A MARINE SURVEY OF THE APANON COASTAL ENVIRONMENT, TALAKAYA AREA, Rota, Mariana Islands

by

Barry D. Smith, Richard H. Randall, Steven S. Amesbury,
Elburn E. Irish, and Chad R. Wylie

Stylophora mordax (Dana, 1846)

Final Report

Submitted to
The Northern Islands Company
Saipan, Commonwealth of the Northern Mariana Islands

UNIVERSITY OF GUAM MARINE LABORATORY
Environmental Survey Report No. 22

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INTRODUCTION AND PROJECT NARRATIVE

by

Barry D. Smith

Introduction

Because of concern about erosion in the watersheds of the Talakhaya region of Rota, Commonwealth of the Northern Mariana Islands (CNMI) and the consequent impacts of sedimentation on nearshore marine ecosystems, the CNMI Coastal Resources Management Program and the CNMI Soil and Water Conservation Districts funded a baseline study of the marine environment of the Apanon coastal area, where five rivers debouch at the shoreline. The Northern Islands Company, Saipan was contracted to conduct the study, and, in turn, the University of Guam Marine Laboratory was subcontracted to perform a baseline marine assessment of the shallow reef platform and upper reef front slope along the Apanon coastal area. Data obtained from this assessment will serve as a baseline reference for government agencies developing management plans and making regulatory decisions about coastal resources in the area.

A proposal to conduct a marine assessment along the Apanon coastal area was submitted to the Northern Islands Company in February 1989, and an agreement between the Northern Islands Company and the University of Guam Marine Laboratory to conduct such an assessment was signed on 12 May 1989. Field work for the assessment was conducted 22-26 May 1989.

Project Description

The principal objective of this study was to conduct a limited marine assessment of the reef platform and adjacent upper reef front slope to a depth of 10 meters (i.e., the reef buttress-and-channel zone) along the Apanon coastal area off the Talakhaya region of Rota, where five rivers debouch at the shoreline. The overall study area is shown in Figure 1. Within this area, a quantitative assessment of major marine organisms was conducted, and the general surface current patterns and substrate characteristics were determined.

Specific scope-of-work items for the study included the following:

1. Map and generally characterize the reef platform and reef front slope within the region at a map scale of 1:10,000. At about 400-m intervals along the length of the study area, provide more detailed characteristics along four transects that extend normal from the shoreline across the reef platform and down the adjacent fore reef slope to a depth of 10 meters. Spacing of these transects can be adjusted to provide more adequate representation of abrupt lateral facies changes in the coastal region. Specific information provided at these transect locations will include:
   a) The distribution and description of apparent physiographic zonation patterns, including vertical relief, water depth, qualitative assessment of the nature of the reef platform substrate (reef rock and unconsolidated sediments).
   b) The zonal distribution and relative abundances of marine organisms including macroalgae, corals, other macrobenthos, and fishes that are present on the reef during daylight hours. Any occurrences of marine angiosperms will be also noted.
   c) Figures of the transect profiles at an appropriate scale will be provided.
2. Provide a general statement about the overall geomorphic history of the study area.
3. Provide recommendations in regard to areas of particular concern.
4. Document any unique and unusual physical and biological features observed within the study region.
5. Provide recommendations for mitigation procedures and restoration of natural conditions in impacted areas.
6. Provide a report that includes the findings of the above scope-of-work items, including maps, figures, tables, and a list of references cited.

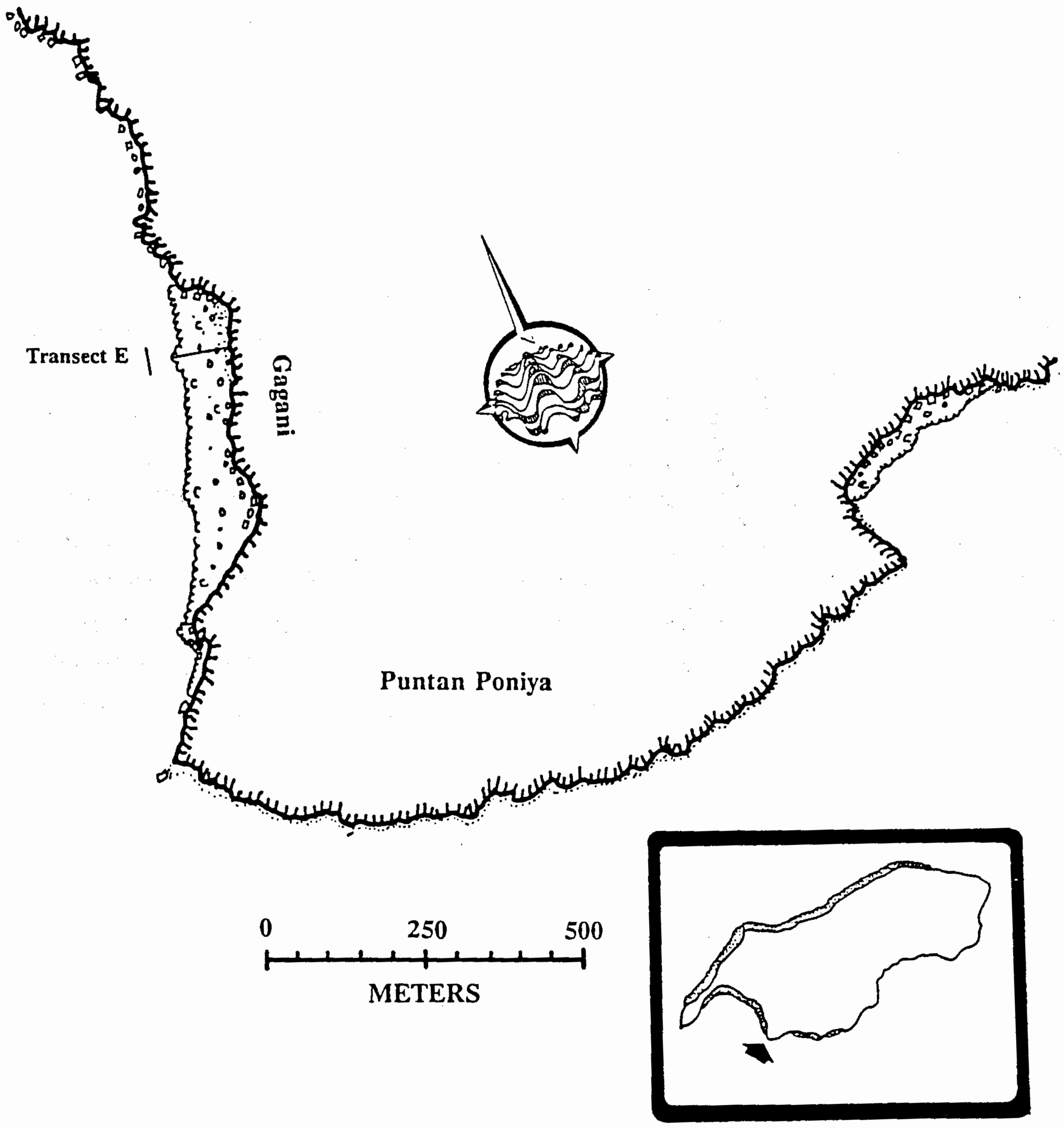


Figure 2. Map of the control transect (Transect E) on Gagani Reef, Sasanhaya Bay. Beach deposits are indicated by stippled areas, and coastal exposures of limestone, beachrock, and emergent reef limestone are indicated by short lines drawn normal to the shoreline. Map scale is 1:10,000. Modified from Eldredge and Randall (1980).

PHYSIOGRAPHIC DESCRIPTION OF THE REEF AND COASTAL AREAS ADJACENT TO APANON AND GAGANI

by

Richard H. Randall

Physiographic Setting of the Apanon Coastal Area

The primary study site [Transects A-D] is located along the southwestern coast of Rota, locally known as Apanon, where a number of small, short, high-gradient streams reach the shoreline (see Fig.1, p.2). The streams drain a small inlier of volcanic terrain, locally called Talakhaya, that outcrops between two levels of younger limestone plateaus. Between the lower level of plateauland and the shoreline, streams have cut small gorges or canyons through the limestone deposits on their way to the coast. Stream flow is intermittent in most streams, occurring primarily during heavy or prolonged periods of rainfall. During our field study, only the Babao River, near Transect D, had any water flow at the mouth. Much of the flow of this stream, as well as some of the others, comes from springs located along the upper contact of the volcanic inlier, where it is unconformably overlain by limestone deposits of the high central plateauland of the island. Rainwater percolates downward through these porous plateauland limestones until it reaches the less permeable volcanic rocks, then flows downdip along the contact, and emerges as springs and seeps along the upper boundary of the inlier. Rocks of the volcanic inlier are eroded into ridge and valley topography and at the surface are extremely weathered to clay minerals. Relatively unweathered volcanic rocks were only observed in stream beds. Slump scars on hillside have exposed red-colored soils and, at places, thick sections of saprolite. Except for freshly slumped regions the hillsides and ridgetops of the volcanic inlier are covered with savanna type vegetation consisting mostly of grasses and woody scrub. Some of the larger stream valleys and lower valley slopes are covered with a mixed forest growth.

Along the Apanon region a low coastal terrace (generally <2.0 meters in elevation) composed of unconsolidated alluvial and storm deposits extends inland a hundred or so meters in the vicinity of Transects A-C. Beaches ranging in width from 15.0 meters at Transect C to 20.5 meters at Transect A are developed along the

The coastal region at Gagani consists of a series of levels of limestone terraces and scarps that extend from the shoreline to the high inland plateauland. Much of the geomorphology along the Gagani area is related to coastal erosion of the gentle southwestward-dipping beds of Poniya Limestone exposed along the western side of Puntan Poniya. This limestone is a well-bedded, argillaceous, detrital limestone that appears to have been deposited as a forereef facies. Beds containing much clay and sand-sized grains are quite friable and alternate with more indurated layers containing abundant coral clasts. Near the shore, wave erosion has removed the friable layers more rapidly, producing extensive ledges which collapse into large blocks. These large blocks buttress the shoreline at places, giving it a very irregular relief and topography. At other places along the shoreline a younger limestone abuts the dipping Poniya beds, forming a very irregular, blocky limestone terrace which is about 10 meters in elevation and similar to the 10-meter limestone terrace described between Transects C and D along the Apanon region. In the vicinity of Transect F, small inliers of volcanic rock outcrop at shoreline and on the inner part of the reef flat platform. Erosion of these inliers has contributed noncarbonate sediments to the shallow reef platform and deeper reef front slope. Beach deposits at the shoreline also contain sand- to boulder-sized volcanic material intermixed with similar-sized bioclastic deposits partly of reef origin and partly from erosion of the nearby Poniya limestone beds.

Beach slopes, width, and other shoreline characteristics of Transect E are shown in a representative vertical profile section in Figure 1.

In the event that our baseline data from the five transects along the Apanon and Gagani regions are to be used for comparative purposes in a future study, the exact location of each transect along the shoreline and its bearing from the shoreline are as follows: 1) Transect A is located 27 meters east of the Fatguan River mouth and bears 3° E. of S. from the shoreline, 2) Transect B is located 60 meters east of the Keko River mouth and bears 1° E. of S. from the shoreline, 3) Transect C is located 202 meters west of the Keko River mouth and bears 180° from the shoreline, 4) Transect D is located 30 meters east of the Babao River mouth and bears 20° W. of S. from the shoreline, and 5) Transect E (control transect located along the Gagani region) is located 225 meters south of the northern end of the Gagani reef platform and bears 20° W. of S in a

Siegrist, In Press). In situ corals on the present inner reef flat platform and emergent median ridge indicate that a flourishing reef community grew on the newly flooded terrace and rapidly grew upward to, or near, sea level equilibrium. About 3000 years B.P. the relative sea level dropped, partially exposing the Holocene reef deposits, forming the present elevated inner reef flat platform and emergent median ridge. The outer, lower level of the reef flat platform, that lies seaward of emergent median ridge, apparently represents upward growth to sea level equilibrium and seaward progradation (reef flat development) since the relative sea level dropped to the present level about 3000 years B.P. Other emergent exposures of Holocene limestone deposits within the study area were observed at the shoreline in the vicinity of Transects C and D. Near Transect C patchy exposures, overlain by beachrock at places, form a narrow band generally less than 50 cm above the present inner reef flat platform level. At Transect D the emergent shoreline deposits are up to 1 meter above the present inner reef flat platform level, and at the mouth of the Babao River they could be traced upstream for 50 or more meters. At other shoreline localities a recrystallized detrital limestone forms emergent patches which are similar to the limestone terrace deposits that form the rocky shorelines west of Transect C. Sea level notches cut into a limestone cliff at +4.0 to +5.0 meters above present MLLW (just west of Transect D) possibly indicate the former Holocene sea level. Other than the present sea level notches cut into rocky shorelines, no other well-developed lower notches were observed within the study area. At first it was thought that the emergent median ridge on the present reef flat platform represented an elevated algal ridge at the seaward edge of a Holocene platform, but no emergent algal ridge facies was observed at any of the emergent limestone exposures. Community structure of corals in emergent Holocene deposits, both along the shoreline and in the median reef platform ridge deposits, is very similar to the upper reef front slope coral communities analyzed during the present study (Table 2). The median reef platform ridge deposits may have been a topographic high, such as a solution rampart developed at the outer margin of the Pleistocene terrace. When the Pleistocene platform was flooded, upward growth there simply was at a higher elevation, and it became the emergent ridge observed today when the relative sea level dropped.

organisms, mainly arthropods and molluscs, graze this algal-penetrated layer. Scrape marks from these grazers are abundant on both the supratidal and intertidal limestone surfaces, as well as their lime-rich fecal pellets which collect in depressions and flat-floored solution pools developed on the upper ridge surface. Twenty species of fossil reef-building corals and several species of fossil molluscs were identified from the emergent ridge, indicating that a flourishing reef facies once thrived at this location. Goniastrea retiformis and Leptoria phrygia were the dominant reef-building corals. Species richness, though, was higher in the immediate vicinity of the Babao River mouth along the shoreline than on the emergent ridge itself.

The outer reef platform is approximately at MLLW level or slightly intertidal, but at Transect A it is slightly subtidal, which accounts for the seven species of corals observed there. The single coral species observed on the outer reef flat platform at Transect B was located in a small pool which retained some 50 centimeters of water during low tides. At Transect C the outer reef flat platform is completely intertidal, but 13 species of corals were recorded from several large open pools where cavernous surge channels penetrating into the platform had collapsed. Except for a few pockets of coarse sand, gravel, and cobble veneering floors of holes and depressions, the outer reef flat surface was swept free of sediments at most places. A short algal turf, generally less than 2 cm high, trapped some fine-grained sand and provided habitat for abundant solitary foraminifers. Surface topography was relatively flat at Transects B and C, with small scattered holes and depressions producing most of the relief. At Transects A and B the surface was hummocky and irregular with topographic relief up to 50 cm in places.

High seas and breaking surf prevented thorough observation of the reef margin at most places. At Transects A, B, and D, the reef margin zone is formed by an irregular system of moderately short, open surge channels separated by very hummocky buttress ridges. At these three transects, surge channels seldom penetrated into the platform more than 6-8 meters. Where observations could be made, the surge channels were generally less than 2 meters deep and had minor amounts of loose sand, gravel, cobbles, and boulders scattered along their floors. At Transect C a low convex algal ridge system is developed at the reef margin. Maximum width of the algal ridge at Transect C was about 28 meters, and the crest was about 30 to 40 cm higher than the general outer reef

Description of the Gagani Reefs

Physiographic zonation patterns and geomorphic history of reefs along the Gagani coastal region at Transect E (control transect) are very similar to those described above for the Apanon reefs. The principal differences at the Gagani transect include the following: 1) there are no surface streams with basins draining volcanic terrain reaching the shoreline; 2) some small volcanic inliers that outcrop through reef deposits on the inner half of the reef flat platform and along the shoreline contribute noncarbonate sediment to both the reef platform and reef front zones; 3) a median ridge of emergent Holocene limestone is absent on the reef flat platform; 4) the outer reef flat platform is slightly deeper, and there is no elevated algal ridge development at the reef margin; and 5) the reef front slope zone is not quite as wide, but it has more topographic relief because of the presence of scattered larger mounds, knobs, and pinnacles.

