LIMITED CURRENT AND UNDERWATER BIOLOGICAL SURVEY AT THE PROPOSED FISHERY COMPLEX SITE ON TOL ISLAND, TRUK

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INTRODUCTION

Background

A tuna fishery complex has been proposed for Tol Island, Truk, on the eastern side of the island in the vicinity of an existing dock (cover figure). The proposed facilities would consist of a cannery meal plant, warehouse, water tank (to serve 1000 people), school buildings, power plant, sewer septic tanks, store, dry dock, fish pond, employees' houses, dispensary, gas station and tanks. The project would involve the filling of a mangrove swamp and fringing reef flat (Figure 1), the total area being approximately 366 meters wide, 320 m long on one end, and 244 m long on the other end.

A preliminary reconnaissance survey of the area was conducted by a University of Guam Marine Laboratory team on April 3, 1977, during a day off from primary studies at the site of a proposed fishery complex on Dublon Island. The findings were presented in a letter to the Executive Officer of the Trust Territory Environmental Protection Board dated June 24, 1977. The reconnaissance survey lasted only about half a day and indicated that the coral-seagrass-mangrove community in the area of the proposed project was a relatively rich one that was not subject to significant man-made stress at that time. However, the survey team recommended that a more extensive survey should be conducted for a project of the magnitude proposed. This report presents the results of a more extensive study conducted December 16-23, 1977.

In addition to the primary study on Tol Island, we were requested to conduct reconnaissance surveys of three proposed dredging sites on Moen, the district center for Truk District. Results of these surveys are presented in the Appendix.

Scope of Work

The Marine Laboratory team was requested to study the site of the proposed fishery complex and adjacent areas and to accomplish the following tasks:

*Obtain background information on the general physical, chemical, and biological characteristics of the marine environment at the site. Provide common names of organisms as well as scientific names.

*Estimate the effects of dredging and fill activities on the mangrove and adjacent reef areas, as well as the effects of discharge of treated cannery waste into lagoon waters for both domestic and industrial wastes.

*Define potential alternate sites for an outfall/diffuser location should currents/tidal flushing at the proposed site be found inadequate or result in excessive biological impact.

*Determine what effect would occur from power plant discharge, which normally includes waste heat, biocides, and inorganic materials if cooling towers or ponds are used.

*Determine the extent and magnitude of surface and subsurface currents at the proposed site, so that reliable predictions on plume dispersion and dilution can be developed.

*Determine the significance of findings to the water quality management system, particularly to make economically and technologically feasible recommendations on effluent and receiving water standards and monitoring procedures.

*Identify and define further significant research that is urgently needed to ensure that the environment and its resources will be adequately protected.

*Compare the environmental impact of the Dublon Fishery site and the Tol Fishery site in terms of temporary and permanent physical and biological damage.

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A Note About Scientific and Common Names

The majority of the specific organisms identified in this report have no common names. Hence, the only possible designation for such organisms is the scientific (Latinized) name. Where there are common names the same name is often applied to more than one organism and the same organism may have more than one common name. The use of such names often leads to hopeless confusion, and the scientific name is the only unambiguous one that can be applied.

The fishes represent the only major group that have common English and Trukese names in general usage. Trukese names may apply to particular recognizable species but are generally used only for those species with particular traditional or commercial importance. Common English names may be applied to most of the families of fishes and to particular species in some instances. The common family names are relatively unambiguous and have been used in this report; common names applied to particular species can be more confusing.

The various species of one very important group, the corals, have virtually no common names in either English or Trukese. Hence, the scientific name is the only one that can be applied to these species.

Wherever possible in this report we have used appropriate common English names as well as scientific names. These common names more often apply to families or other groups rather than to individual species.

