)	.1
	M					(1/46)	.04	(4/10)	.6 ± .97		
	S			(2/38)	.05	(1/30)	.03	(3/10)	.3		
Cerithium nodulosum	N	(1/32)	.03					(1/10)	.1		
	M					(1/46)	.02				
	S							(2/10)	.4 ± .97	(3/30)	.1
Lambis lambis	N					(1/16)	.06				
Vasum sp.	N	(1/32)	.06								
Bivalvia											
Pinna muricata	N	(1/32)	.06								
Lima lima	S					(3/30)	.13 ± .43				
Spondylus sp.	S					(1/30)	.03				
Tridacna maxima	N					(1/16)	.06			(1/20)	.05
	M					(3/46)	.07 ± .25				
	S			(2/38)	.05					(6/30)	.2 ± .41
Asteroidea											
Culcita novaeguineae	M					(1/46)	.02				
Linckia laevigata	N									(1/20)	.1
Ophiuroidea											
Ophiocoma sp. 1	N							(2/10)	.2	(2/20)	.15 ± .49
	M							(1/10)	.1		
	S			(2/38)	.05	(2/30)	.13 ± .57			(1/30)	.03
Ophiocoma sp. 2	S							(2/10)	.3 ± .67	(9/30)	1.2 ± 2.41
Ophioderma sp.	N							(1/10)	.1		

Table 1. continued

Reef Area / Reef Subarea / Statistic		TUMON BAY: Sand (f)	Sand $\bar{Y} \pm s$	INNER REEF FLAT Scattered Coral (f)	Scattered Coral $\bar{Y} \pm s$	Coral (f)	Coral $\bar{Y} \pm s$	OUTER REEF FLAT Pavement and Pool (f)	Pavement and Pool $\bar{Y} \pm s$	Pavement (f)	Pavement $\bar{Y} \pm s$
Echinoidea											
Echinometra mathaei	N			(1/22)	.05					(6/20)	1.05 ± 2.28
	M					(2/46)	.04 ± .21	(1/10)	.1		
	S			(4/38)	.13 ± .41	(9/30)	3.13 ± 6.62	(2/10)	.3 ± .67	(1/30)	.03
Tripneustes gratilla	N			+							
Diadema sp.	S			(1/38)	.03	(1/30)	.03			(1/30)	.03
Echinothrix diadema	N							(3/10)	.3	(1/20)	.05
	M					(1/46)	02				
	S			(1/38)	.03					(1/30)	.17
Holothuroidea											
Stichopus chloronotus	N									(1/20)	.05
	M					(4/46)	.09 ± .28	(3/10)	.09 ± 1.73		
	S			(1/38)	.03					(3/30)	.1
Stichopus horrens	M					(2/46)	.04 ± .21				
	S			(1/38)	.03	(3/30)	.13 ± .43			(2/30)	.07
Actinopyga echinites	N			(1/22)	.05			(5/10)	1.70 ± 2.21	(4/20)	.2 ± .41
	M					(3/46)	.09 ± .35				
	S			(1/38)	.03	(4/30)	.13	(3/10)	.4 ± .7	(11/30)	2.03 ± 4.33
Bohadschia argus	N			(1/22)	.05	(3/16)	.19	(2/10)	.2		
	M					(6/46)	1.5 ± .84				
	S			(1/38)	.03	(5/30)	.17	(1/10)	.1	(1/30)	.03
Bohadschia marmorata	N	(2/32)	.06			(3/16)	.50 ± 1.32				
	S			(3/38)	.08	(12/30)	2.47 ± 4.59	(2/10)	.7 ± 1.89	(6/30)	.2 ± .41
Holothuria atra	N	(4/32)	.56 ± 2.18	(22/22)	11.32 ± 5.47	(15/16)	8.12 ± 5.56	(10/10)	7.0 ± 3.53	(16/20)	2.15 ± 1.66
	M	(27/28)	23.14 ± 15.17	(14/14)	40.57 ± 10.83	(44/46)	15.33 ± 12.06	(2/10)	.2		
	S	(2/12)	.17	(21/38)	6.05 ± 8.18	(17/30)	12.13 ± 12.77	(10/10)	22.6 ± 12.29	(30/30)	17.13 ± 10.93
Holothuria nobilis	N							(1/10)	.1		
Holothuria hilla	N					(1/16)	.06			(1/20)	.05
	M	(1/28)	.07 ± .38	(3/14)	.43 ± 1.09	(11/46)	.57 ± 1.28				
	S			(3/38)	.21 ± .87	(11/30)	2.20 ± 3.85	(3/10)	.6 ± .97	(7/30)	.4 ± .86
Holothuria impatiens	N									(1/20)	.05
	S					(1/30)	.07				