References Cited

Bell, S. C. 1988. Sedimentary history and early diagenesis of Holocene reef limestone on Rota (Mariana Islands). Unpubl. M.S. Thesis, Univ. Maryland, College Park, MD. 82 p.

Bell, S. C., and H. G. Siegrist, Jr. In Press. Patterns in reef diagenesis: Rota, Mariana Islands. Proc. Sixth Internat. Coral Reef Congress, Townesville, Australia.

Randall, R. H., and B. D. Smith. 1988. A reconnaissance marine survey of the Mochong-As Matmos coastal area of Rota in the Mariana Islands. Univ. Guam Mar. Lab., Environ. Surv. Rept. 21. 28 p.

Sugimura, A. (ed.). 1986. Sea-level changes and tectonics in the middle Pacific (Japanese HIPAC Team). Kobe Univ., Japan. 126 p.

CURRENT PATTERNS AND SUBSTRATE CHARACTERIZATION

by

Elburn E. Irish and Richard H. Randall

The distribution and accumulation of sedimentary materials is strongly influenced by patterns of water circulation. These circulation patterns were measured to determine direction and speed of water movement in the study area.

The substrate on the reef is determined largely by the characteristics of parent materials (both terrestrial and submarine), water movements, and biological activity. The substrate was characterized at each of the transect locations.

Because the greatest potential impact to the shoalwater region along the Apanon coastal region is from stream-borne terrestrial sedimentation, several beach and reef front slope sediment samples were collected and analyzed for insoluble residue, HCl-soluble Fe, and KCl-exchangeable NH_4^+ and NO_x. Such analyses provide estimates of the present amounts of terrestrial sediment incorporation into beach and reef front slope zones and also provide a data base for future comparison.

Methods

Current Analysis

Measurements of currents were made on the reef platform and reef slope zones along the Apanon coastal area of Rota on May 23-27, 1989. For determining current patterns on the reef flat platform, fluorescein dye was injected into the water at various intervals along the transect line running from the beach to the reef margin. Dye injections were made just below the surface of the water in order to reduce the influence of wind-generated surface water movement. At each injection location, the distance the dye patch traveled, the elapsed time, and the direction of movement were recorded.

Current patterns in the waters over the reef slope were measured by the use of a drogue consisting of a cross-shaped galvanized sheet metal vane (50 cm X 50 cm) suspended from a float. The drogue was released from a boat which was anchored in 8 m of water (approximately 100 m offshore) at each of the Apanon transects (A-D). The drogue was allowed to float with the current for a measured distance (determined by a

Results and Discussion

Current Analysis and Discussion

Current speed and bearing, water depth, distance from shore, and tide stage data are given in Table 1 for each transect station. Current velocity vectors for each transect station are plotted in Figure 1.

Reef platform currents are generated primarily by waves that break along the seaward reef margin. As an approaching wave crest breaks, water is moved shoreward across the outer reef platform by translatory wave motion, through gaps in the limestone ridge, and onto the slightly higher inner reef flat platform. A few seconds later, as the wave trough approaches, part of the water transported onto the reef margin, and possibly some from the outermost part of the reef platform, reverses direction and flows seaward until the next crest arrives. Oscillatory currents, with directions more or less perpendicular to the shoreline, are thus generated on the reef margin and outermost part of the reef platform.

The remaining water transported onto the reef platform flows hydrostatically from higher to lower platform elevations, generating longshore currents with strong lateral vectors with respect to the reef margin. Seaward flowing currents are generated on the reef platform where longshore water flow returns to the open sea, primarily through reef margin depressions and large reentry channels that penetrate the reef platform.

Reef platform topography and elevation primarily determine current direction, and the amount of water transported onto the platform by breaking waves determines current speed. Some minor currents are also generated by water flowing on and off the platform during flooding and ebbing tides, but again, the direction of such currents is controlled by platform topography and elevation.

Currents during ebbing tide conditions on the inner reef platform at Transects A - D all had strong westerly components, or there was no detectable water movement at all (Table 1, Stations 3 & 4 at Transects A - C and Station 3 at Transect D; and Figure 1). During low tides, especially when accompanied by low wave assault or calms, water becomes impounded on the inner reef flat platform and currents are absent. Current speed on the inner reef platform ranged from no detectable water movement to 0.23 m/sec during ebbing tide conditions, but would most likely be higher during high tide when more water would be present.

Sediment Sample Analysis

The results of the sediment analyses are presented in Table 3. Assuming that the HCl-soluble sediment fraction consists mostly of biogenic skeletal carbonates of reef origin, there was little terrestrial sediment incorporation into sediments in the upper reef front zones at Transects A, B, C, and E, and only a moderate amount at Transect D. Although the Babao River has the largest drainage basin and apparently carries the highest sediment load, Transect D, located just 30 meters east of the river mouth, had the second highest values of coral substrate coverage and density (see Table 1). Soluble Fe, NH_4^+, and total nitrates (NO_x) were also high at Transect D. The HCl-soluble fraction of beach sediments was more variable, probably reflecting the considerable variation in sorting and texture that was apparent along the Apanon coast.

References Cited

Jones, M. N. 1984. Nitrate reduction by shaking with cadmium, alternative to cadmium columns. Water Res. 18(5):643-646.

Matson, E. A. 1989. Biogeochemistry of Mariana Islands coastal sediments: terrestrial influence of $\delta^{13}C$, Ash, $CaCO_3$, Al, Fe, Si and P. Coral Reefs 7:153-160.

Matson, P. A. , P. M. Vitousek, J. J. Ewel, M. J. Mazzarino, and G. P. Robertson. 1987. Nitrogen transformations following tropical forest felling and burning on a volcanic soil. Ecology 68(3):491-502.

Murray, J. W., and G. Gill. 1978. The geochemistry of iron in Puget Sound. Geochim. Cosmoschim. Acta 42:9-19.

Rosenfeld, J. K. 1979. Ammonium adsorption in nearshore anoxic sediments. Limnol. Oceanogr. 24:356-364.

Table 1. Water current data for Transects A - D along Apanon coastal area.

Transect A: May 23, 1989 High Tide at 0744 = 0.5m
Low Tide at 1519 = -0.1m

Sta No	Dist from shore (m)	Current speed (m/sec)	Depth (m)	Bearing (deg)	Tide stage
1	60m	0.22	0.23	188	EBB
1	60m	0.19	0.23	180	EBB
1	60m	0.19	0.23	180	EBB
2	45m	0.19	0.25	308	EBB
2	45m	0.21	0.25	320	EBB
2	45m	0.10	0.25	322	EBB
3	30m	0.11	0.23	303	EBB
3	30m	0.16	0.23	300	EBB
3	30m	0.11	0.23	295	EBB
4	10m	0.04	0.23	298	EBB
4	10m	0.07	0.23	291	EBB
4	10m	0.04	0.23	298	EBB
Date: May 24, 1989		Start: 1000 Finish: 1020		High Tide at 0816 = 0.7 Low Tide at 1601 = -0.1	
5	110m	0.08	8	260	EBB
5	110m	0.10	8	253	EBB
5	110m	0.10	8	252	EBB

Transect B: May 23, 1989 Start: 10:30 High Tide at 0744 = 0.5m
Finish: 12:00 Low Tide at 1519 = 0.1m

Sta No	Dist from shore (m)	Current speed (m/sec)	Depth (m)	Bearing (deg)	Tide stage
1	60m	0.50	0.30	240	EBB
1	60m	0.30	0.30	287	EBB
1	60m	0.35	0.30	280	EBB
2	50m	0.53	0.30	288	EBB
2	50m	0.25	0.30	287	EBB
2	50m	0.34	0.30	270	EBB
3	30m	No	0.23	No	EBB
3	30m	Move-	0.23	Move-	EBB
3	30m	ment	0.23	ment	EBB
4	10m	0.23	0.15	277	EBB
4	10m	No	0.15	No	EBB
4	10m	Movement	0.15	Movement	EBB
Date: May 24, 1981		Start: 1200 Finish: 1215		High Tide at 0816 = 0.7 Low Tide at 1601 = 0.1	
5	110m	0.13	8	275	EBB
5	110m	0.14	8	258	EBB
5	110m	0.12	8	259	EBB

Table 2. Substrate characterization of Transects A-D along the Apanon coastal area, Rota. Point counts of four different substrate characteristics (A-D) are given for each quadrant station. Percent cover for each class of substrate is also given for each area along the transect. The reef zones are abbreviated I,O, and S for inner reef platform, outer reef platform and reef front slope respectively. Definitions of substrate are given in text. Distance along the transects on the reef slopes are in parentheses.

A - Pavement
B - Sand
C - Cobble
D - Gravel

Station No.	Distance from shore (m)	Reef type	A	B	C	D
Transect A:						
1	60	O	2		20	10
2	45	O	19	11	2	
3	30	I	32			
4	10	I	32			
5	110(50m)	S	29	1	2	
5	110(25m)	S	30		2	
5	110(0m)	S	23	7	2	
Total Points: Inner Reef Platform			64			
Total Points: Outer Reef Platform			21	11	22	10
Total Points: Reef Front Slope			82	8	6	
% Substrate: Inner Reef Platform			100%			
% Substrate: Outer Reef Platform			33%	17%	34%	16%
% Substrate: Reef Front Slope			85%	8%	7%	
Transect B:						
1	60	O	32			
2	50	O	31	1		
3	30	I	32			
4	10	I	32			
5	110(50m)	S	27		5	
5	110(25m)	S	31		1	
5	110(0m)	S	31	1		
Total Points: Inner Reef Platform			64			
Total Points: Outer Reef Platform			63	1		
Total Points: Reef Front Slope			89	1	6	
% Substrate: Inner Reef Platform			100%			
% Substrate: Outer Reef Platform			98%	2%		
% Substrate: Reef Front Slope			93%	1%	6%	
Transect C:						
1	80	O	16	10		6
2	60	O	30	1		1
3	40	I	32			
4	20	I	32			
5	110(50m)	S	29	3		
5	110(25m)	S	32			
5	110(0)	S	31	1		
Total Points: Inner Reef Platform			64			
Total Points: Outer Reef Platform			46	11	7	
Total Points: Reef Front Slope			92	4		
% Substrate: Inner Reef Platform			100%			
% Substrate: Outer Reef Platform			72%	17%	11%	
% Substrate: Reef Front Slope			96%	4%		

Table 3. Analysis of beach and reef front slope sediment samples from Transects A-E.

Transect	Percent Soluble in HCl	HCl Soluble Fe (u mol./g dry sed.)	KCl Exchangeable NH_4^+ (u mol./g dry sed.)	KCl Exchangeable NO_x (u mol./g dry sed.)	Collection Date
Reef Front Slope Samples *					
A	97.0	0.42	0.53	0.0068	May 24, 1989
B	95.3	0.75	0.35	0.0078	May 24, 1989
C	97.8	0.26	0.50	0.0800	May 25, 1989
D	84.1	0.94	0.67	0.1700	May 25, 1989
E	99.0	0.21	0.053	0.0040	May 25, 1989
Beach Samples **					
A	32.3	0.76	0.23	0.11	May 26,1989
B	59.0	1.13	0.23	0.092	May 26,1989
C	82.7	0.82	0.23	0.088	May 26,1989
D	48.5	1.11	0.38	0.065	May 26, L989
E	(no sample taken)				

Samples not rinsed
HCl is 20% for 24 hrs.
KCl is 2M for 2 hrs.
*Reef front slope samples collected at 6 meters depth
**Beach samples collected 2 meters above high tide level

percent algal coverage (excluding turf algae and diatoms) ranged between 1.0%-43.8%. Turf algae covered between 33.9%-86.9% of the reef flat transects.

A consistent pattern for percent cover of macroalgae was not observed between the inner and outer reef flat but there was some difference in frequency of occurrence of certain species. Laurencia sp. and Gracilaria sp. were found only on the inner reef flat while algae such as Ectocarpus breviarticulatus, Gelidiella acerosa, and Asparagopsis taxiformis (including the sporophyte form, Falkgenbergia) were found only on the outer reef flat were wave action was intense. The inner and outer reef flats of transects B and C were divided by emergent Holocene limestone outcrops which protected the inner reef from wave action. The outer reef flat of transect D was characterized by an emergent wave-washed bench platform which contained numerous algal species common to such exposed wave areas (Table 1).

Tsuda (1969) and Randall & Smith (1988) found no marine angiosperms during their surveys of Rota. The present study found several small patches of the seagrass Enhalus acroides between transects C and D in the inner reef flat. The two largest patches measured approximately 7.5 m x 3 m and 8 m x 5 m. This area of the study site contained the only protected sandy substrate, which is needed for seagrass succession.

Reef Front

The results of the reef front transects A-E are presented in Table 2. A total of 15 species were observed, 12 of those occurring on the transects. Percent algal coverage (excluding turf algae and diatoms) ranged between 36.1%-38.7% for transects A-D and 13.0% for transect E. Turf algae were abundant on all 5 reef front transects and ranged between 42.9%-58.2% coverage.

Transects A-D were similar in algal composition. These transects were dominated by blue-green algae such as Schizothrix mexicana and Microcoleus lyngbyaceus. Other algae such as Halimeda opuntia, Amphiroa fragilissima, and Asparagopsis taxiformis were also abundant. Transect E differed from the other sites by the presence of Tydemannia expeditionis and Calothrix crustacea which grew on and between the abundant live coral colony branches. Site E was also protected from most

Table 1. Reef flat percent cover and percent frequency of the benthic algae along five transects (A,B,C,D,and E). Transects were subdivided into inner and outer zones as indicated by the distance from shore. Plain numbers indicate percent coverage; numbers in parentheses indicate percent frequency of occurrence. Algal species occurring in the vicinity of the transect are marked with X.

	TRANSECTS									
	A		B		C		D		E	
	0-35	35-60	0-35	35-60	0-40	40-80	0-20	20-30	0-30	30-60
CYANOPHYTA										
Hormothamnion enteromorphoides Grunow		0.6(10)		X	X	X			X	X
Microcoleus lyngbyaceus (Kutz.) Crouan				X		X				
Schizothrix calcicola (Ag.) Gomont						1.6(19)			0.5(8)	
Schizothrix mexicana Gomont	X	X		X		1.2(19)	X	X	1.6(25)	
CHOLROPHYTA										
Boergesenia forbesii (Harv.) Feldmann	0.5(7)									
Boodlea composita (Harv.) Brand								X		
Caulerpa cupressoides (West) C. Ag.									X	
Caulerpa racemosa (Forsk.) J. Ag.						X		X	X	1.0(8)
Chaetomorpha sp.								X		
Chlorodesmis fastigiata (C. Ag.) Ducker						X		X		
Cladophoropsis sp.								X		
Dictyosphaeria cavernosa (Forssk.) Boerg.								X		
Neomeris annulata Dickie									X	
PHAEOPHYTA										
Chnoospora minima (Hering) Papenfuss								X		
Ectocarpus breviarticulatus J. Ag.		X		X		X		X		
Feldmannia indica (Sonder) Womersley & Bailey	X								1.0(8)	
Padina tenuis Bory			X		X		X			
Sargassum cristaefolium C. Ag.								X		
Sphacelaria tribuloides Meneghini			X			X				
Turbinaria ornata (Turn.) J. Ag.		X		X				X	X	X
RHODOPHYTA										
Acanthophora spicifera (Vahl.) Boerg.							X	X		
Amphiroa fragilissima Lamx.									X	
Asparagopsis taxiformis (Delile) Collins & Hervey		10.6(20)	X	41.3(80)		X		X		
Centoceras clavulatum (C. Ag.) Mont.								X		
Gelidiella acerosa (Forssk.) Feldmann & Hamel								15.6(25)		

Table 2. Reef front percent cover and percent frequency of the benthic algae along five 50 m transects perpendicular to transects A-E. Plain numbers indicate percent coverage; numbers in parentheses indicate percent frequency of occurrence. Algal species occurring in the vicinity of the transect are marked with X.