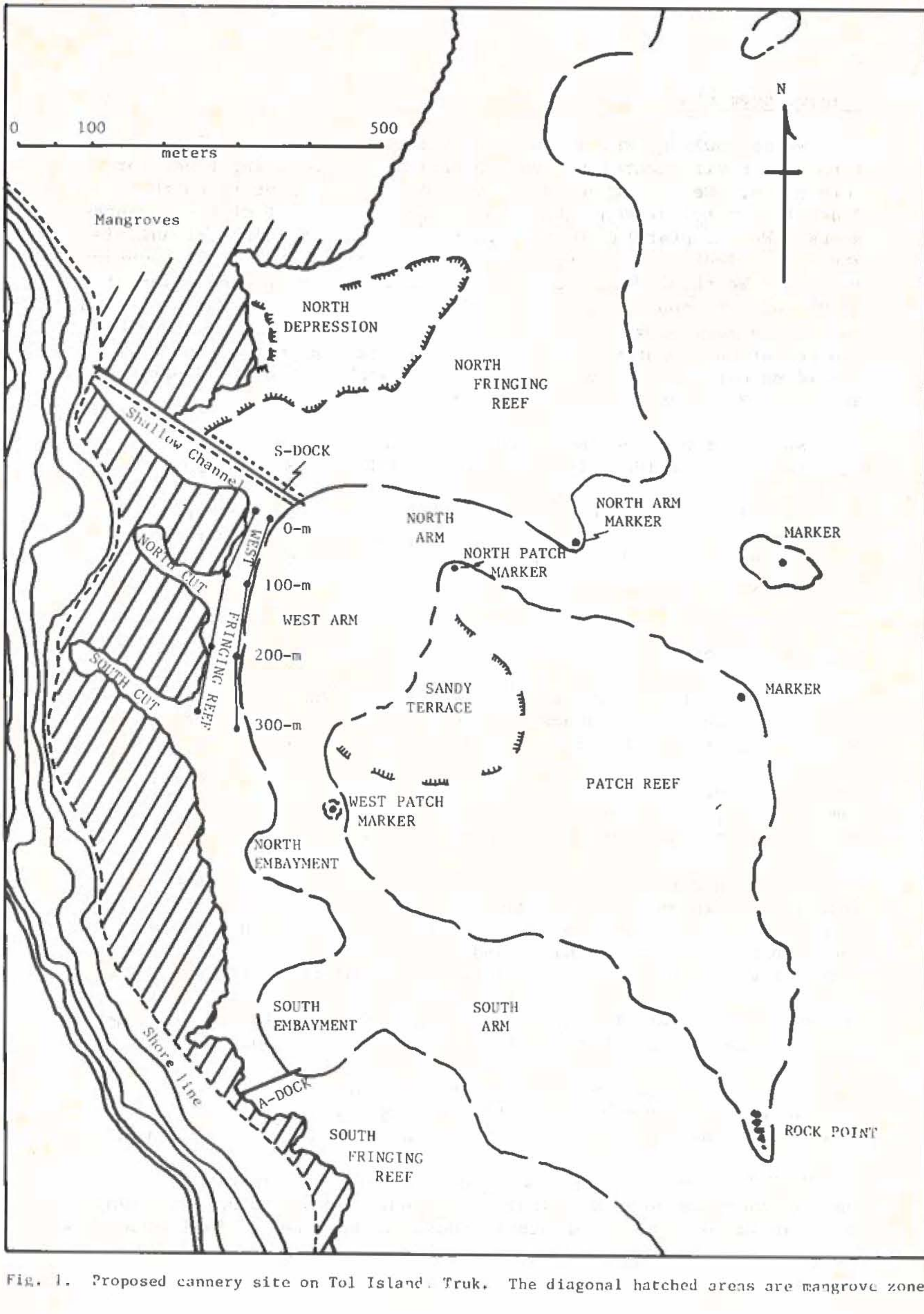

Fig. 1. Proposed cannery site on Tol Island, Truk. The diagonal hatched areas are mangrove zones.

General Description and Physiographic Setting of the Study Area

The study area is located on the east side of Tol Island in the western part of Truk Lagoon (cover figure). Tol is the largest and highest of the numerous volcanic islands situated within the lagoon and is characterized by steep stream-dissected slopes and mountain peaks up to 434 m (Mt. Tumuital) in elevation. The island is irregular in outline because of a number of large embayments that penetrate inland toward the central part. In its greatest dimensions the island is about 5.25 nautical miles long (including Polle Island) and 4.65 nautical miles wide. Low coastal terraces and steep volcanic rock slopes border the shoreline. Lagoon fringing reefs of variable width border both the more exposed peripheral and protected embayment shorelines at most places around the island. Mangrove swamp occupies the intertidal part of the fringing reef platforms at many places and is particularly well developed along the platforms fringing the larger embayments and the eastern side of the island at the study area. Offshore patch reefs, that rise up from the lagoon floor, abound around the island. One of the larger of these patch reefs is located just offshore of the fringing reef platform at the study site (Fig. 1).