Table 1. continued

Reef Area Reef Subarea Statistic		INNER REEF FLAT Sand (f)	$\bar{Y} \pm s$	Scattered Coral (f)	$\bar{Y} \pm s$	TUMON BAY Coral (f)	$\bar{Y} \pm s$	OUTER REEF FLAT Pavement and Pool (f)	$\bar{Y} \pm s$	Pavement (f)	$\bar{Y} \pm s$
<u>Holothuria</u> <u>leucospilota</u>	N	(1/32)	.03	(3/22)	.27 ± .77	(11/16)	5.25 ± 9.31	(10/10)	19.5 ± 14.21	(7/20)	3.25 ± 6.53
	M	(1/28)	.07 ± .38	(1/14)	.14 ± .53	(6/46)	.28 ± .96			—	—
	S			(3/38)	.45 ± 1.87	(4/30)	.47 ± 1.85	(7/10)	6.0 ± 7.89	(29/30)	8.17 ± 6.01
<u>Holothuria</u> <u>pervicax</u>	N					(2/16)	.12	(2/10)	.2		
	M					(2/46)	.04 ± .21			—	—
synaptid sp.	N			(2/22)	.09	(2/16)	.12	(1/10)	.1		
	M			(1/14)	.21 ± .80					—	—
	S			(1/38)	.03	(3/30)	.1				
Crustacea <u>Stenopus</u> <u>hispidus</u>	N			(2/22)	.09						

Table 2. Macroinvertebrates found along three transects in Agana Bay [N=(1) north, M=(2) middle, S=(3) south]. The frequency (f) is the number of 10 m^2 quadrats in which the species or genus was observed (the numerator) over the total number of 10 m^2 quadrats examined (the denominator). The means and standard deviations are of the numbers of individuals per 10 m^2 quadrat. The "+" means the species was observed near, but not on, the transects. There was no pavement and pool subzone on the outer reef flat along the North Transect.

Reef Area Reef Subarea Statistic		INNER REEF FLAT Sand (f)	$\bar{Y} \pm s$	Scattered Coral (f)	$\bar{Y} \pm s$	AGANA BAY Coral (f)	$\bar{Y} \pm s$	OUTER REEF FLAT Pavement and Pool (f)	$\bar{Y} \pm s$	Pavement (f)	$\bar{Y} \pm s$
TAXA	Transect										
Gastropoda <u>Trochus</u> <u>niloticus</u>	N					(1/18)	.06	—	—		
	M					(4/34)	.12	(1/10)	.1		
	S					(2/34)	.06	(1/18)	.06	(2/6)	33
<u>Cerithium</u> <u>nodulosum</u>	N					(1/18)	.06	—	—		
<u>Lambis</u> <u>lambis</u>	M					(1/34)	.03				
<u>Vasum</u> sp.	M			(1/48)	.02						
Bivalvia <u>Pinna</u> <u>muricata</u>	N	(4/92)	.04					—	—		
<u>Tridacna</u> <u>maxima</u>	N					(1/18)	.06	—	—		
	M					(1/34)	.06				
	S							(1/18)	.06		
Cephalopoda <u>Octopus</u> sp.	S									(1/6)	.17
Asteroidea <u>Linckia</u> <u>laevigata</u>	N					(8/18)	.72 ± 1.02	—	—		
	M							(1/10)	.1		
	S					(7/34)	.24 ± .50	(1/18)	.06	(5/6)	.83
Ophiuroidea <u>Ophiocoma</u> sp.	N					(1/18)	.06	—	—		
	M									(14/14)	21
Echinoidea <u>Echinometra</u> <u>mathaei</u>	N			(1/12)	.08	(2/18)	.11	—	—		
	M					(2/34)	.06	(1/10)	.1		
	S	(2/78)	.03								
<u>Tripneustes</u> <u>gratilla</u>	S	(2/78)	.03	(2/18)	.11						
<u>Diadema</u> sp.	N					(7/18)	.61 ± .92	—	—		
	M			(1/48)	.02					+	
	S					(7/34)	.65 ± 1.72	(5/18)	.44 ± .86		