	TRANSECTS				
	A	B	C	D	E
CYANOPHYTA					
Calothrix crustacea Schousboe & Thuret					X
Hormothamnion enteromorphoides Grunow				X	
Microcoleus lyngbyaceus (Kutz.) Crouan	3.7(18)	10.2(46)	9.7(55)	11.7(59)	2.3(18)
Schizothrix calcicola (Ag.) Gomont	2.6(5)	1.1(9)	2.3(9)	1.7(5)	4.3(18)
Schizothrix mexicana Gomont	26.1(55)	22.2(68)	15.1(73)	23.0(82)	X
CHLOROPHYTA					
Halimeda opuntia (L.) Lamx.	0.3(5)	1.1(14)	4.8(41)	2.0(18)	0.9(5)
Neomeris annulata Dickie	0.6(9)				
Tydemannia expeditionis W. v. Bosse					0.9(9)
RHODOPHYTA					
Amphiroa foliacea Lamx.	X	X	X	X	X
Amphiroa fragilissima Lamx.	1.4(14)	0.3(5)	0.9(9)	0.3(5)	4.6(32)
Asparagopsis taxiformis (Delile) Collins & Hervey	2.8(14)	0.3(5)	0.9(5)		
Desmia hornemanni Lyngb.	X	0.9(9)	0.3(5)		
Galaxaura fasciculata Kjellm.	X	X		X	
Galaxaura marginata Lamx.	0.6(9)				
Porolithon sp.			1.4(5)		
Algal turf	58.2(86)	53.1(96)	50.9(100)	51.7(96)	42.9(82)
Diatom scuz					0.9(5)
Rock		2.0(9)	3.1(18)	3.1(9)	27.3(82)
Sand	1.7(9)	1.1(9)	2.3(18)	0.9(5)	6.0(18)
Live coral	0.9(5)	4.6(27)	3.7(32)	4.3(23)	9.9(55)
Soft coral			0.3(5)		
Sponge	1.1(9)	3.1(36)	3.7(18)	1.4(18)	0.3(5)

ABUNDANCE AND DISTRIBUTION OF REEF CORALS

by

Richard H. Randall

Reef-building scleractinian, octocorallian, and hydrozoan corals are sessile invertebrates with potentially long life spans and with distribution patterns that depend upon the particular setting found from one habitat to another. Their stony calcium carbonate skeletons are major contributors to both in situ framework and detrital reef deposits in shoal-water fringing reef environments. Characteristic coral communities develop in response to variable environmental conditions found from one habitat to another, ranging from conditions completely unfavorable for corals to optimum conditions where corals are the dominant organisms in the community. Corals are sensitive to many environmental variables, particularly suspended materials in the water column, sediment accumulation on the substrate upon which they grow, water currents, seawater dilution from surface drainage and groundwater discharge, temperature fluctuations, emersion on shallow platforms during low tides, and various forms of pollution from toxic substances and thermal, storm drain, and sewage discharges. Because of their sensitivity to these environmental factors, corals can be useful as indicator organisms which reflect the quality of the environment. Assessment of the present coral communities on the shoal-water reef habitats along the Apanon and Gagani coastal regions will establish baseline data from which changes in the quality of the reef environment can be determined or predicted.

The principal objectives of this part of the study were to determine the abundance and distribution of reef-building corals within the shoalwater Apanon coastal region and to document the effect of a number of small streams that debouch at the shoreline on the community structure of corals.

Methods

Coral communities were analyzed along transects by using the plotless point-centered or point-quarter technique of Cottam et al. (1953). Five transects were established within the study area by placing a plastic surveyor's tape along the bottom on the reef flat platform and seaward reef front slope locations, as shown in Figures 1 and

9. Importance value = Relative density + relative percent coverage + relative frequency

Colony size distribution data (Y = arithmetic mean, s = standard deviation, and w = size range) were also calculated from the point-quarter data. The coral encountered during the point-quarter analysis indicate the predominant and common species along the transects. The presence of uncommon and rare species, not encountered during the point-quarter analysis, was determined for each transect by making 10-minute snorkel observations along each side of the transect line within the various zones discriminated.

Results and Discussion

Quantitative analysis of the coral species encountered on transects is presented in Table 1. An overall list of species was compiled (Table 2) for each transect zone by combining those encountered during the point-quarter analysis (Table 1) with those from snorkel observations.

A cumulative total of 72 coral species representing 11 families and 25 genera was recorded from Transects A-E. Sixty-five species representing 11 families and 23 genera were recorded from Transects A-D along the Apanon coastal region, and 37 species representing 10 families and 23 genera were recorded from Transect E along the Gagani coastal region (Table 2). Of the 72 species, 11 were common to all transects, 9 were common to 4 transects, 11 were common to 3 transects, 24 were common to 2 transects, and 17 were recorded at only a single transect location. A comparison of the corals of the two regions reveals that 6 species were found only at the Gagani region (Transect E) while 35 species were found only at the Apanon region (Transect A-D). Thirty-one species were common to both coastal areas.

Species richness was highest at Transect D, where 45 species were encountered, and lowest at Transect B, where 30 species were recorded. At Transects A-D corals were absent on the inner reef flat because of platform emergence and water temperature elevation in isolated pools and depressions during low tides. Corals were also absent on the outer reef flat at Transect D because of platform emergence, and only one coral colony was observed in a small pool that retained water in the same zone at Transect B. Seven species of corals were recorded from the outer reef flat at

Gagani site, but were not observed at the Apanon site.

References Cited

Cottam, G., J. T. Curtis, and B. W. Hale. 1953. Some sampling characteristics of a population of randomly dispersed individuals. Ecology 34:731-757.

Table 1. Cont.

Transect, Reef Zone, and Coral Taxons	Size Distribution (Dia. in cm) n	$\bar{Y}$	s	w	Freqency	Relative Frequecy	Density	Relative Density	Percent Cover	Relative Percent Cover	Importance Value
Transect B											
Intertidal Bench (0-27.5 M) (no corals encountered)											
Emergent Ridge (27.5-38.5 M) (no corals encountered)											
Outer Reef Flat Platform (38.5-71) (no corals encountered)											
Reef Front Slope (2-6 Meters Deep)											
Pocillopora elegans	3	27.7	9.6	16.7-34.3	0.30	9.68	0.09	8.33	0.57	19.33	37.34
Millepora platyphylla	2	32.4	29.6	11.5-53.3	0.20	6.45	0.06	5.56	0.68	23.06	35.07
Porites lobata	4	19.7	8.1	11.5-30.3	0.20	6.45	0.12	11.11	0.40	13.56	31.12
Pocillopora eydouxi	1	49.4	-	-	0.10	3.23	0.03	2.78	0.56	18.99	25.00
Montipora verrilli	3	15.5	6.5	8.1-20.0	0.30	9.68	0.09	8.33	0.18	6.10	24.11
Pocillopora verrucosa	3	3.8	0.8	3.0-4.5	0.20	6.45	0.09	8.33	0.01	0.34	15.12
Favia stelligera	2	10.2	5.9	6.0-14.3	0.20	6.45	0.06	5.56	0.05	1.70	13.71
Pocillopora setchelli	2	9.1	2.0	7.7-10.5	0.20	6.45	0.06	5.56	0.04	1.36	13.37
Acropora cerealis	2	7.5	3.6	4.9-10.0	0.20	6.45	0.06	5.56	0.03	1.02	13.03
Montastrea curta	2	6.7	0.9	6.0-7.3	0.20	6.45	0.06	5.56	0.02	0.69	12.70
Porites lichen	3	4.1	1.8	2.0-5.3	0.10	3.23	0.09	8.33	0.01	0.34	11.90
Acropora sp. 1	1	21.9	-	-	0.10	3.23	0.03	2.78	0.11	3.73	9.74
Acropora humilis	1	17.5	-	-	0.10	3.23	0.03	2.78	0.07	2.37	8.38
Acropora surculosa	1	18.0	-	-	0.10	3.23	0.03	2.78	0.07	2.37	8.38
Goniastrea retiformis	1	14.3	-	-	0.10	3.23	0.03	2.78	0.05	1.70	7.71
Porites lutea	1	14.5	-	-	0.10	3.23	0.03	2.78	0.05	1.70	7.71
Heliopora coerulea	1	12.0	-	-	0.10	3.23	0.03	2.78	0.03	1.02	7.03
Platygyra pini	1	7.0	-	-	0.10	3.23	0.03	2.78	0.01	0.34	6.35
Hydnopora microconos	1	4.5	-	-	0.10	3.23	0.03	2.78	0.005	0.17	6.18
Acanthastrea echinata	1	4.0	-	-	0.10	3.23	0.03	2.78	0.004	0.14	6.15
Totals	36	14.6	12.2	2.0-53.3			1.08		2.949		
Transect C											
Intertidal Bench (0-30 M) (no corals encountered)											
Emergent Ridge (30-45 M) (no corals encountered)											
Outer Reef Flat Platform (45-82 M)											
Pocillopora setchelli	8	10.2	3.4	7.0-18.0	0.43	100.00	0.022	100.00	0.019	100.00	300.00
Totals	8	10.2	3.4	7.0-18.0			0.022		0.019		
Reef Front Slope (2-6 Meters Deep)											
Goniastrea retiformis	4	25.0	24.5	9.5-61.4	0.40	12.12	0.68	10.00	5.71	20.46	42.58
Millepora platyphylla	3	36.2	14.2	20.0-46.3	0.30	9.09	0.51	7.50	5.75	20.60	37.19
Porites lutea	6	15.1	9.5	3.5-28.1	0.30	9.09	1.01	15.00	2.43	8.71	32.80

Table 1. Cont.

Transect, Reef Zone, and Coral Taxons	Size Distribution (Dia. in cm) n	$\bar{Y}$	s	w	Freqency	Relative Frequecy	Density	Relative Density	Percent Cover	Relative Percent Cover	Importance Value
Astreopora myriophthalma	1	5.5	-	-	0.10	3.03	0.15	2.50	0.04	0.17	5.70
Favia favus	1	6.0	-	-	0.10	3.03	0.15	2.50	0.04	0.17	5.70
Galaxea fascicularis	1	6.0	-	-	0.10	3.03	0.15	2.50	0.04	0.17	5.70
Montipora caliculata	1	5.9	-	-	0.10	3.03	0.15	2.50	0.04	0.17	5.70
Acanthastrea echinata	1	4.9	-	-	0.10	3.03	0.15	2.50	0.03	0.12	5.65
Totals	40	13.8	18.9	2.0-106.3			6.00		25.58		
Transect E											
Inner Reef Flat Platform (0-35 M) (no corals encountered)											
Outer Reef Flat Platform (35-60 M)											
Favia stelligera	1	28.6	-	-	0.25	9.09	0.18	6.25	1.17	36.91	52.25
Acropora valida	3	11.3	5.8	6.0-17.5	0.25	9.09	0.55	18.75	0.64	20.19	47.98
Pocillopora setchelli	4	4.0	0.8	3.0-5.0	0.50	18.18	0.73	25.00	0.09	2.84	46.02
Acropora cerealis	1	21.8	-	-	0.25	9.09	0.18	6.25	0.68	21.45	36.79
Pocillopora verrucosa	2	4.0	0.0	4.0-4.0	0.50	18.18	0.36	12.50	0.05	1.58	32.26
Acropora digitifera	1	16.3	-	-	0.25	9.09	0.18	6.25	0.38	11.99	27.33
Porites (S.) rus	2	4.1	0.1	4.0-4.2	0.25	9.09	0.36	12.50	0.05	1.58	23.17
Psammocora haimeana	1	8.1	-	-	0.25	9.09	0.18	6.25	0.09	2.84	18.18
Porites superfusa	1	3.5	-	-	0.25	9.09	0.18	6.25	0.02	0.63	15.97
Totals	16	9.0	7.8	3.0-28.6			2.90		3.17		
Reef Front Slope (2-6 Meters Deep)											
Pavona varians	2	32.4	34.9	7.7-57.1	0.10	3.33	0.17	5.00	2.20	35.37	43.70
Acropora monticulosa	2	35.4	14.6	25.0-45.7	0.10	3.33	0.17	5.00	1.80	28.94	37.27
Goniastrea retiformis	6	5.6	1.5	2.8-7.0	0.40	13.33	0.51	15.00	0.13	2.09	30.42
Porites (S.) rus	2	21.9	27.6	2.4-41.4	0.20	6.67	0.17	5.00	1.14	18.33	30.00
Pocillopora setchelli	5	8.9	5.2	3.0-15.5	0.20	6.67	0.42	12.50	0.33	5.31	24.48
Porites lichen	4	6.9	2.5	4.6-9.5	0.30	10.00	0.34	10.00	0.14	2.25	22.25
Goniastrea edwardsi	4	4.4	0.9	3.5-5.5	0.30	10.00	0.34	10.00	0.o5	0.80	20.80
Pocillopora verrucosa	3	3.8	1.9	2.4-6.0	0.20	6.67	0.25	7.50	0.03	0.48	14.65
Galaxea fascicularis	2	7.1	1.5	6.0-8.1	0.20	6.67	0.17	5.00	0.07	1.13	12.80
Porites lutea	1	12.5	-	-	0.10	3.33	0.08	2.50	0.10	1.61	7.44
Montipora verrilli	1	11.4	-	-	0.10	3.33	0.08	2.50	0.09	1.45	7.28
Millepora platyphylla	1	9.4	-	-	0.10	3.33	0.08	2.50	0.06	0.96	6.97
Favites russelli	1	4.9	-	-	0.10	3.33	0.08	2.50	0.02	0.32	6.15
Psammocora sp. 1	1	4.9	-	-	0.10	3.33	0.08	2.50	0.02	0.32	6.15
Favia favus	1	3.5	-	-	0.10	3.33	0.08	2.50	0.01	0.16	5.99
Pavona sp. 2	1	4.6	-	-	0.10	3.33	0.08	2.50	0.01	0.16	5.99

Table 2. List of coral species recorded from (X), or observed (O) within a 5-meter wide band along each side of Transects A-E. IRF = inner reef flat platform or intertidal bench zone, ORF = outer reef flat platform zone, and RFS = reef front slope.

Transects	A			B			C			D			E		
Reef Zones	IRF	ORF	RFS	IRF	ORF	RFS	IRF	ORF	RFS	IRF	ORF	RFS	IRF	ORF	RFS
Coral Taxons															
Class ANTHOZOA															
Order SCLERACTINIA															
Suborder ASTROCOENIINA															
Family ASTROCOEIIDAE															
Stylocoeniella armada (Ehrenberg)															x
Family THAMNSTERIIDAE															
Psammocora digitata Milne Edwards & Haime									o			o		x	
Psammocora haimeana Milne Edwards & Haime									o						
Psammocora nierstraszi van der Horst															x
Psammocora sp. 1		x													
Family POCILLOPORIDAE															
Stylophora mordax (Dana)												x			x
Pocillopora ankeli Scheer & Pillai									o			o		o	
Pocillopora damicornis (Linnaeus)		x													
Pocillopora danae Verrill												o			
Pocillopora elegans Dana			x			x			x			x			
Pocillopora eydouxi Milne Edwards & Haime			o			x			x			o			
Pocillopora ligulata Dana									x			o			
Pocillopora setchelli Hoffmeister		x	x			x		x	x			o		x	x
Pocillopora verrucosa (Ellis & Solander)			x			x		o	x			x		x	x
Family ACROPORIDAE															
Acropora azurea Veron & Wallace		x	o					o	o			x		o	
Acropora cerealis (Dana)			x			x		o	x			x		x	
Acropora digitifera (Dana)			o			o		o				x		x	
Acropora humilis (Dana)			o			x			o			x			
Acropora irregularis (Brook)			x						o			o			
Acropora monticulosa (Bruggeman)			o									o			x
Acropora nasuta (Dana)			x									o			
Acropora ocellata (Klunzinger)												x			
Acropora quelchi (Brook)									x						
Acropora smithi (Brook)									o			x			

Table 2. Cont.