The shoreline and general extent of the mangrove swamps, fringing and patch reef areas, lagoon channel, and offshore lagoon regions near the study area are shown in Fig. 1. Location names shown on this map are not official place names, but were coined by the study team to facilitate description of the region.

The immediate coastal region consists of steep basaltic slopes with a narrow terrace along the shoreline. The terrace is occupied for the most part by residential dwellings, gardens, pig pens, footpaths, and at the north end near S-dock, warehouses for storing copra, buildings which house a fish smoking and shredding plant, and some boat building and repair facilities. Flat land along the shoreline is scarce and at places the low coastal terrace has been widened somewhat by building rock seawalls out onto the adjacent mangrove flat and landfilling.

The intertidal coastal region is occupied by an extensive mangrove swamp that ranges in width from nearly 300 m immediately south of S-dock to a narrow fringe about 50 m wide near A-dock. <u>Rhizophora</u> species dominate the swamp and are densest along the lagoonward fringe. Along the inner part of the swamp the trees are taller and more widely spaced with some open mud-flat areas on the shoreline that have apparently been cleared of trees for some reason. Mangroves have also been cleared to provide boat access channels to the shoreline along the south side of S-dock and at two other locations 100 and 300 m south of S-dock.

The sediments along the inner part of the swamp contain considerable amounts of terrigenous clay, silt, and sand intermixed with smaller amounts of organic matter and coarse bioclastic sediments of marine origin. These deposits form a soft plastic mud which is difficult to walk across. In a lagoonward direction the sediments show less terrigenous and organic material, grading into sand and rubble-sized bioclastic material of reef origin. This outer part of the mangrove swamp is much firmer.

A lagoon fringing reef of irregular width borders the entire study area (Fig. 1). North of S-dock the North Fringing Reef is about 525 m wide. Between S- and A-docks the West Fringing Reef forms a narrow platform ranging from 45 to 175 m wide and south of A-dock the South Fringing Reef widens to about 450 m. A large reef embayment is formed between the wide North and South Fringing Reefs and two smaller indentations form the North and South Embayments along the southern part of West Fringing Reef. The area between the North and South Fringing Reefs is occupied for the most part by a pear-shaped Patch Reef 950 m long and 575 m wide. The deep water between the Patch Reef and adjacent fringing reefs forms a channel which has arbitrarily been divided into a North, West, and South Arm. The channel ranges in width from 75 to 300 m and is up to 26 m (14 fathoms) deep.

North of S-dock an enclosed lagoon, called the North Depression, occupies the inner part of the North Fringing Reef. This enclosed lagoon is 1 to 5 m deeper than the adjacent reef-flat platform and the water is very turbid, a result of suspended clay-sized particles. The floor of the enclosed lagoon consists mostly of dark plastic mud in the deeper pockets and a gritty sandy mud along the outer peripheral margin where it merges with the shallower reef-flat platform. Another deeper region occupies the northwest part of the Patch Reef. It is a predominantly a sand-floored terrace about 3 to 5 m deep where it borders the West Arm and gradually shoals toward the southwest to the general patch reef level.

On the basis of overall gross morphology the reef areas can be divided into a number of physiographic divisions. The largest of these divisions are the extensive shallow reef-flat platforms, steep lagoon slopes, and channel and lagoon floors. Smaller divisions include the sand-floored terrace located on the northwest part of the large offshore Patch Reef and the enclosed lagoon located on the inner part of the North Fringing Reef. The physiographic divisions are shown in vertical profile in Fig. 2.