Table 2. continued

Reef Area Reef Subarea Statistic		AGANA BAY INNER REEF FLAT Sand (f)	 $\bar{Y} \pm s$	 Scattered Coral (f)	 $\bar{Y} \pm s$	 Coral (f)	 $\bar{Y} \pm s$	 OUTER REEF FLAT Pavement and Pool (f)	 $\bar{Y} \pm s$	 Pavement (f)	 $\bar{Y} \pm s$
Echinothrix diadema	N					(2/18)	.11	—			
	M					(1/34)	.03	(1/10)	.1		
	S							(1/18)	.06	(2/6)	.33
Holothuroidea											
Stichopus chloronotus	N					(2/18)	.11	—			
Stichopus horrens	N					(1/18)	.06	—			
Actinopyga echinites	N	(2/92)	.04 ± .33	(3/12)	.33 ± .65	(4/18)	.28 ± .57	—			
	M					(2/34)	.06	(2/10)	.02		
	S			(1/18)	.06			(1/18)	.06	(4/6)	1.5 ± 1.6
Bohadschia argus	N	+		(3/12)	.25	(1/18)	.06	—			
	M					(2/34)	.06				
	S					(8/34)	.32 ± .64	+			
Bohadschia marmorata	N	+		(1/12)	.08			—			
Holothuria atra	N	(28/92)	1.66 ± 3.14	(12/12)	8.33 ± 3.20	(17/18)	11.78 ± 6.17	—		(1/18)	.62
	M	(28/44)	3.32 ± 4.51	(38/48)	4.48 ± 4.50	(21/34)	2.5 ± 2.98	(5/10)	1.0 ± 1.3	(1/14)	.07
	S	(69/78)	7.33 ± 8.39	(18/18)	33.83 ± 8.56	(32/34)	8.85 ± 8.10	(17/18)	6.61 ± 3.60	(6/6)	4.0 ± 1.90
Holothuria nobilis	N	(1/92)	.01	(1/12)	.08	(1/18)	.06	—			
Holothuria hilla	N					(3/18)	.17	—			
	S					(1/34)	.03				
Holothuria leucospilota	N	(4/92)	.07 ± .36	(4/12)	.33	(7/18)	.78 ± 1.26	—			
	M			(5/48)	.56 ± 2.04	(14/34)	1.56 ± 2.49	(10/10)	7.3 ± 3.47	(1/14)	.57
	S					(17/34)	3.15 ± 4.43	(6/18)	.39 ± .61	(6/6)	5.17 ± 3.54
Holothuria pervicax	N					(1/18)	.06	—			
synaptid sp.	N					(1/18)	.06	—			
	S	(1/78)	.01								
Crustacea											
Stenopus hispidus	N			(2/12)	.17	(2/18)	.11	—			
	M					(1/34)	.03				

Table 3. Macroinvertebrates found along three transects in Agat Bay [N=(1) north, M=(2) middle, S=(3) south]. The frequency (f) is the number of 10 m^2 quadrats in which the species or genus was observed (the numerator) over the total number of 10 m^2 quadrats examined (the denominator). The means and standard deviations are of the numbers of individuals per 10 m^2 quadrat. The "+" means the species was observed near, but not on, the transects.

Reef Area Statistic		AGAT BAY Inner Reef Flat (f)	 $\bar{Y} \pm s$	 Outer Reef Flat (f)	 $\bar{Y} \pm s$
TAXA	Transect				
Gastropoda					
Trochus niloticus	M			(1/32)	.03
	S	(1/40)	.02	(2/18)	.11
Bivalvia					
Tridacna maxima	M	(1/40)	.02	(2/32)	.06
	S			(3/18)	.17
Asteroidea					
ophidiasterid sp.	S			(2/18)	.11
Ophiuroidea					
Ophiocoma sp.	M			(4/32)	.31 ± 1.03
Echinoidea					
Echinometra mathaei	N	(2/14)	.29 ± .83	(2/4)	.5
	M			(10/32)	.88 ± 1.74
	S	(1/40)	.02	(7/18)	.5 ± .7
Diadema sp.	N	(1/14)	.07		
	M			(4/32)	.16 ± .45
	S			(2/18)	.11
Echinothrix diadema	N	(2/14)	.29 ± .83	(2/4)	2.5
	M			(17/32)	3.19 ± 4.78
	S			(13/18)	1.56 ± 1.38
Heterocentrotus mammillatus	M			(1/32)	.03
Holothuroidea					
Actinopyga echinites	N	(1/14)	.07		
	M			(4/32)	.34 ± 1.00
	S	(10/40)	.38 ± .77		
Actinopyga mauritiana	M			(5/32)	.22 ± .61
	S	(1/40)	.02	(2/18)	.11
Holothuria atra	M	(2/40)	.12	(8/32)	.31 ± .59
	S	(16/40)	.82 ± 1.13	(1/18)	.06
Holothuria leucospilota	M	(1/40)	.02	(1/32)	.03
	S	(9/40)	.55 ± 1.69	(1/18)	.06