Transects / Reef Zones / Coral Taxons	A			B			C			D			E		
	IRF	ORF	RFS	IRF	ORF	RFS	IRF	ORF	RFS	IRF	ORF	RFS	IRF	ORF	RFS
Favites flexuosa (Dana)						o			x						
Favites russelli (Wells)												o			x
Goniastrea edwardsi Chevalier			x			o						o			x
Goniastrea retiformis (Lamarck)		x	x			x		o	x			o	o		x
Platygyra daedalea (Ellis & Solander)			o						o						o
Platygyra pini Chevalier			x			x			x			x			
Leptoria phrygia (Ellis & Solander)						o			o						
Hydnophora microconos (Lamarck)			o			x						x			
Montastrea curta (Dana)			o			x									
Leptastrea purpurea (Dana)			x			o						x			
Cyphastrea serailia (Forskal)			x												
Diploastrea heliopora (Lamarck)															o
Family OCULINIDAE															
Galaxea fascicularis (Linnaeus)			o			o		o	o			x			x
Family MUSSIDAE															
Acanthastrea echinata (Dana)						x						x			
Lobophyllia corymbosa (Forskal)												o			
Order COENOTHECALIA															
Family HELIOPORIDAE															
Heliopora coerulea (Linnaeus)						x			o			o			
Class HYDROZOA															
Order MILLEPORINA															
Family MILLEPORIDAE															
Millepora dichotoma Forskal			o												
Millepora platyphylla Hemprich & Ehreberg			x			x		o	x			x			x
Total Species per Transect Zone	0	7	36	0	1	30	0	13	34	0	0	45	2	14	30
Total Genera per Transect Zone	0	5	14	0	1	16	0	7	13	0	0	19	2	5	16
Total Species per Transect		39			30			38			45			37	
Total Genera per Transect		15			15			13			19			16	

Emergent Limestone Ridge

Molluscs were also the predominant taxon in terms of species diversity and abundance among the macroinvertebrate community of the emergent limestone ridge. Molluscan diversity was higher on the emergent limestone ridge (13 species) than on the intertidal bench (8 species). Most of the increase in molluscan diversity was among predatory predatory neogastropods, particularly vermivorous species of muricids and conids.

Large numbers of a sessile vermetid snail, probably Petaloconchus sp., occurred on the seaward, wave-washed edge of the emergent limestone ridge, but because their shells were so densely crowded and time was limited, they were considered to be too numerous to count for this study. The limpet Patelloida chamorrorum also was very common in this habitat.

Echinoderms associated with this zone were restricted to water-filled depressions and channels coursing through the ridge. The sea cucumbers Holothuria leucospilota and Holothuria atra were present but in low numbers. The sea urchin Echinothrix diadema was observed under a ledge in the emergent limestone ridge adjacent to Transect A.

Outer Reef Flat Platform

The outer reef flat platform macroinvertebrate fauna strongly resembled that of the emergent limestone ridge. Molluscan diversity increased to 14 species. All of these except the bubble shell Haminoea cymbalum were vermivorous neogastropods in the families Muricidae, Vasidae, Mitridae, and Conidae.

Sea cucumbers were predominant on the outer reef flat platform in terms of biomass. Actinopyga mauritiana was found in higher energy areas, while Holothuria atra occupied the floor of sandy depressions in this zone. Holothuria leucospilota was found extending from beneath rocks near the boundary of the emergent limestone ridge and the outer reef flat platform. One Heterocentrotus mammillatus was observed near the reef margin adjacent to one transect.

Other macroinvertebrates inhabiting this zone included colonies of the soft coral Sinularia spp. in a channel near the reef margin. The encrusting sponge Dysidea cf.

forms, it was difficult to distinguish individual colonies for quantification. An olive-colored species was also abundant on all transects. A species of sponge resembling Phyllospongia foliascens was observed on the reef adjacent to two transects.

Control Site

Because the reef flat at the control site lacked an emergent limestone ridge, the reef flat was divided into only two zones, namely the inner reef flat and the outer reef flat. The inner reef flat zone was characterized by a moat that retained a greater volume of water at low tide than the outer reef flat. Depressed areas of the inner reef flat that retain water at the lowest spring tides supported a relatively dense population of the sea cucumbers Holothuria atra and Stichopus chloronotus. On the outer reef flat, which is exposed at low tide, sea cucumbers were rare.

A lower diversity of molluscs was observed on the reef flat at the control site than in the study area. However, the vermivorous neogastropods were predominant at this site as elsewhere. The muricids were noticeably less diverse. The money cowrie Cypraea moneta inhabited both the inner and outer reef flat, but the species was not numerous. The sessile vermetid Dendropoma maxima was observed on a colony of the coral Porites lutea.

The reef front slope at the control site supported a relatively diverse assemblage of echinoderms. The sea urchin Echinometra mathaei outnumbered the urchin Echinostrephus aciculatus at this site, and the sea cucumber Holothuria edulis and the ophiuroid cf. Ophiomastix sp. were found at the control site but not at the study site.

Discussion

The limestone bench zone of the study area has a dearth of macroinvertebrates. However, it is difficult in a study of a short duration to determine the exact causes for the paucity of species. Although siltation may play a role in reducing environmental quality for macroinvertebrates, other factors may be equally important. For example, water retained pools at low tides may absorb sufficient solar radiation to exceed the thermal tolerance of many invertebrate species. Futhermore, input of freshwater on the bench at low tides may reduce the salinity to lethal levels for marine invertebrates.

Table 1. Distribution and abundance of conspicuous macroinvertebrates along Transects A and B on the reef flat of the Apagon coastal area of Rota. Data are presented as mean ± standard deviation (number of quadrats) of organisms counted in 10-m^2 quadrats along a transect line spanning the reef flat. Sponges occurring on transects are represented by the symbol #. Species observed on the reef adjacent to the transect but not occurring in the quadrats are represented by the symbol @. The occurrence of dead individuals along the transect is denoted by an asterisk (*).

	TRANSECT A			TRANSECT B		
	Bench	Ridge	ORF Platform	Bench	Ridge	ORF Platform
PHYLUM PORIFERA						
Cinachyra australiensis (Carter)						
Dysidea cf. herbacea (Keller)			#			#
PHYLUM CNIDARIA						
Sinularia spp.						
Palythoa cf. toxica Walsh & Bowers						
Palythoa tuberculosa (Esper, 1791)						@
PHYLUM MOLLUSCA						
Acanthopleura gemmata (Sowerby)		@				
Patelloida chamorrorum Lindberg & Vermeij					17.50±24.75	
Turbo argyrostomus Linnaeus					*	
Turbo setosus Gmelin						
Nerita plicata Linnaeus	0.50±1.41(8)					
Nerita polita Linnaeus						
Littorina coccinea (Gmelin)						
Littorina undulata Gray	0.13±0.35(8)					
Dendropoma maxima Sowerby						
Melanoides tuberculata (Mueller)	*					
Cerithium alveolus (Hambron & Jaquinot)	0.25±0.46(8)					
Clypeomorus batillariaeformis Habe & Kosuge						
Clypeomorus bifasciata (Sowerby)						
Lambis chiragra Linnaeus	*					
Strombus mutabilis Swainson						
Cypraea moneta Linnaeus						
Bursa bufonia (Gmelin)	*					
Drupa morum Roeding			0.60±0.89(5)			
Drupa ricinus (Linnaeus)		1.00±0.00(1)	0.40±0.89(5)			@
Morula granulata (Duclos)		5.00±0.00(1)			5.50±7.78(2)	
Morula nodicostata (Pease)	@	@				
Morula squamosa (Pease)	0.38±1.06(8)					
Morula uva (Roeding)	0.38±0.52(8)	7.00±0.00(1)	4.60±5.81(5)			@
Thais aculeata (Deshayes)					1.50±2.12(2)	
Thais armigera (Link)			0.20±0.45(5)			
Latirus polygonus barclayi (Reeve)					*	
Vasum turbinellus (Linnaeus)			0.20±0.45(5)		*	
Nebularia cucumerina (Lamarck)						
Strigatella litterata (Lamarck)						

Table 2. Distribution and abundance of conspicuous macroinvertebrates along Transects C and D on the reef flat of the Apanon coastal area of Rota and along Transect E on the reef flat at Gagani Reef. Data are presented as mean ± standard deviation (number of quadrats) of organisms counted in 10-m^2 quadrats along a transect line spanning the reef flat. Sponges occurring on transects are represented by the symbol #. Species observed on the reef adjacent to the transect but not occurring in the quadrats are represented by the symbol @. The occurrence of dead individuals along the transect is denoted by an asterisk (*).

	TRANSECT C			TRANSECT D		TRANSECT E	
	Bench	Ridge	ORF Platform	Bench	Ridge	IRF	ORF
PHYLUM PORIFERA							
Cinachyra australiensis (Carter)				0.25±0.50(4)			
Dysidea cf. herbacea (Keller)		#	#			#	
PHYLUM CNIDARIA							
Sinularia spp.			0.25±0.71(8)				
Palythoa cf. toxica Walsh & Bowers					@		
Palythoa tuberculosa (Esper, 1791)							
PHYLUM MOLLUSCA							
Acanthopleura gemmata (Sowerby)							
Patelloida chamorrorum Lindberg & Vermeij		@			@		
Turbo argyrostomus Linnaeus							
Turbo setosus Gmelin					0.5±0.71(2)		
Nerita plicata Linnaeus							
Nerita polita Linnaeus	@				@		
Littorina coccinea (Gmelin)					@		
Littorina undulata Gray							
Dendropoma maxima Sowerby						0.29±0.76(7)	
Melanoides tuberculata (Mueller)					*		
Cerithium alveolus (Hambron & Jaquinot)							
Clypeomorus batillariaeformis Habe & Kosuge	0.17±0.41(6)						
Clypeomorus bifasciata (Sowerby)					*		
Lambis chiragra Linnaeus							
Strombus mutabilis Swainson					*		
Cypraea moneta Linnaeus						0.14±0.38(7)	0.40±0.55(5)
Bursa bufonia (Gmelin)							
Drupa morum Roeding			5.38±8.86(8)		1.50±2.12(2)	0.14±0.38(7)	3.60±3.78(5)
Drupa ricinus (Linnaeus)			2.63±1.77(8)		8.00±2.83(2)		0.60±1.34(5)
Morula granulata (Duclos)		3.67±5.51(3)			5.50±0.71(2)		
Morula nodicostata (Pease)							
Morula squamosa (Pease)		0.33±0.58(3)			2.00±2.83(2)		
Morula uva (Roeding)			1.50±0.93(8)		0.50±0.71(2)	1.29±2.21(7)	1.40±2.19(5)
Thais aculeata (Deshayes)		0.33±0.58(3)					
Thais armigera (Link)			0.13±0.35(8)		@		
Latirus polygonus barclayi (Reeve)		*			@		
Vasum turbinellus (Linnaeus)		0.67±1.15(3)	0.50±0.76(8)		0.50±0.71(2)	0.29±0.49(7)	1.80±2.49(5)
Nebulaariacucumerina (Lamarck)			0.13±0.35(8)				
Strigatella litterata (Lamarck)		0.33±0.58(3)	0.25±0.46(8)				

Table 3. Distribution and abundance of macroinvertebrates along transects on the 6-m isobath on the reef front of the Apanon coastal area (Transects A-D) and Gagani Reef, Sasanhaya Bay, Rota (Transect E). Data are presented as mean ± standard deviation of organisms counted in ten 10-m^2 quadrats along a 50-m transect line. Sponges occurring on transects are represented by the symbol #. Species observed on the reef adjacent to the transect but not occurring in the quadrats are represented by the symbol @. The occurrence of dead individuals along the transect is denoted by an asterisk (*).

TRANSECT	A	B	C	D	E
PHYLUM PORIFERA					
Dysidea cf. herbacea (Keller)	#	#	#	#	#
Phyllospongia cf. foliascens (Pallas)		@	@		
gray sponge	#	#	#	#	
olive sponge	#	#	#	#	
PHYLUM CNIDARIA					
Lobophytum sp.				0.2±0.6	0.1±0.3
Sarcophyton sp.			@		
Sinularia spp.		2.1±2.2	1.9±2.6	0.2±0.4	1.3±2.2
Palythoa cf. toxica Walsh & Bowers				@	@
Palythoa tuberculosa (Esper)	0.3±0.5				
cf. Zoanthus pacificus Walsh & Bowers	@				
PHYLUM ANNELIDA					
Spirobranchus giganteus (Pallas)		@		@	@
PHYLUM MOLLUSCA					
Tectus pyramis (Born)			*	0.1±0.3	0.1±0.3
Trochus histrio Reeve				@	*
Astraea rhodostoma (Lamarck)	@			0.1±0.3	
Cerithium nesioticum Pilsbry & Vanetta			*		
Lambis chiragra (Linnaeus)	@				
Strombus microurceus (Kira)		*			@
Cypraea helvola Linnaeus				*	
Cypraea isabella Linnaeus					*
Cypraea moneta Linnaeus	0.1±0.3		0.2±0.6	0.3±0.9	0.1±0.3
Cypraea poraria Linnaeus			*		
Bursa bufonia (Gmelin)			*		
Drupa grossularia Roeding				@	
Drupa ricinus (Linnaeus)		@	@		
Drupa rubusidaeus Roeding					@
Drupella elata (Blainville)	@				@
Morula biconica (Blainville)				@	@
Muricodrupa funiculus (Wood)			@		*
Thais armigera (Link)			@		
Coralliophila violacea (Kiener)					@
Pyrene punctata (Bruguiere)			@		*
Cantharus iostomus (Gray)					*

FISHES FROM APANON, ROTA

by

Steven S. Amesbury

METHODS

The fish on the reef flats were censused along 50-m transects parallel to the beach (i.e., perpendicular to the transect line used for the coral and macroinvertebrate censuses). Four transects (A through D) were located at Apanon Reef, and a fifth control transect (E) was located at Gagani Reef in Sasanhaya Bay. Because of various conditions of tide phase and rough water, the fish transects were situated somewhat differently at each of the transect sites:

Transect A: TR1 was run on the inner reef flat approximately 40 m from the reef edge; TR2 was also located on the inner reef flat, but closer to the beach, approximately 50 m from the reef edge; both were run during low tide.

Transect B: TR1 was run on the outer reef flat, approximately 30 m from the reef edge; TR2 was located on the inner reef flat at about 50 m from the reef edge; both were run during low tide.

Transect C: TR1 was run during low tide on the inner reef flat; the 50-m transect meandered through the deeper parts of the reef flat; TR2 was also run on the inner reef flat but at high tide; a list was also made of fish species in a deep hole on the outer reef flat.

Transect D: TR1 was run during low tide on the inner reef flat and meandered through the deeper parts of the reef; TR2 was run at high tide on the inner reef flat.

Transect E: TR1 was run during low tide on the inner reef flat and meandered through the deeper parts of the reef.

Fish communities on the flats of shallow, wave-swept fringing reefs in the Mariana Islands appear to be dominated by a very similar suite of species be they in Saipan (Amesbury, 1988), Guam (Amesbury, 1978), or Rota (this report).

The abundance of fishes on the reef flat is variable and is probably affected by tide height, topographic relief, wave exposure, and seasonal abundance of various fish species.

The fish communities on the reef front at Apanon are very similar to those at Obyan-Naftan, Saipan (Amesbury, 1988), also an exposed reef front habitat. The reef front at Gagani is less exposed to oceanic swells and has much greater coral development than Apanon. These factors may be reflected in the somewhat different species composition, greater species richness, and higher fish abundance at Gagani than at Apanon.

LITERATURE CITED

Amesbury, S. S. 1978. Studies on the biology of the reef fishes of Guam. Univ. Guam Mar. Lab, Tech. Rept. 52. 58 p.

Amesbury, S. S. 1988. Fishes. In: R. H. Randall, S. D. Rogers, E. E. Irish, S. C. Wilkins, B. D. Smith, and S. S. Amesbury. A marine survey of the Obyan-Naftan Reef Area, Saipan, Mariana Islands. Univ. Guam Mar. Lab., Tech. Rept. 90. pp. 48-55.

Table 1a. Continued.

	TRANSECTS						
	A		B		C		
	TR1	TR2	TR1	TR2	TR1	TR2	HOLE
MUGILIDAE							
unidentified		+		4			
MULLIDAE							
Parupeneus barberinus	+						
P. cyclostomus		+					
MURAENIDAE							
unidentified							
POMACENTRIDAE							
Abudefduf sordidus		+	+		+	1	+
Chrysiptera glauca	20	21	3	12	13	47	
C. leucopoma	5		38		3	2	+
Stegastes albifasciatus					+		+
S. nigricans							+
SCARIDAE							
juveniles					+		
TETRAODONTIDAE							
Canthigaster solandri	1			3			
No. Fish per 100 m^2:	84	83	63	121	95	166	---
No. Species on Transect:	10	5	7	9	6	8	---
No. Species in Area:	11	10	11	10	10	12	10

Table 1b. Fishes observed on reef flat transects at Apanon, Rota, May 1989. Numbers represent counts in transect swath. Other fish present in the area are indicated by "+."