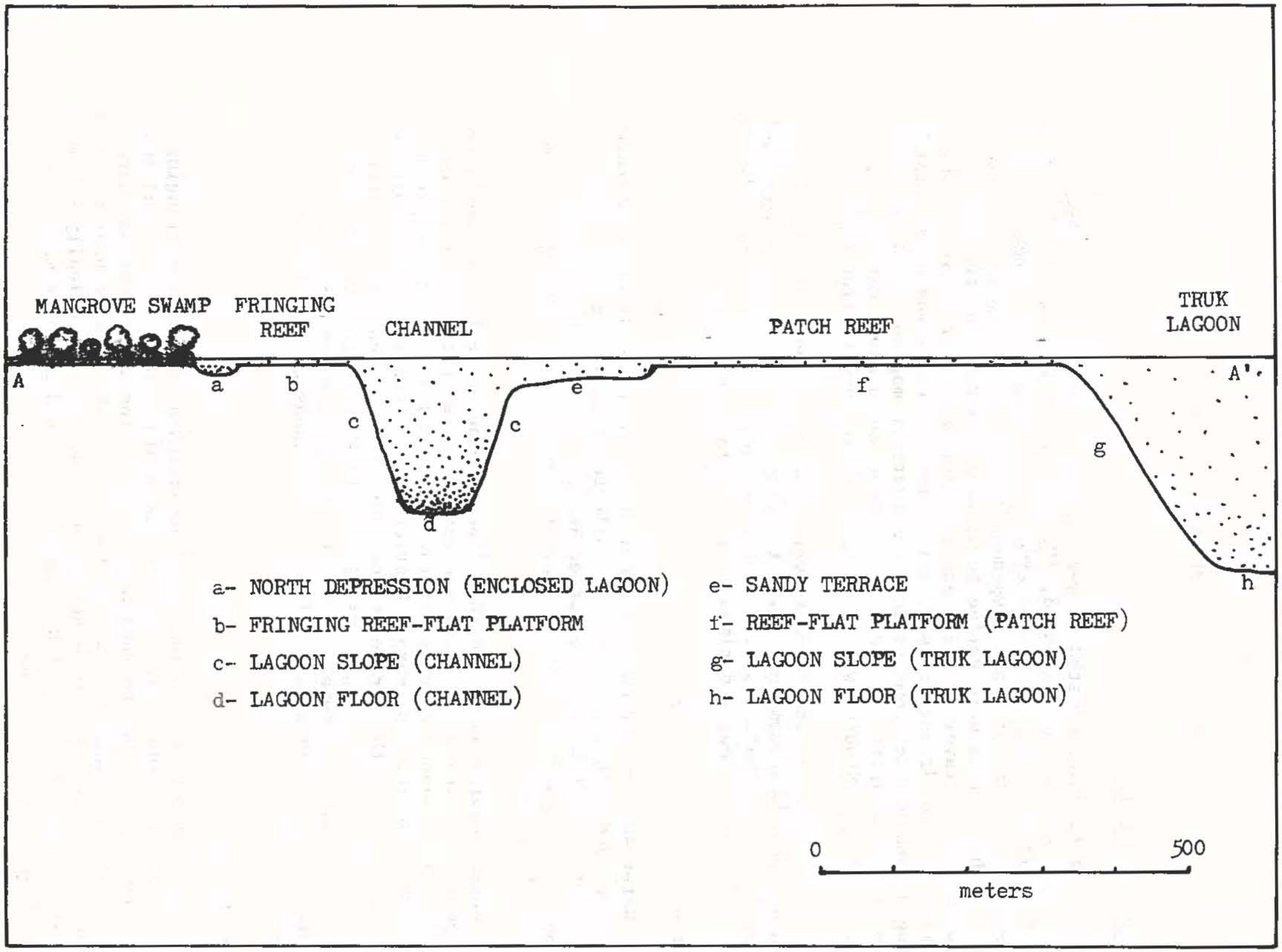

Fig. 2. Vertical profile through the Tol Island study site showing the principal physiographic reef divisions. The profile extends from the mangrove swamp north of S-Dock (A) to the lagoon floor on the southeast corner of the Patch Reef (A′) as shown in Figure 3. Density of stippling indicates relative turbidity.

METHODS

Water Circulation

Water circulation studies were conducted in the North, West, and South Arms of the channel on 18, 19, 20, and 21 December, 1977. Water movement in the channels was determined by using drift drogues. These consisted of aluminum vanes suspended from buoys by lengths of line. The lengths of line were varied to suspend the vanes at two depths, in a surface water layer of 1-2 m and a subsurface layer of 6-7 m. The position of the drogues at successive time intervals was determined by using a hand-bearing compass to triangulate on mappable features. The time of drogue drift and distance traveled was used to determine water mass velocity. Studies were run during rising and falling tides.

Wind direction and velocity were measured at periodic intervals with a hand-held anemometer. Tide readings were taken from a tide staff at periodic intervals, usually at the beginning and end of each drogue set, and at the predicted times of tidal highs and lows.