Table 4. A comparison of the number of species and population densities of holothurians between the three transects in Tumon Bay and Agana Bay. The population density and relative importance of Holothuria atra are also compared between the three transects.

TRANSECT	AGANA BAY S	AGANA BAY M	AGANA BAY N	TUMON BAY S	TUMON BAY M	TUMON BAY N
SAND						
No. species	2	1	6	1	3	3
No./10m^2	7.34	3.32	1.78	.17	23.28	.65
No.H.atra/10m^2	7.33	3.32	1.66	.17	23.14	.56
% H. atra	99.9	100	93	100	99.4	86
SCATTERED CORAL						
No. species	2	2	6	9	4	5
No./10m^2	33.89	5.04	9.4	6.94	41.35	11.78
No.H.atra/10m^2	33.83	4.48	8.33	6.05	40.57	11.32
% H. atra	99.8	89	89	87	98	96
CORAL						
No. species	4	4	10	9	8	7
No./10m^2	12.35	4.18	13.42	17.87	17.94	14.36
No.H.atra/10m^2	8.85	2.5	11.78	12.13	15.33	8.12
% H. atra	72	60	88	68	85	57
PAVEMENT AND POOL						
No. species	4	3		6	2	7
No./10m^2	7.06	8.32		30.4	.29	28.8
No.H.atra/10m^2	6.61	1.0		22.6	0	7.0
% H. atra	94	12		74	0	24
PAVEMENT						
No. species	3	2	1	8		6
No./10m^2	10.67	.64	.62	28.13		5.75
No.H.atra/10m^2	4.0	.07	.62	17.13		2.15
% H. atra	37	11	100	61		37

Table 5. A comparison of the number of species and population densities of holothurians between Tumon Bay, Agana Bay and Agat Bay.

	INNER REEF FLAT Sand	INNER REEF FLAT Scattered Coral	INNER REEF FLAT Coral	OUTER REEF FLAT
TUMON BAY				
No. species	4	9	11	12
No./10 m^2	8.0	20.0	16.7	18.7
AGANA BAY				
No. species	7	6	10	4
No./10 m^2	4.1	16.1	10.0	5.5
AGAT BAY				
No. species		4		4
No./10 m^2		.7		,6

Table 6. Macroinvertebrates found along eight transects in Ylig Bay. Four transects were from the north side of the bay and four were from the south side of the bay. The frequency (f) is the number of 10 m^2 quadrats in which the species or genus was observed (the numerator) over the total number of 10 m^2 quadrats examined (the denominator). The means and standard deviations are of the numbers of individuals per 10 m^2 quadrat. The "+" means the species was observed near, but not in, the transects.

	North (f)	North $\bar{Y} \pm s$	South (f)	South $\bar{Y} \pm s$
Trochus niloticus	(4/100)	.04	(1/130)	.01
Lambis lambis			(1/130)	.01
Echinometra mathaei	(4/100)	.07 ± .38		
Tripneustes gratilla	(2/100)	.02		
Diadema sp.	(1/100)	.01		
Echinothrix diadema	(3/100)	.06		
Echinothrix calamaris			(2/130)	.02
Stichopus chloronotus			(1/130)	.01
Actinopyga echinites	(3/100)	.09 ± .59		
Actinopyga mauritiana			+	
Bohadschia argus	(2/100)	.03		
Holothuria atra	(25/100)	3.45 ± 8.94	(4/130)	.03
Holothuria leucospilota	(20/100)	.85 ± 3.36	(6/130)	.05 ± .26
synaptid sp.			(1/130)	.01