	TRANSECTS D		E
	TR1	TR2	TR1
ACANTHURIDAE			
Acanthurus lineatus			+
A. nigrofuscus			+
A. triostegus			21
Ctenochaetus striatus			+
APOGONIDAE			
Apogon novemfasciatus	1		
ATHERINIDAE			
unidentified			
BLENNIIDAE			
unidentified			
CHAETODONTIDAE			
Chaetodon auriga		+	
C. citrinellus			1
C. ephippium			+
C. lunula	1	+	1
GRAMMISTIDAE			
Grammistes sexlineatus			
HOLOCENTRIDAE			
Sargocentron diadema			
LABRIDAE			
Halichoeres margaritaceus			19
H. marginatus	1	4	+
H. trimaculatus		1	33
Labroides dimidiatus			
Stethojulis bandanensis	+	2	31
Thalassoma purpureum			+
juveniles	2	1	9
LUTJANIDAE			
Lutjanus monostigmus			

Table 1a. Fishes observed on reef flat transects at Apanon, Rota, May 1989. Numbers represent counts along transect swath. Other species in the area are indicated by "+."

	TRANSECTS						
	A		B		C		
	TR1	TR2	TR1	TR2	TR1	TR2	HOLE
ACANTHURIDAE							
Acanthurus lineatus			1				+
A. nigrofuscus			1				
A. triostegus	2	7	3	2	1	20	
Ctenochaetus striatus							
APOGONIDAE							
Apogon novemfasciatus	1					+	
ATHERINIDAE							
unidentified	15						+
BLENNIIDAE							
unidentified			+	+			
CHAETODONTIDAE							
Chaetodon auriga							
C. citrinellus	1						
C. ephippium							
C. lunula						+	
GRAMMISTIDAE							
Grammistes sexlineatus						+	
HOLOCENTRIDAE							
Sargocentron diadema		+		1			
LABRIDAE							
Halichoeres margaritaceus			16			3	+
H. marginatus					1	+	+
H. trimaculatus	12	25		38	75	34	
Labroides dimidiatus				1			
Stethojulis bandanensis	23	27	+	53	+	58	+
Thalassoma purpureum			+				+
juveniles	4	3	2	7	2	1	
LUTJANIDAE							
Lutjanus monostigmus		+					

At all 5 transect locations, 50-m transects were run at a depth of 6 m on the reef front. These transects were also oriented parallel to the shoreline.

During each transect survey, fish were enumerated by species within a 2-m wide swath along the 50-m transect line (a total area of 100 m^2). After the transect count, a list was made of other species of fish that occurred in the immediate area but which were not seen during the enumeration.

RESULTS

Fish species richness was generally low (10 to 12 species) on the reef flat transects A through D (Tables 1a and 1b). At transect E, however, 18 species were observed within the immediate vicinity of the transect line. Fish abundance varied widely on the reef flat transects, being highest at transect E. At the two transects where counts were made at both high and low tide (transects C and D), fish abundance was considerably higher at high tide.

The reef flat fish community was dominated by species of the family Pomacentridae, particularly Chrysiptera leucopoma and C. glauca, and species of the family Labridae, particularly Halichoeres margaritaceus, H. trimaculatus, and Stethojulis bandanensis.

On the reef front transects, both fish species richness and fish abundance were highest at transect E (Table 2). On transects A through D, fish abundance varied from 65 to 146 fish per 100 m^2, and fish species richness ranged from 25 to 41. Surprisingly, the transect with the greatest fish abundance, transect A, was the transect with the fewest species.

The dominant fish species in the reef front habitat were the acanthurid Ctenochaetus striatus, the labrids Halichoeres margaritaceus and Thalassoma quinquevittatum, and the pomacentrids Chrysiptera leucopoma and Stegastes fasciolatus. Several of the species that were abundant on the reef front transect E were not abundant or were absent from the other reef front transects (Table 2).

DISCUSSION

The fish communities on the reef flat at Apanon (transects A through D) and Gagani (transect E) were fairly homogeneous in terms of species composition, but the community at Gagani contained more species and a greater overall abundance of fishes.

Table 3. Continued.

TRANSECT	A	B	C	D	E
Latirus nodatus (Gmelin)	@				
Latirus polygonus barclayi (Reeve)		@			
Peristernia nassatula (Lamarck)			@		
Vasum ceramicum (Linnaeus)		0.1±0.3	0.2±0.4		0.1±0.3
Vasum turbinellus (Linnaeus)	0.4±0.5	0.3±0.7	0.1±0.3	*	
Pusia lauta (Reeve)			@		
Pusia speciosa (Reeve)			@		
Conus ebraeus Linnaeus					*
Conus flavidus Lamarck				@	
Conus imperialis Hwass	0.1±0.3		0.1±0.3		
Conus litoglyphus Hwass			@		
Conus litteratus Linnaeus				*	
Conus miles Linnaeus	0.3±0.7	0.3±0.5	0.1±0.3	0.2±0.4	
Conus moreleti Crosse				@	*
Conus rattus Hwass			*		
Conus sanguinolentus Quoy & Gaimard			@	@	
Conus sponsalis Hwass	@		@	@	
Chromodoris sp.					0.1±0.3
Dendrodoris tuberculosa (Quoy & Gaimard)					0.1±0.3
Phyllidia sp.	0.1±0.3				
Tridacna maxima (Roeding)	0.5±0.7	0.4±0.7	0.6±0.7	0.6±1.1	
Octopus cf. cyanea Gray			0.1±0.3		
PHYLUM ARTHROPODA					
Stenopus hispidus (Olivier)					0.1±0.3
Thalassina sp.			@		
Dardanus spp.		0.1±0.3		0.1±0.3	
Trizopagurus strigatus (Herbst)	0.1±0.3				
Trapezia sp.			@		
PHYLUM ECHINODERMATA					
Linckia multifora (Lamarck)	0.6±0.7	0.7±0.8	3.8±1.7	0.6±1.0	0.3±0.5
cf. Ophiomastix sp.					0.2±0.4
Echinometra mathaei (de Blainville)	8.0±5.2	4.1±3.1	6.0±4.3	4.7±3.7	7.4±8.9
Echinostrephus aciculatus A. Agassiz	20.3±8.8	22.5±8.9	18.8±9.9	25.5±8.7	1.5±2.0
Echinothrix diadema (Linnaeus)	0.2±0.4	0.4±0.5	0.4±0.5	0.1±0.3	0.1±0.3
Actinopyga mauritiana (Quoy & Gaimard)		@	0.5±0.8	@	
Holothuria edulis Lesson					0.1±0.3
Stichopus chloronotussBrandt	0.1±0.3	0.5±1.3	@		0.1±0.3

Table 2. Continued.

	TRANSECT C Bench	Ridge	ORF Platform	TRANSECT D Bench	Ridge	TRANSECT E IRF	ORF
<u>Conus</u> <u>chaldaeus</u> Roeding			0.25±0.71(8)				
<u>Conus</u> <u>coronatus</u> Gmelin	0.17±0.41(6)		0.13±0.35(8)			0.29±0.76(7)	0.40±0.89(5)
<u>Conus</u> <u>ebraeus</u> Linnaeus	0.33±0.52(6)						
<u>Conus</u> <u>flavidus</u> Lamarck						0.14±0.38(7)	
<u>Conus</u> <u>miliaris</u> Hwass			0.25±0.46(8)			0.14±0.38(7)	
<u>Conus</u> <u>rattus</u> Hwass			0.38±0.52(8)		0.50±0.71(2)		0.20±0.45(5)
<u>Conus</u> <u>sanguinolentus</u> Quoy & Gaimard							
<u>Conus</u> <u>sponsalis</u> Hwass			1.63±2.56(8)				2.20±2.17(5)
<u>Haminoea</u> <u>cymbalum</u> (Quoy & Gaimard)		1.67±2.89(3)	0.13±0.35(8)		@		
<u>Ctena</u> <u>bella</u> (Conrad)	*						
<u>Tridacna</u> <u>maxima</u> (Roeding)							
<u>Quidnipagus</u> <u>palatum</u> Iredale	*						
<u>Scutarcopagia</u> <u>scobinata</u> (Linnaeus)	*						
PHYLUM ARTHROPODA							
<u>Tetraclita</u> sp.					*		
<u>Thalassina</u> sp.							
<u>Calcinus</u> spp.							
<u>Clibanarius</u> spp.	@				@		
<u>Dardanus</u> spp.			0.13±0.35(8)			0.14±0.38(7)	
<u>Trizopagurus</u> <u>strigatus</u> (Herbst)							
<u>Petrolisthes</u> sp.							
<u>Carpilius</u> <u>maculatus</u> (Linnaeus)							
<u>Eriphia</u> <u>sebana</u> (Shaw & Nodder)			0.13±0.35(8)		@		
<u>Etisus</u> sp.			@				
PHYLUM ECHINODERMATA							
cf. <u>Ophiocoma</u> sp.	0.33±0.52(6)						
<u>Echinometra</u> <u>mathaei</u> (de Blainville)							0.20±0.45(5)
<u>Echinothrix</u> <u>diadema</u> (Linnaeus)							0.20±0.45(5)
<u>Heterocentrotus</u> <u>mammillatus</u> (Linnaeus)			@				
<u>Actinopyga</u> <u>mauritiana</u> (Quoy & Gaimard)			1.50±1.77(8)		@	0.29± 0.49(7)	
<u>Holothuria</u> <u>atra</u> Jaeger	2.50±1.76(6)	1.00±1.73(3)			@	8.29±14.26(7)	
<u>Holothuria</u> <u>leucospilota</u> (Brandt)	0.83±1.33(6)	0.67±1.15(3)	0.38±1.06(8)		@	0.29± 0.76(7)	
<u>Stichopus</u> <u>chloronotus</u> Brandt						2.00± 3.56(7)	0.20±0.45(5)

Habitats: Bench = Intertidal bench
Ridge = Emergent limestone ridge
ORF Platform = Outer reef flat platform
IRF = Inner reef flat
ORF = Outer reef flat

Table 1. Continued.

	TRANSECT A			TRANSECT B		
	Bench	Ridge	ORF Platform	Bench	Ridge	ORF Platform
Conus chaldaeus Roeding		2.00±0.00(1)	0.40±0.89(5)			
Conus coronatus Gmelin						
Conus ebraeus Linnaeus	0.25±0.46(8)		0.40±0.55(5)			
Conus flavidus Lamarck						
Conus miliaris Hwass			0.20±0.45(5)			
Conus rattus Hwass						
Conus sanguinolentus Quoy & Gaimard			*			
Conus sponsalis Hwass			1.00±0.71(5)			
Haminoea cymbalum (Quoy & Gaimard)			1.00±1.41(5)	15.25±8.96(4)		
Ctena bella (Conrad)						
Tridacna maxima (Roeding)	*					
Quidnipagus palatum Iredale						
Scutarcopagia scobinata (Linnaeus)						
PHYLUM ARTHROPODA						
Tetraclita sp.						
Thalassina sp.	0.13±0.35(8)					
Calcinus spp.						
Clibanarius spp.				@		
Dardanus spp.			0.20±0.45(5)			@
Trizopagurus strigatus (Herbst)						
Petrolisthes sp.						
Carpilius maculatus (Linnaeus)	*					
Eriphia sebana (Shaw & Nodder)						
Etisus sp.						
PHYLUM ECHINODERMATA						
cf. *Ophiocoma* sp.						
Echinometra mathaei (de Blainville)						
Echinothrix diadema (Linnaeus)			@			
Heterocentrotus mammillatus (Linnaeus)						
Actinopyga mauritiana (Quoy & Gaimard)	0.25±0.71(8)		0.60±0.55(5)			0.29±0.76(7)
Holothuria atra Jaeger			0.80±1.30(5)			
Holothuria leucospilota (Brandt)				0.75±1.50(4)	4.00±0.00(2)	
Stichopus chloronotus Brandt						

Habitats: Bench = Intertidal bench
Ridge = Emergent limestone ridge
ORF Platform = Outer reef flat platform

The emergent limestone ridge and the outer reef flat platform are similar in species composition of macroinvertebrates to other areas in the Mariana Islands. Studies of Tanapag reef platform (Neill, 1985; Potter, 1987) and Obyan reef platform (Smith, 1988) in Saipan produced similar results to the present study. Similar to the macroinvertebrate communities on the reef at Obyan, Saipan (Smith, 1988), the Apanon reef supported few of the ascidians, cerithiids, and buccinids noted at Tanapag (Neill, 1985; Potter, 1987).

Noteworthy for its absence at Apanon was the topshell Trochus niloticus. Introduced in the Mariana Islands for its commercial and food value (South Seas Government, Fisheries Experiment Station, 1939), this species does not appear to be established at Rota. Although seemingly suitable habitat is present, no specimens were observed at any of the sites surveyed during this study, and only one dead specimen was found in a previous survey (Randall and Smith, 1988).

References Cited

Neill, J. B. 1985. Macroinvertebrates. pp. 37-53. In R. H. Randall (ed.), A marine survey of the Tanapag reef platform adjacent to Unai Papau. Univ. Guam Mar. Lab., Misc. Rept. 48.

Potter, T. S. 1987. Macroinvertebrates. pp. 70-126. In R. H. Randall (ed.). A marine survey of the northern Tanapag reef platform, Saipan, Mariana Islands. Univ. Guam Mar. Lab., Tech. Rept. 87.

Randall, R. H., and B. D. Smith. 1988. A reconnaissance marine survey of the Mochong-As Matmos coastal area of Rota in the Mariana Islands. Univ. Guam Mar. Lab., Environ. Surv. Rept. 21. 28 p.

Smith, B. D. 1988. Conspicuous epibenthic macroinvertebrates. pp. 38-47. In R. H. Randall, S. D. Rogers, E. E. Irish, S. C. Wilkins, B. D. Smith, and S. S. Amesbury, A marine survey of the Obyan-Naftan reef area, Saipan, Mariana Islands. Univ. Guam Mar. Lab., Tech. Rept. 90.

South Sea Government, Fisheries Experiment Station. 1939. Experiments on transplantation of top shells. Rept. Fish. Exp. Sta., South Seas Govt. 2:121-126.

herbacea was also found in the vicinity of the reef margin. One specimen of the hermit crab Dardanus spp. was observed occupying the shell of Vasum turbinellus. The stone crab Eriphia sebana was observed in a crevice in the substrate near the boundary between the emergent limestone ridge and the outer reef flat platform.

Reef Front Slope

Echinoderms were the predominant element of the macroinvertebrate community of the reef front slope, and echinoids were the most conspicuous component of echinoderm populations. The boring sea urchin Echinostrephus aciculatus was abundant on horizontal and oblique surfaces of the substrate on all transects of the study site but less numerous at the control site. A second boring echinoid, Echinometra mathaei, was common on all transects including the control. Echinothrix diadema was present on all transects but in low numbers.

The coral reef asteroid Linckia multifora occurred on all reef front transects, but was common only on Transect C. Sea cucumbers were present at all the transect sites, but they did not occur within the area surveyed at all sites.

Molluscs were less abundant and less diverse on the reef front slope transects than they were on either the emergent limestone ridge or the outer reef flat platform. However, vermivorous neogastropods were predominant on the reef front slope as elsewhere. Two species of trochaceans and one cowrie were the only nonpredatory prosobranch gastropods in this zone.

The giant clam Tridacna maxima occurred on all transects in the study area. These bivalves ranged in size from about 5-25 cm in valve diameter.
Other molluscs observed on the transects included the nudibranch Phyllidia sp. and Octopus cf. cyanea.

Macroinvertebrate cnidarians other than stony corals were represented by soft corals. Sinularia spp. were the most widespread and numerous, while Lobophytum sp. occurred on one transect, and Sarcophyton sp. was observed adjacent to another. Zoanthids were present but not in large numbers.

Sponges were abundant on all transects. Two species, Dysidea cf. herbacea and a gray sponge, were ubiquitous. Because of the nature of their encrusting, colonial growth

ABUNDANCE AND DISTRIBUTION OF CONSPICUOUS MACROINVERTEBRATES

by

Barry D. Smith

Methods

Populations of conspicuous epibenthic macroinvertebrates were sampled along four transects established on reef flat platform and reef front systems of the Apanon coastal area of Rota and along one transect on the reef flat platform and reef front at Gagani reef in Sasanhaya Bay, Rota (see Figs. 1 and 2, pp. 2 and 5). Species of macrobenthos occurring within 1 m of the transect line were identified and enumerated by an observer swimming along the line. Data were recorded for 5-m segments of the line. Thus, transects consisted of *n* rectangular quadrats, each of which covered an area of 10 m^2.