Nutrients

Water samples for chemical analyses of nitrite-nitrogen, nitrate-nitrogen, and orthophosphate were collected from 12 stations (Fig. 3) and returned to the Water Resources Research Center for analyses. Dissolved oxygen (DO), salinity, and temperature measurements were made at the study site.

Water samples on the North and West Fringing Reefs were collected by opening precleaned polyethylene bottles beneath the water surface. The West Arm channel samples (surface and 10 m) were collected with a van Dorn bottle. The sample bottles were packed in an ice chest with ice and placed in the Marine Resources reefer on Moen until the return flight to Guam. The samples remained cold (not frozen) enroute and were placed in the freezer at WRRC to await subsequent analyses. The nutrients were analyzed according to the methods of Strickland and Parsons (1968).

Productivity

Ten productivity stations were established on the West Fringing Reef (Fig. 3). Four pairs of stations at 0 m, 100 m, 200 m, and 300 m were used for sunrise and sunset samplings. The inner stations were adjacent to the mangrove zone and the outer stations were near the reef margin. Additionally, two mangrove stations were periodically sampled. A sampling set consisted of DO, temperature, and salinity measurements, as well as water mass movement.

Community productivity was determined by measuring changes in dissolved oxygen of water flowing across a given area of reef flat and then multiplying this change in concentration by the total volume flow of water to obtain the total change in oxygen caused by metabolic activity of the community. Samples for oxygen analysis were collected in a plastic bucket and siphoned into glass-stoppered BOD bottles. Fixing reagents were added to the bottles immediately and the preserved samples were held for later titration. Procedures followed the azide modification of the standard Winkler method (APHA, 1976).

Current velocity was determined by timing the movements of fluorescein dye dropped into water moving along a measured distance (5 m) and then using a hand-held compass to measure the direction of movement. Water depth along the path of dye movement was also measured. At low tides, the water movement at the 300-m stations was extremely slow or nonexistent. In either case a 5-m dye track was not feasible, so the movement of the dye patch in 5 minutes was recorded. The volume transport of water was calculated for a 1-m wide transect by multiplying current velocity by depth. The two 300-m transects were laid out parallel to the direction of water movement on the shallow fringing reef of the study area (Fig. 3). These two transects are designated "outer transect" and "inner transect" respectively in this report and were approximately 50 m apart.

Water temperature was measured with a mercury thermometer at the time of each oxygen sampling until the thermometer was broken. However, very small temperature differences were observed in the measured values; and there are a sufficient number of measurements to characterize the prevailing temperatures at the time of our study.

<u>Sediments and Sedimentation</u>

Sediment samples were collected on the fringing reefs and Patch Reef for determination of the general constituents, particle size, organic content, and foraminiferal composition. Additionally a determination of the suspended load in the water column of the West Fringing Reef was conducted.

Seven bulk samples (approximately 500 g) were collected on the West Fringing Reef and two bulk samples on the southeastern end of the Patch Reef (Fig. 3). These samples consisted of surface sediments (top 5-8 cm). Samples were scooped into glass jars and sealed without the addition of a preservative. Comparisons of the relative anaerobic activities (visual observations) of the mangrove zone, West Fringing Reef, and Patch Reef sediments were made on samples returned to the laboratory. Sediments were examined qualitatively with a stereomicroscope (10 to 90 x).

Twenty foraminiferal samples were collected from the North and West Fringing Reefs, the West Arm of the channel by scuba diving, and the southern edge of the Patch Reef (Fig. 3). These samples were preserved in 2 percent buffered rose bengal formalin.

The suspended load, expressed as sedimentation rates, was determined by using a settling tube method. Studies conducted by Dr. Charles Birkeland (personal communication) indicated that this method could provide reasonable assessments of reef sedimentation rates if conducted over an adequate time interval. The 5-day period of sediment accumulation was insufficient time to generate enough satisfactory data for statistical analysis.

The settling tubes are 41 cm sections of PVC pipe with inside diameters ranging from 2.25 to 2.40 cm, aperture areas of 4 to 4.5 cm^2, wired to rebar stakes. The bottoms of the tubes were sealed with rubber or cork stoppers. The stakes were hammered vertically into the reef at the sampling stations. The apertures of the tubes were 45 to 50 cm above the substratum.