Areas adjacent to the transects were also examined to record the presence of species inhabiting the reef but not occurring within the selected study sites. Remains of dead macroinvertebrates were noted when present, but they were not quantified.

Results

Intertidal Bench

Few epibenthic macroinvertebrates inhabited the intertidal bench in the Apanon study area (Tables 1 and 2). In terms of species diversity, molluscs were predominant in this zone, but, with few exceptions, they were not numerous. Nerites and periwinkles were found on beach rock along the shoreline, and most of the remaining gastropods occupied rubble pockets or depressions in the substrate. The bubble shell Haminoea cymbalum was very abundant on silt-laden algal turf on the bench at Transect B.

Most of the macroinvertebrates in this zone were restricted to pools of water perched on the bench at low tide. The sea cucumber Holothuria atra was the most abundant echinoderm, but Holothuria leucospilota and Actinopyga mauritiana were also present. A single sponge, Cinachyra australiensis, was observed on the bench at Transect D, and one Thalassina sp. was observed at the entrance to its burrow at Transect A.

Table 2. Cont.

Transects / Reef Zones / Coral Taxons	A ORF	A IRF	A RFS	B IRF	B ORF	B RFS	C IRF	C ORF	C RFS	D IRF	D ORF	D RFS	E IRF	E ORF	E RFS
Acropora squarrosa (Ehrenberg)			x						x						
Acropora surculosa (Dana)			o		x			o	x			o			o
Acropora valida (Dana)						o			o					x	o
Acropora sp. 1						o			o					x	o
Montipora caliculata (Dana)			o						x			x			
Montipora ehrenbergii Verrill			o			o			x			x			
Montipora elschneri Vaughan			o						o						o
Montipora foveolata (Dana)						o									
Montipora tuberculosa (Lamarck)												o			
Montipora venosa (Ehrenberg)			o												o
Montipora verrilli Vaughan			x			x		o				o			x
Montipora verrucosa (Lamarck)									x						
Astreopora myriophthalma (Lamarck)												x			
Suborder FUNGIINA															
Family AGARICIIDAE															
Pavona duerdeni Vaughan												o			o
Pavona varians Verrill												x			x
Pavona sp. 2															x
Pavona sp. 3			o												x
Cardineroseris planulata (Dana)															o
Family PORITIDAE															
Porites annae Crossland		x												o	
Porites (*Porites*) *australiensis* Vaughan			x					o				o		o	
Porites (*Porites*) *lichen* Dana			x			x			x						x
Porites (*Porites*) *lobata* Dana			x			x			x						
Porites (*Porites*) *lutea* Milne Edwards & Haime		x	x		o	x		o	x			o	o	o	x
Porites (*Porites*) *murrayensis* Vaughan									o			o			
Porites (*Porites*) *superfusa* Gardiner								o						x	o
Porites (*Synaraea*) *rus* (Forskal)														x	x
Suborder FAVIINA															
Family FAVIIDAE															
Favia favus (Forskal)			x									x			x
Favia matthaii Vaughan												o			o
Favia pallida (Dana)						o						o			
Favia stelligera (Dana)			x			x			x			x		x	o

Table 1. Cont.

Transect, Reef Zone, and Coral Taxons	Size Distribution (Dia. in cm)				Freqency	Relative Frequecy	Density	Relative Density	Percent Cover	Relative Percent Cover	Importance Value
	n	$\bar{Y}$	s	w							
<u>Pavona</u> sp. 3	1	3.5	-	-	0.10	3.33	0.08	2.50	0.01	0.16	5.99
<u>Stylocoeniella armata</u>	1	2.4	-	-	0.10	3.33	0.08	2.50	0.01	0.16	5.99
<u>Stylophora mordax</u>	1	4.0	-	-	0.10	3.33	0.08	2.50	0.01	0.16	5.99
Totals	40	9.7	12.0	2.4-57.1			3.34		6.22		

Table 1. Cont.

Transect, Reef Zone, and Coral Taxons	Size Distribution (Dia. in cm) n	Ȳ	s	w	Freqency	Relative Frequecy	Density	Relative Density	Percent Cover	Relative Percent Cover	Importance Value
Montipora ehrenbergii	4	17.4	15.0	6.5-38.8	0.30	9.09	0.68	10.00	2.51	8.99	28.08
Acropora cerealis	4	11.1	7.1	3.0-17.5	0.30	9.09	0.68	10.00	0.85	3.05	22.14
Pocillopora eydouxi	1	51.0	-	-	0.10	3.03	0.17	2.50	3.45	12.36	17.89
Pocillopora ligulata	3	13.9	4.3	9.0-16.9	0.20	6.06	0.51	7.50	0.82	2.94	16.50
Porites lobata	1	47.9	-	-	0.10	3.03	0.17	2.50	3.05	10.93	16.46
Acropora squarrosa	2	19.8	14.5	9.5-30.0	0.20	6.06	0.34	5.00	1.31	4.69	15.75
Pocillopora setchelli	2	12.0	0.0	12.0-12.0	0.10	3.03	0.34	5.00	0.38	1.36	9.39
Pocillopora elegans	1	25.0	-	-	0.10	3.03	0.17	2.50	0.83	2.97	8.50
Acropora surculosa	1	14.0	-	-	0.10	3.03	0.17	2.50	0.26	0.93	6.46
Favites flexuosa	1	10.4	-	-	0.10	3.03	0.17	2.50	0.14	0.50	6.03
Favia stelligera	1	9.9	-	-	0.10	3.03	0.17	2.50	0.13	0.47	6.00
Montipora verrucosa	1	10.0	-	-	0.10	3.03	0.17	2.50	0.13	0.47	6.00
Montipora caliculata	1	6.5	-	-	0 10	3.03	0.17	2.50	0.06	0.21	5.74
Acropora quelchi	1	6.0	-	-	0.10	3.03	0.17	2.50	0.05	0.18	5.71
Platygyra pini	1	4.0	-	-	0.10	3.03	0.17	2.50	0.02	0.07	5.60
Pocillopora verrucosa	1	4.0	-	-	0.10	3.03	0.17	2.50	0.02	0.07	5.60
Porites lichen	1	3.2	-	-	0.10	3.03	0.17	2.50	0.01	0.04	5.57
Totals	40	17.7	14.7	3.0-61.4			6.97		27.91		
Transect D											
Intertidal Bench (0-20 M)	(no corals encountered)										
Emergent Bench (20-31 M)	(no corals encountered)										
Outer Reef Flat Platform (31- 56 M)	(no corals encountered)										
Reef Front Slope (2-6 Meters Deep)											
Millepora platyphylla	3	57.3	50.5	5.5-106.3	0.30	9.09	0.45	7.50	17.67	69.08	85.67
Pocillopora verrucosa	4	14.2	13.1	2.4-30.0	0.40	12.12	0.60	10.00	1.57	6.14	28.26
Leptastrea purpurea	3	7.8	4.3	4.0-12.4	0.30	9.09	0.45	7.50	0.26	1.02	17.61
Platygyra pini	4	6.3	3.4	2.0-10.2	0.20	6.06	0.60	10.00	0.23	0.90	16.96
Acropora azurea	4	5.5	2.5	3.0-9.0	0.20	6.06	0.60	10.00	0.15	0.59	16.65
Acropora ocellata	4	9.5	2.7	5.7-11.5	0.10	3.03	0.60	10.00	0.46	i.80	14.83
Stylophora mordax	1	42.4	-	-	0.10	3.03	0.15	2.50	2.17	8.48	14.01
Acropora cerealis	2	12.9	0.2	12.7-13.0	0.20	6.06	0.30	5.00	0.39	1.52	12.58
Montipora ehrenbergii	2	7.6	3.7	4.9-10.2	0.20	6.06	0.30	5.00	0.15	0.59	11.65
Pocillopora elegans	2	5.3	3.2	3.0-7.5	0.20	6.06	0.30	5.00	0.08	0.31	11.37
Pavona varians	1	39.1	-	-	0.10	3.03	0.15	2.50	1.20	4.69	10.22
Acropora humilis	1	21.5	-	-	0.10	3.03	0.15	2.50	0.55	2.15	7.68
Acropora digitifera	1	12.0	-	-	0.10	3.03	0.15	2.50	0.17	0.66	6.19
Favia stelligera	1	12.0	-	-	0.10	3.03	0.15	2.50	0.17	0.66	6.19
Acropora smithi	1	9.9	-	-	0.10	3.03	0.15	2.50	0.12	0.47	6.00
Hydnophora microconos	1	6.6	-	-	0.10	3.03	0.15	2.50	0.05	0.20	5.73

Table 1. Coral size distribution, frequency and relative frequency, density and relative density, percent coverage and relative percent coverage, and importance values for coral species at Transects A-E. Species are listed in order of their importance values.

Transect, Reef Zone, and Coral Taxons	Size Distribution (Dia. in cm) n	$\bar{Y}$	s	w	Freqency	Relative Frequecy	Density	Relative Density	Percent Cover	Relative Percent Cover	Importance Value
Transect A											
Intertidal Bench (0-43 M)	(no corals encountered)										
Emergent Ridge (43-47 M)	(no corals encountered)										
Outer Reef Flat Platform (47-69 M)											
Porites lutea	7	26.9	22.8	4.9-68.4	0.40	22.22	0.11	43.75	1.00	45.93	111.90
Goniastrea retiformis	2	52.5	43.8	21.5-83.5	0.20	11.11	0.03	12.50	0.91	41.80	65.41
Pocillopora setchelli	2	6.0	1.4	5.0-7.0	0.40	22.22	0.03	12.50	0.005	0.23	34.73
Porites annae	1	43.5	-	-	0.02	11.11	0.02	6.25	0.23	10.50	27.86
Acropora azurea	2	8.5	2.1	5.0-9.9	0.20	11.11	0.03	12.50	0.02	0.92	25.53
Psammocora sp. 1	1	7.5	-	-	0.20	11.11	0.02	6.25	0.01	0.46	17.45
Pocillopora demicornis	1	4.0	-	-	0.20	11.11	0.02	6.25	0.002	0.09	17.45
Totals	16	23.4	24.5	4.0-68.4			0.26		2.177		
Reef Front Slope (2-6 Meters Deep)											
Porites lutea	1	65.5	-	-	0.10	3.23	0.06	2.78	2.00	50.89	56.90
Pocillopora verrucosa	3	13.9	12.5	4.0-28.0	0.30	9.68	0.18	8.33	0.42	10.69	28.70
Porites australiensis	2	22.2	1.1	21.4-22.9	0.20	6.45	0.12	5.56	0.46	11.70	23.71
Favia stelligera	4	8.8	5.9	4.9-17.5	0.20	6.45	0.24	11.11	0.19	4.83	22.39
Goniastrea retiformis	3	12.0	4.9	8.0-17.5	0.20	6.45	0.18	8.33	0.22	5.60	20.38
Montipora verrilli	3	7.3	2.2	5.0-9.4	0.30	9.68	0.18	8.33	0.08	2.04	20.05
Porites lobata	3	4.6	1.7	3.0-6.3	0.30	9.68	0.18	8.33	0.03	0.76	18.77
Porites lichen	3	9.5	4.0	6.5-14.0	0.20	6.45	0.18	8.33	0.14	3.56	18.34
Favia favus	2	5.7	1.1	4.9-6.5	0.20	6.45	0.12	5.56	0.03	0.76	12.77
Pocillopora setchelli	2	3.8	1.1	3.0-4.5	0.20	6.45	0.12	5.56	0.01	0.25	12.26
Platygyra pini	2	10.5	6.4	6.0-15.0	0.10	3.23	0.12	5.56	0.12	3.05	11.84
Millepora platyphylla	1	12.0	-	-	0.10	3.23	0.06	2.78	0.07	1.78	7.79
Pocillopora elegans	1	10.8	-	-	0.10	3.23	0.06	2.78	0.05	1.27	7.28
Acropora irregularis	1	7.9	-	-	0.10	3.23	0.06	2.78	0.03	0.76	6.77
Acropora squarrosa	1	6.7	-	-	0.10	3.23	0.06	2.78	0.02	0.51	6.52
Goniastrea edwardsi	1	7.0	-	-	0.10	3.23	0.06	2.78	0.02	0.51	6.52
Leptastrea purpurea	1	7.0	-	-	0.10	3.23	0.06	2.78	0.02	0.51	6.52
Acropora cerealis	1	5.5	-	-	0.10	3.23	0.06	2.78	0.01	0.25	6.26
Cyphastrea serailia	1	5.3	-	-	0.10	3.23	0.06	2.78	0.01	0.25	6.26
Totals	36	10.8	11.1	3.0-65.5			2.16		3.93		

Transect A, which remained covered by a few centimeters of water during low spring tides. Although most of the outer reef flat platform at Transect C was emergent during low spring tides, 13 species of corals were recorded from several surge channel pools. Good water circulation is maintained in these pools via cavernous surge channels to the reef front slope. At Transect E, 14 species of corals were recorded from subtidal parts of the outer reef flat, and 2 species were recorded from scattered pools on the mostly intertidal inner reef flat. On the reef front slope species richness ranged from 30 species on Transects B and E to 45 species on Transect D.

Coral density on the outer reef flat ranged from 0.02 on Transect C to 2.90 on Transect E. On the reef front slope coral density ranged from 1.08 on Transect B to 6.79 on Transect C. Percentage of substrate coverage by corals on the outer reef flat ranged from 0.02% on Transect C to 3.93% on Transect A, and on the reef front slope from 2.95% at Transect B to 27.91% at Transect C.

Mean coral colony size on the outer reef flat ranged from 9.0 cm on Transect E to 23.4 cm on Transect A, and on the reef front slope from 9.0 cm on Transect E to 17.7 cm on Transect C.

No particular pattern of species occurrence in relation to coral importance values (measured as the sum of their relative frequency, density, and percentage of substrate coverage values) was demonstrated when species with the five highest values in each of the reef front slope zones were compared. Millepora platyphylla and Pocillopora verrucosa each ranked within the top five highest values at three transects, and Porites lutea, Favia stelligera, Goniastrea retiformis, and Acropora cerealis each ranked within the top five highest values at two transects. The remaining 11 species ranked within the top five highest values at only one transect each.

In summary there does not appear to be any noticeable impacts on the coral communities as a result of discharge of freshwater and terrestrial sedimentation from the rivers along the Apanon coastal region. Also there does not appear to be any difference between the Gagani site (Transect E) and the Apanon sites (Transects A-D) that could be attributable to stream discharge at the latter. Values of coral density, percentage of substrate coverage, and mean colony size were considerably higher at most reef front transect sites along the Apanon coast than those at the Gagani site. Species such as Porites (Synaraea) rus, characteristic of turbid water habitats, were abundant at the

2, pp. 2 and 5. Sampling points were then established by throwing a geology hammer from the surface at five-meter intervals along the length of each transect. Throws along Transects A-E on the reef flat platform were made by standing at each five-meter interval and tossing the hammer over one's shoulder into a five-meter-wide corridor along the west side of the transect line. Throws along Transect A-E on the reef front slope were made by swimming over each five-meter interval facing toward the sea and tossing the hammer over one's back into a five-meter-wide corridor on the landward side of the transect line. Where the hammer came to a rest, a sample point was established at the intersection of the hammer handle and head. Four quadrants were then formed around the point by establishing one axis along the hammer handle and another at right angles to it along the hammer head. The coral nearest the sample point in each quadrant was located, and its specific name, size (diameter or maximum length and width), and the distance from the center of the corallum to the sample point were recorded. From these point-quarter data the following calculations were used to estimate community structure parameters:

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

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

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

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

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

6. $$\text{Relative percent coverage} = \frac{\text{Percent coverage for a species}}{\text{Total coverage for all species}} \times 100$$

7. $$\text{Frequency} = \frac{\text{Number of points at which a species occurs}}{\text{Total number of points}}$$

8. $$\text{Relative frequency} = \frac{\text{Frequency value for a species}}{\text{Total of frequency value for all species}} \times 100$$

Table 2. Continued.

		TRANSECTS				
		A	B	C	D	E
Number of algal genera/transect		7	6	8	4	5
Number of algal species/transect		8	7	9	5	5
Overall percent algal coverage (excluding turf and diatoms)		38.1	36.1	36.3	38.7	13.0
Total number of algal genera observed	12					
Total number of algal genera/all transects	11					
Total number of algal species observed	15					
Total number of algal species/all transects	12					

Table 1. Continued.

	TRANSECTS									
	A		B		C		D		E	
	0-35	35-60	0-35	35-60	0-40	40-80	0-20	20-30	0-30	30-60
<u>Gelidiella</u> sp.								X		
<u>Gracilaria</u> sp.	2.2(14)				6.6(13)					
<u>Jania capillacea</u> Harvey		X						X		
<u>Laurencia</u> sp.	14.3(50)		26.0(33)		19.1(56)		14.1(25)	X		
<u>Liagora</u> sp.		X						X		
<u>Porolithon</u> sp.		1.3(10)		2.5(20)		X				X
ANTHOPHYTA										
<u>Enhalus acoroides</u> (L. f.) Royle	(see text)									
Algal Turf	35.3(64)	86.9(90)	33.9(50)	53.1(100)	54.7(88)	59.0(81)	68.0(100)	35.9(75)	61.5(100)	83.3(83)
Diatom scuz	X		X	0.6(10)	X		X			
Rock	8.9(21)	0.6(10)	38.0(42)	2.5(20)	12.5(25)	34.8(69)	15.6(63)	48.4(100)	2.1(8)	15.6(33)
Sand	38.8(57)		2.1(17)		7.0(25)		2.3(25)		32.3(67)	
Sponge						3.5(6)			1.0(8)	
Number of algal genera/transect	3	3	1	2	2	1	1	1	2	1
Number of algal species/transect	3	3	1	2	2	2	1	1	3	1
Overall percent algal coverage (excluding turf and diatoms)	17.0	12.5	26.0	43.8	25.7	2.8	14.1	15.6	3.1	1.0
Total number of algal genera observed	29									
Total number of algal genera/all transects	8									
Total number of algal species observed	32									
Total number of algal species/all transects	10									

heavy wave action. Macroalgae from the Division Phaeophyta were not observed on or in the vicinity of the reef front transects.

Additional species differences, especially in terms of population densities, would be expected to occur during different times of the year.

Literature Cited

Randall, R. H. and B. D. Smith. 1988. A reconnaissance marine survey of the Mochong-As Matmos coastal area of Rota in the Mariana Islands. Univ. Guam Mar. Lab., Environ. Surv. Rept. No. 21.

Tsuda, R. T. 1969. pp. 3-14. In R. T. Tsuda (Ed.), Biological results of an expedition to Rota, Mariana Islands. Univ. Guam, Div. of Biosciences and Marine Studies, Misc. Rept. No. 4.

Wilkins, S. de C. 1988. A quantitative assessment of marine plants. pp. 16-21. In R. H. Randall et al., A marine survey of the Obyan-Naftan reef area, Saipan, Mariana Islands. Univ. Guam Mar. Lab., Tech. Rept. No. 90.

A QUANTITATIVE ASSESSMENT OF MACROALGAE

by

Chad R. Wylie

Methods

Macroalgae were quantified by a modification of the point-quadrat method described by Wilkins (1988). A total of 10 transects (A-E reef flat and A-E reef front) were analyzed by this method. A 25 cm x 25 cm quadrat frame was equally subdivided to form a grid containing 16 interior points. The gridded quadrat was tossed every 5 meters on both sides of randomly distributed transects lines. Algal species which occurred directly beneath each point were recorded. Microalgae which could not be identified in the field were lumped together as algal turf. If no marine algae was found under a point then whatever was present (e.g., sand, rock, live coral, or other invertebrate) was recorded.

The data collected from the point-quadrat method provides a rapid general assessment of macroalgal species percent cover and frequency of occurrence. Thus, patterns of distribution and evenness or patchiness of marine algae can be easily recognized.

Percent cover was calculated by taking the total points at which a species occurred in a transect, divided by the total points per transect. The result was multiplied by 100 to yield percent. Frequency of occurrence was calculated by taking the number of quadrat tosses in which a species occurred, divided by the number of tosses per transect. The result was multiplied by 100 to yield percent. Any other algae seen along the transect were also recorded.

Results and Discussion

Reef Flat Platform

The results for the reef flat transects A - E are presented in Table 1. A total of 32 species of marine algae were observed, but only 10 species occurred on the transect lines. The transects were arbitrarily subdivided into inner and outer reef flat zones as indicated by the distance from shore (Table 1). Inner reef flat percent algal coverage (excluding turf algae and diatoms) ranged between 3.1%-26.0% while outer reef flat

Table 2. Continued.

Station No.	Distance from shore (m)	Reef type	A	B	C	D
Transect D:						
1	30	O	12	2	11	3
2	20	I	27	2	3	
3	10	I	32			
4	110(50m)	S	32			
4	110(25m)	S	32			
4	110(0m)	S	32			
Total Points: Inner Reef Platform			59	2	3	
Total Points: Outer Reef Platform			12	2	11	7
Total Points: Reef Front Slope			96			
% Substrate: Inner Reef Platform			92%	3%	5%	
% Substrate: Outer Reef Platform			38%	6%	34%	22%
% Substrate: Reef Front Slope			100%			

Table 1. Continued.

Transect C: May 26, 1989 Start: 0930 High Tide at 0535 = 0.5
Finish: 1020 Low Tide at 1734 = 0.2

Sta No	Dist from shore (m)	Current speed (m/sec)	Depth (m)	Bearing (deg)	Tide stage
1	70m	0.36	.60	240	EBB
1	70m	0.50	.60	280	EBB
1	70m	0.33	.60	240	EBB
2	50m	0.10	.60	245	EBB
2	50m	0.09	.60	237	EBB
2	50m	0.22	.60	237	EBB
3	25m	0.17	.30	250	EBB
3	25m	0.06	.30	273	EBB
3	25m	0.12	.30	265	EBB
4	10m	0.13	.35	278	EBB
4	10m	0.13	.35	237	EBB
4	10m	0.11	.35	263	EBB

Date: May 25, 1989 Start: 0945 High Tide at 0855 = 0.7
Finish: 1000 Low Tide at 1645 = 0.1

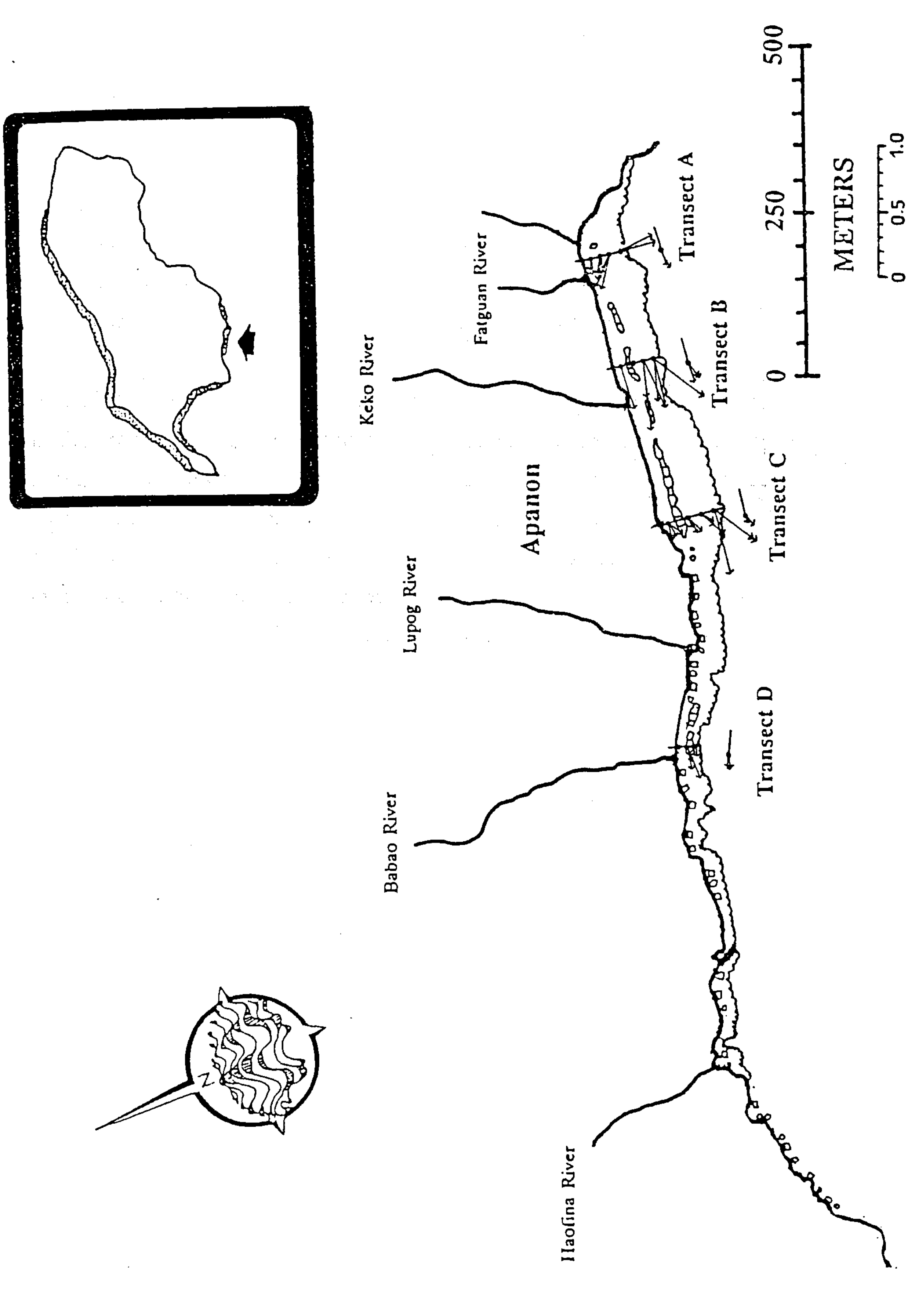
Sta No	Dist from shore (m)	Current speed (m/sec)	Depth (m)	Bearing (deg)	Tide stage
5	115m	0.04	8	275	EBB
5	115m	0.06	8	258	EBB
5	115m	0.06	8	259	EBB

Transect D: May 26, 1989 Start: 1030 High Tide at 0950 = 0.6
Finish: 1120 Low Tide at 1120 = -0.1

Sta No	Dist from shore (m)	Current speed (m/sec)	Depth (m)	Bearing (deg)	Tide stage
1	25m	0.08	0.10	342	EBB
1	25m	0.05	0.10	340	EBB
1	25m	0.07	0.10	296	EBB
2	15m	0.08	0.30	277	EBB
2	15m	0.16	0.30	283	EBB
2	15m	0.21	0.30	273	EBB
3	5m	No	0.30	No	EBB
3	5m	Move-	0.30	Move-	EBB
3	5m	ment	0.30	ment	EBB

Date: May 25,1989 Start: 1100 High Tide at 0855 = 0.7
Finish: 1115 Low Tide at 1645 = -0.1

Sta No	Dist from shore (m)	Current speed (m/sec)	Depth (m)	Bearing (deg)	Tide stage
4	110m	0.07	8	290	EBB
4	110m	0.06	8	295	EBB
4	110m	0.07	8	297	EBB



Fatguan River
Keko River
Lupog River
Babao River
Haofina River
Apanon
Transect A
Transect B
Transect C
Transect D
0
250
500
METERS
0
0.5
1.0
METERS
per sec.

Currents during ebbing tide conditions on the outer reef platform at Transects A - D all had strong westerly components except for station 1 at transect A which flowed southward in a seaward direction (Table 1 and Figure 1). Water exiting the reef platform through a depressed reef margin zone at Transect A explains the presence of strong seaward-flowing currents at Station 1. During low spring tides, currents are absent on the outer reef platform where the surface is exposed or where water is impounded in holes and depressions. Current speed on the outer reef platform ranged from 0.10 to 0.60 m/sec during ebbing tide conditions, but during high tide conditions, water speed would most likely be faster.

Surface currents during ebbing tide conditions on the seaward reef slope at Transects A - D all had strong westerly components parallel to the reef margin axis (Table 1 and Figure 1). Current speed on the seaward reef slope ranged from 0.04 to 0.14 m/sec during ebbing tide conditions.

Substrate Analysis and Discussion

The results of the analysis of the substrate are presented in Table 2.

The inner reef platform consists mostly of reef rock pavement with minor amounts of sand- and cobble-sized sediments veneering the reef rock pavement in holes and depressions. At most places, the reef rock pavement was covered with a short algal turf, generally less that a cm thick, which contained abundant sand-sized sediments among the filaments.

The outer reef platform consists mostly of reef rock pavement with some sand- and cobble-sized sediments veneering reef rock pavement in holes and depressions at Transect B and C. At transects A and D, the outer reef platform consists of about one-third reef rock pavement and about two-thirds sand- to cobble-sized sediments veneering reef rock pavement in holes and depressions. At most places reef rock pavement substrates on the outer reef platform were covered with a short algal turf which contained abundant sand-sized sediments and benthic foraminifera among the filaments.

The seaward reef slope consists mostly of reef rock pavement with minor amounts of sand- and cobble-sized sediments in holes and depressions and along channel floors. Much of the reef rock pavement is veneered with crustose red algae instead of the short algal turf that covers pavement areas on the reef platform.

measured line between the drogue and the boat), and the time spent by the drogue to reach this distance and the direction of drift were recorded. From these data, current speed and direction were derived.

Substrate Characterization

The substrate at each station was characterized by using two quadrats, each of which was configured with eight intersecting cords to form 16 equidistant points. Quadrats were placed on opposite sides of the transect lines so that a total of 32 points were recorded at each station. The substrate under each of the 32 points was assigned to one of 4 classes designated as pavement, sand, gravel, and cobbles. Pavement was reef rock or hard skeletal surfaces usually covered with turf intermixed with small amounts of sand-sized sediments. Sand was defined as particles less than 2 mm in diameter; gravel as particles from 2 to 10 mm in diameter; and cobbles as particles larger than 10 mm in diameter.

The reef was divided in three different zones: inner reef platform, outer reef platform and reef slope. The inner reef platform was separated from the outer reef platform at Transects B, C, and D by an emergent limestone ridge 40-50 meters from shore. Percent cover of substrate types for each zone was calculated by dividing the points of each substrate class by total points recorded in the zone and multiplying by 100.

Analysis of Sediment Samples

Samples of sediments were collected from a depth of 6 meters on the reef front slope at all transect stations and from an elevation of 2 meters above the high tide level on the beach at all of the Apanon transect stations. Sediments were stored in plastic bags and returned to the laboratory where they were dried at 60 °C. Associated waters were not rinsed from the samples. Sediments were then digested in ~20 volumes of 20% HCl (Baker Analyzed Reagent) for 24 hr to determine the HCl-soluble fraction and HCl-soluble Fe (Murray and Gill, 1978) following the methods outlined in Matson (1989). KCl-exchangeable NH_4^+ (Rosenfeld, 1979) and NO_x (Matson et al., 1987) were analyzed with an Orion ammonia probe and the cadmium reduction technique of Jones (1984), respectively.