Ten sedimentation stations were established at the following locations: the reef flat adjacent to the mangrove zone (3); outer fringing reef margin (3); upper channel slopes (3); and the lagoonward end of S-dock (Fig. 3). Settling tubes were left in the field for 5-days. When the tubes were recovered the contents were rinsed into zip-lock plastic bags using a seawater 5 percent formalin wash. Due to the small volume of accumulation in the tubes care was taken to recover all the trapped sediments. The preserved sediments were returned to the laboratory for analysis.

The seawater salts were removed by thoroughly rinsing the suspended sediments on a 325 mesh sieve (45 microns) with deionized water. The suspended sediment loss was negligible in relation to the total accumulated. A qualitative determination of the nature of the material smaller than 45 microns was made with a stereomicroscope. The wash water was then discarded. Porcelain weighing dishes were dried one hour at 550°C, desiccated overnight, and weighed. The dishes were reheated to 110°C, desiccated, and weighed. The washed sediments were rinsed into the tared weighing dishes and dried to a constant weight at 110°C. The tared sediments were returned to the desiccator for subsequent organic analysis.

The ash-free organic content of the bulk and suspended sediment samples were determined by the incineration method. Subsamples (10 to 15 g) of the bulk samples were washed, dried (110°) and tared in weighing dishes that had previously been tared at 550°C and 110°C, respectively.

The tared sediment samples were heated in a muffle furnace to 550°C and combusted for one hour. Combusted samples were desiccated overnight and weighed. The residue weight substracted from the initial dried weight yielded the ash-free organic content.