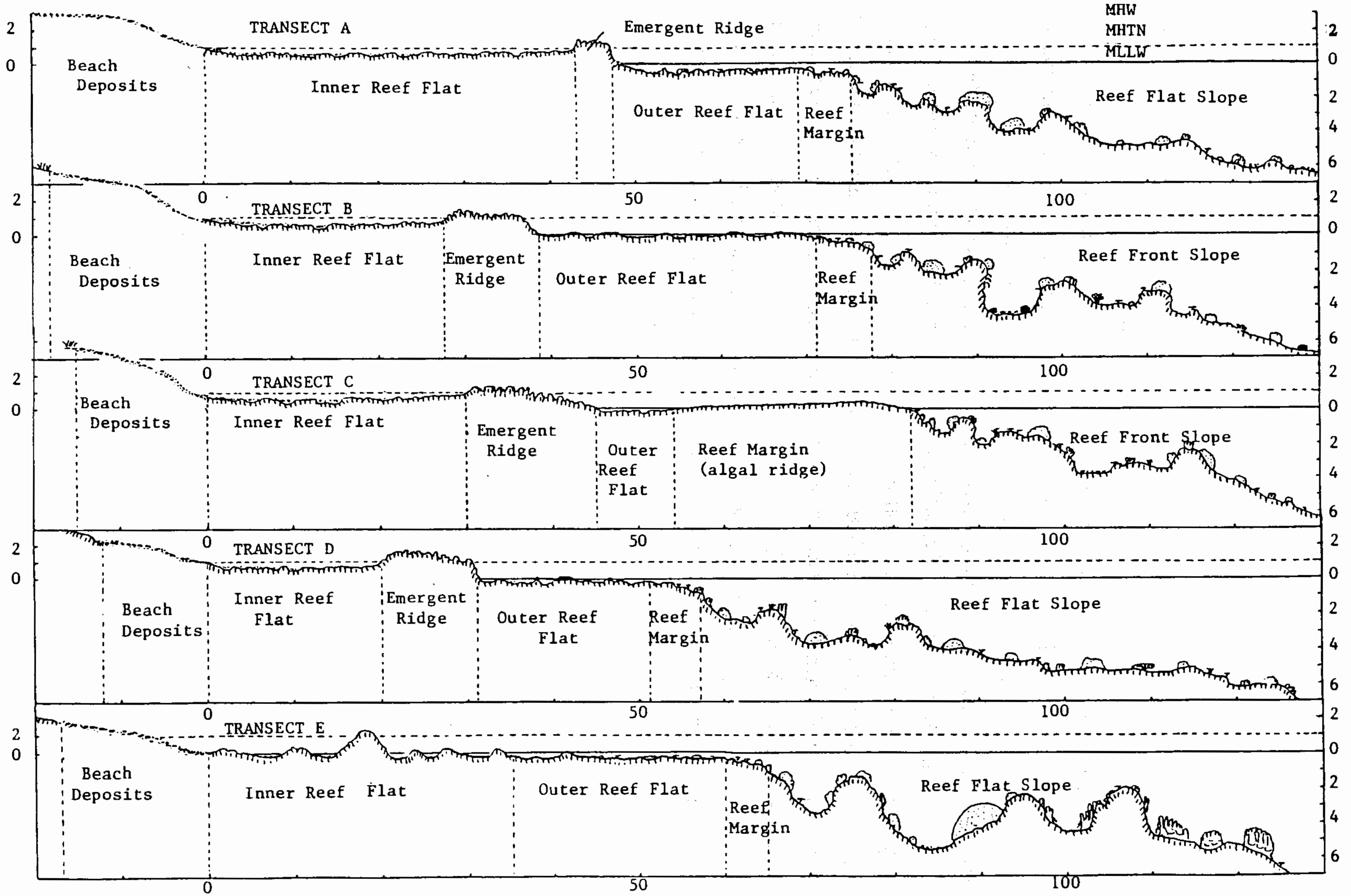


Figure 1. Vertical profiles representative of Transects A-E showing physiographic zonation patterns, water depth, beach slopes in degrees, and the distribution of reef platform sediment (stippling). Beach deposits are indicated by stippling and emergent limestone and reef rock pavement are indicated by a solid line with vertical bars below. The dashed sea level line indicates mean high water MHW and the solid sea level line indicates mean lower low water (MLLW). Vertical exaggeration is x 2.0 and horizontal and vertical scales are in meters.

flat platform level. Open surge channels separated by honey-combed, flat-topped buttress ridges made up the short forecrest slope. On the longer backcrest ridge slope these same surge channels grow outward along their upper margin, developing overhanging ledges which sometimes fuse and form cavernous sections below. At a number of places these cavernous surge channels formed open pools along their length, generally as a result of roof collapse.

The reef front slope along most of the study area drops downward rather steeply for several meters at the reef margin edge, and then slopes more gently downward, generally to a sediment-floored submarine terrace at about 10 meters in depth. At some locations this 10-meter terrace was poorly developed or absent. Where it was present, a steep slope or low scarp generally formed a boundary between the two zones. A fairly well-developed channel and buttress topography occupies the upper reef front slope and, at most places, constitutes a seaward continuation of the surge channel-buttress system found along the reef margin. Knobs, pinnacles, and mounds impart a more complex topography to the upper buttress ridge surfaces in the deeper water of the reef front slope than in the shallower water of the reef margin. Occasionally large reentry channels, much wider and deeper than the more regularly spaced ones of the channel-buttress system, extended from the 10-meter submarine terrace to or near the reef margin edge. These reentry channels are tens of meters across and are frequently veneered with an undetermined thickness of boulder rubble and coarse sand and gravel. Although we did not have time to determine whether or not all of these reentry channels were located directly opposite from shoreline river mouths, it is suspected that the one near Transect D and at least some of the others are. Thus, it appears that the reentry channels represented stream channels before the Holocene transgression.

About 30 meters west of Transect D, a very large, boulder-strewn reentry channel is located directly opposite the Babao River gorge and mouth. Sediments on the reef front slope zone were mostly restricted to surge and reentry channel floors. Sampling at about 6 meters depth along the mid-part of each transect revealed a mixture of bioclastic sand, gravel, cobbles, and boulders of reef origin intermixed with a smaller fraction of mostly sand-sized volcanic grains of terrestrial origin.

Description of the Reef Zones

The present reef flat platform consists of three physiographic zones as follows: 1) an intertidal inner platform that ranges in width from 20 meters at Transect D to 43 meters at Transect A; 2) an intermittent, mostly supratidal ridge of Holocene limestone that occupies the middle part of the platform and ranges in width from 4 meters at Transect A to 15 meters at Transect C; and 3) an outer platform that is about 0.75 to 1.0 meter lower in elevation than the inner platform and ranges in width from 19 meters at Transect A to 37 meters at Transect C.

The surface of the inner reef flat platform is eroded into an irregular, reticulate pattern of pools separated from each other by relatively flat zones of reef rock pavement. Some pools are separated from each other by narrow zones of pavement a decimeter or so wide, while others are separated by up to several meters or more of pavement. During low spring tides the pools remain mostly filled with water, but are cut off from circulation from other parts of the reef. When these tide conditions coincide with midday insolation, water temperatures may be elevated to sublethal or lethal levels for coral growth, a factor which most likely explains their complete absence on this inner part of the reef flat platform. A layer of mostly sand with some gravel and cobbles veneers the floors of most pools along the shoreline, but those further out on the platform or those located where the platform is narrow, may be swept free of most sediments. At a few places along the inner part of the platform black plastic mud formed a layer beneath the coarser material on the floor of some pools. Such areas with underlying mud could easily be identified because of their spongy feeling when walked upon. Such pockets of black plastic mud were also found on the inner parts of platforms along the northern coast of Rota in an earlier study (Randall and Smith, 1988) where surface drainage to the coast was absent.

The mostly emergent ridge of Holocene limestone that separates the inner and outer parts of the reef flat platform is extremely weathered, forming a rugged, solution-pitted karrenfeld topography that rises at places from +1.0 to +2.0 meters above the inner and outer platform levels, respectively. The submillimeter limestone surface layer is penetrated by endolithic algae which give it a grey color where supratidal and a darker grey to greenish-black color on intertidal surfaces. Numerous intertidal seaward direction from a volcanic inlier that protrudes about 2 meters above the inner reef flat platform surface several meters from the shoreline. These transect locations are shown in Figure 1, p. 2 and Figure 2, p. 5. Reef front slope transects run parallel to the reef margin axis at about the 6-meter submarine contour. The transect bearings from the shore approximately bisect the middle part of these reef front slope transects. Because of irregular reef front topography, coral assessment on these reef front transects ranged in depth from 2 to 6 meters.

DESCRIPTION OF THE APANON REEFS

Geomorphic History of the Reefs

Along the Apanon coastline a fringing reef system with a narrow reef platform is intermittently developed between Puntan Poniya on the west and an unnamed point along the Gaonan coastal region on the east. At most locations along the southern coast of Rota such reef flat platforms are absent, and the immediate shoreline is occupied by coastal cliffs or very narrow, mostly supratidal, erosional, bench platforms that are generally less than 10 meters wide. Submerged apron reefs and veneering reef communities along these southern coastal benches and cliffs have not yet grown upward to present sea level equilibrium and formed reef flat platforms like those along the Apanon coast. Principal physiographic zonation patterns developed along the present fringing reef system at Apanon include: 1) a reef flat platform consisting of a higher inner level separated from a lower outer level by an intermittent, median band of mostly supratidal Holocene limestone, 2) a wave-washed reef margin at the outer edge of the reef platform, and 3) a seaward reef front slope that gently dips downward from the reef margin to an irregularly developed 10-meter submarine terrace. Principal physiographic zonation patterns, water depth, and other characteristics of this Apanon section of fringing reefs are shown in representative vertical profile sections at Transects A-D in Figure 1.

The reef platform along the Apanon regiionprobably owes its existence to the presence of a narrow Pleistocene terrace that was flooded during the Holocene about 5000-6000 years B.P. (Sugimura, 1986; Bell, 1988; Randall and Smith, 1988; Bell and shoreline of the low coastal terrace. Texturally, these beach deposits are composed of light-colored bioclastic sand, gravel, and cobbles of reef origin intermixed with similar-sized, darker- colored volcanic deposits of terrestrial origin. Some of the volcanic material has been transported to the beach as weathered gravel and cobble-sized clasts where it then further decomposes into sand-sized particles. Worn and fragmented pieces of corals, mollusc shells, foraminifer tests, fragments of articulated and crustose red calcareous algae, and Halimeda segments make up a conspicuous fraction of the bioclastic beach material. Some beachrock and emergent Holocene limestone deposits form a narrow band along the shoreline in the vicinity of Transect C. An irregular limestone terrace, generally less than 10 meters in elevation, occupies the coastal region between Transects C and D. At the shoreline the terrace forms an irregular blocky scarp cut with short reentry areas. In the vicinity of the Babao River a low (generally <1.0 meter elevation), emergent band of Holocene limestone forms a narrow intermittent bench some 200 meters in length between the 10-meter terrace and the shoreline. Pockets of beach deposits, similar to those described along the shoreline between Transects A and C, interrupt or cover the emergent terrace at several places. Transect D is located where one of these pockets of beach deposits reaches the shoreline.

Beach slopes, width, and other shoreline characteristics of Transects A-D are shown in representative vertical profile sections in Figure 1.

Physiographic Setting of the Gagani Coastal Area

In order to facilitate assessment of the impact of coastal streams on the community structure of marine organisms along the Apanon region, a control site (Transect E) was established at a similar physiographic reef area, but with no surface drainage to the coast, along the southeastern part of Sasanhaya Bay (see Fig. 2, p. 5). Although this coastal area, known locally as Gagani, is located in a more protected setting from prevailing wave assault by Puntan Poniya, it was the only nearby coastal area along the southern coast of Rota with a narrow fringing reef flat platform and submarine reef front slope characteristics similar to that found along the Apanon study site.

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Technical Specialties - Marine safety, boat operation, and current characterization

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Technical Specialties - Macroalgae, seagrasses, and current characterization

Field Methodology

The Apanon study area was quantitatively assessed along four transects (A-D) as shown in Figure 1. On the shallow reef flat platform, transects were established perpendicular from the shoreline across the reef flat to the reef margin. On the reef front slope, assessments were conducted along 50-meter transects established on the 6-meter submarine contour. This contour was selected rather than the proposed 10-meter contour because the terrace was better developed at 6 meters and because the 10-meter contour was covered with sand and rubble, with little relief or spatial diversity. Therefore, any changes that are likely to occur in the reef community would be better detected on the 6-meter terrace. The distribution and community structure of macroalgae, seagrasses, reef-building corals, fishes, macroinvertebrates other than corals, general surface current patterns, and substrate characteristics were analyzed along all transects.

In order to enable investigators to draw better informed conclusions about the study site, a fifth transect was established as a control on Gagani Reef in Sasanhaya Bay (Figure 2). Because no rivers empty into Sasanhaya Bay, the control transect not only provides a baseline assessment of Gagani Reef for future reference, it also allows comparisons to be made between the Apanon area, which receives sediments, and similar areas that do not receive significant amounts of sediments. The control site at Gagani Reef was assessed along one transect (E) as described above.

Personnel

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Technical Specialty - Macroinvertebrates other than corals

Richard H. Randall - Co-Principal Investigator

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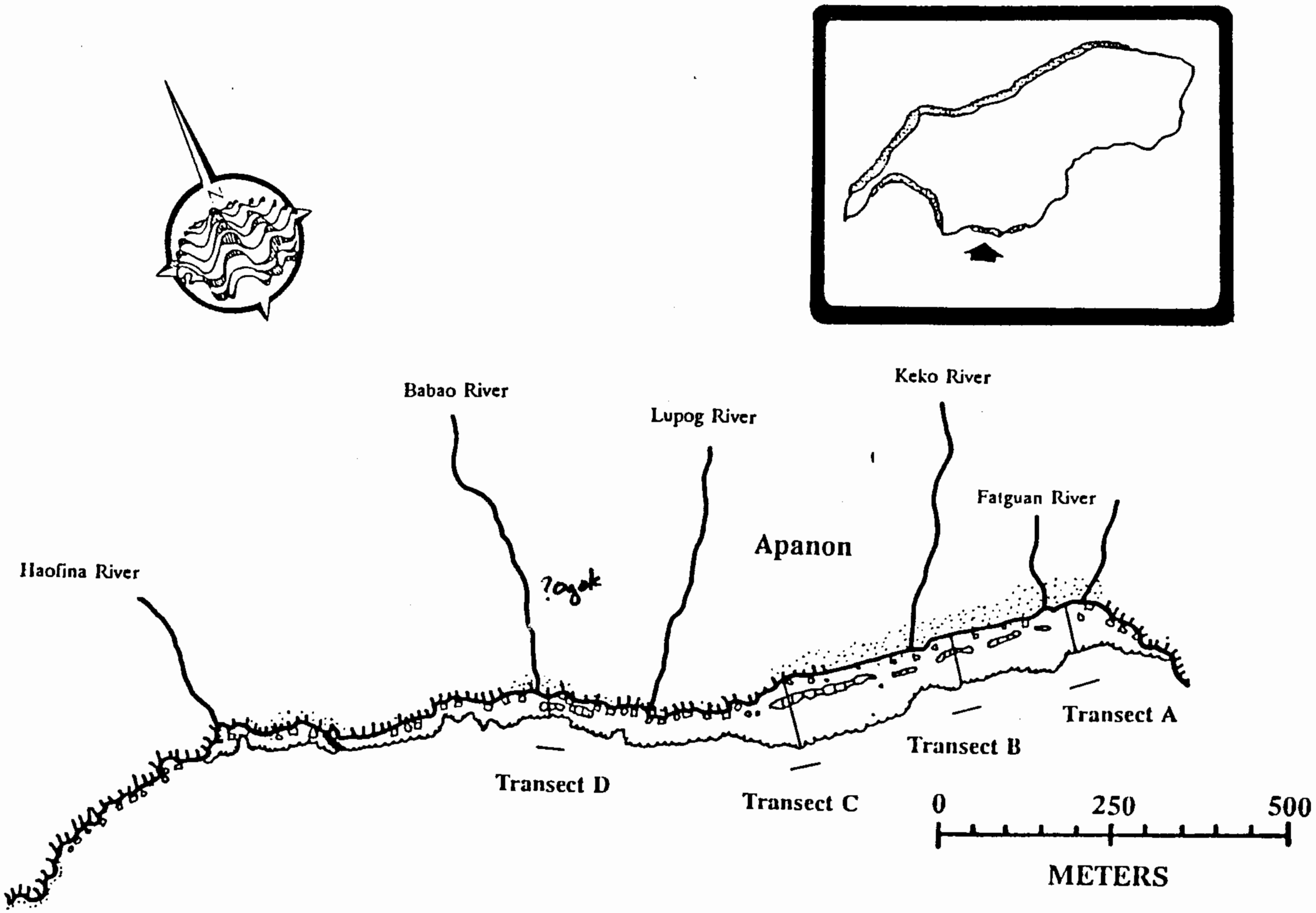

Figure 1. Map of the Apanon study site showing the location of Transects A, B, C, and D. Beach deposits are indicated by stippled areas, and coastal exposures of limestone, beachrock, and emergent reef limestone are indicated by short lines drawn normal to the shoreline. Map scale is 1:10,000. Modified from Eldredge and Randall (1980).

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