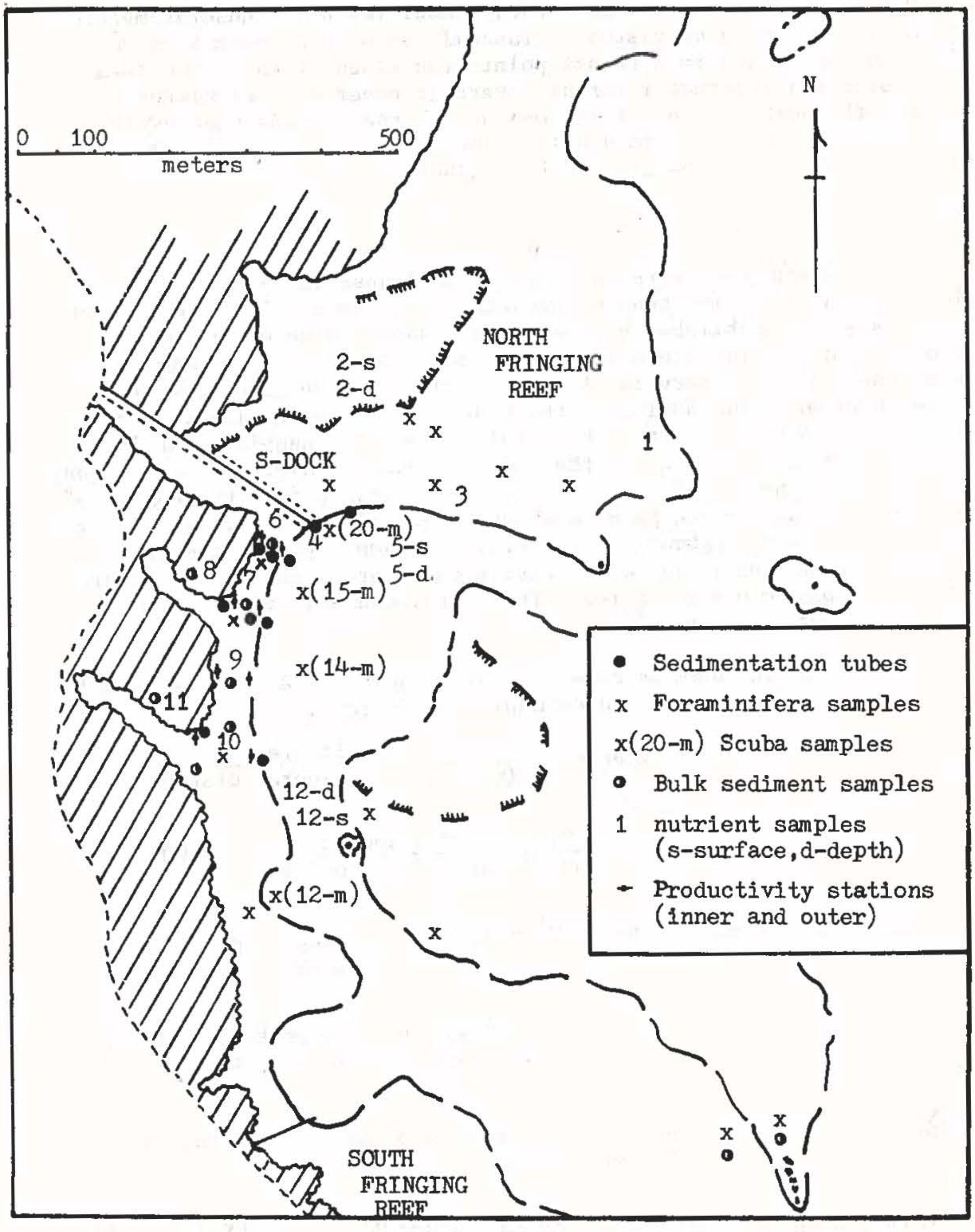

Fig. 3. Locations of sedimentation tubes, sediment samples, productivity stations, and nutrient sampling sites.

Marine Plants

Marine plants were quantified by a modified point-quadrat method (Tsuda, 1972), which consisted of randomly tossing a 25-cm X 25 cm gridded quadrat with 16 internal points ten times at each 10-m (5-m in some instances) transect interval. Percent cover was calculated by dividing the number of points at which each species was seen by the total number of points examined (16 times the number of tosses) and multiplying by 100 to obtain percent values.

Corals

Coral communities were analyzed along transects 1-7 by using the point-centered or point-quarter technique (Cottam et al., 1953). The transects were established by placing a plastic surveyors tape along the bottom at the locations indicated in Figure 4. Sample points were established at 5-m intervals along the line. A line bisecting the sample point at right angles to the transect line established four quadrants around the point. The coral nearest the sample point in each quadrant was located and the specific name, diameter of the colony (or width and length measurement), and the distance from the center of the colony to the sample point was recorded. If no colony was observed within the maximum distance of 1-m from the sample point, the quadrant was recorded as having no colony with a diameter of zero and a sample point-to-colony distance of 1-m. Therefore, the unit area of the survey quadrant was .785 m^2.

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

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

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

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

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

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

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

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

$$\text{relative frequency} = \frac{\text{frequency value for a species}}{\text{total frequency values for all species}} \times 100$$

importance value = relative density + relative percent coverage + relative frequency

The presence of additional coral species not encountered in the transect samples was determined for each transect by making 10-minute observations along each side of the transect line for each 100 m of transect length. The number of coral species and an estimation of their relative abundances were determined for each transect or reef zone, mapped in Figure 4. Estimation of species abundance was made by using the following scale and symbols: D=dominant - the predominant coral within a reef zone, A=abundant - a species generally present but with a patchy distribution pattern within a reef zone, O=occasional - a species with only localized distribution within a reef zone, and R=rare - a species represented by only one or two occurrences within a reef zone.

For each species encountered on the transects or reef zones, one or more representative colonies or parts of colonies were collected for positive identification.

At transects 8A and 8B no quantitative data were collected, but species occurrence and their relative abundance were recorded along the region indicated in Fig. 4.

Alcyonacean (soft corals) coral communities along the transects were sampled by using the line-intercept technique (Cox, 1972). The length of line interval lying above each soft-coral colony was recorded along the transect line. Percentage of substrate coverage by soft corals was then calculated as follows:

$$\text{percent coverage} = \frac{\text{sum of transect intervals overlying soft corals}}{\text{total length of transect}} \times 100$$

Macroinvertebrates

The checklist of macroinvertebrates was compiled by qualitative examinations for the presence of species. The West and North Fringing Reefs, southern edge of the Patch Reef, and West Arm of the channel adjacent to the fringing reef (scuba) were examined. Unidentified species were collected (when feasible) and returned to the Marine Laboratory for identification.

Quantitative assessment of sponge size distribution, frequency, density, and percent substratum coverage was made at transect 7 (North Fringing Reef) by using the point-quarter technique (described in the coral method section).

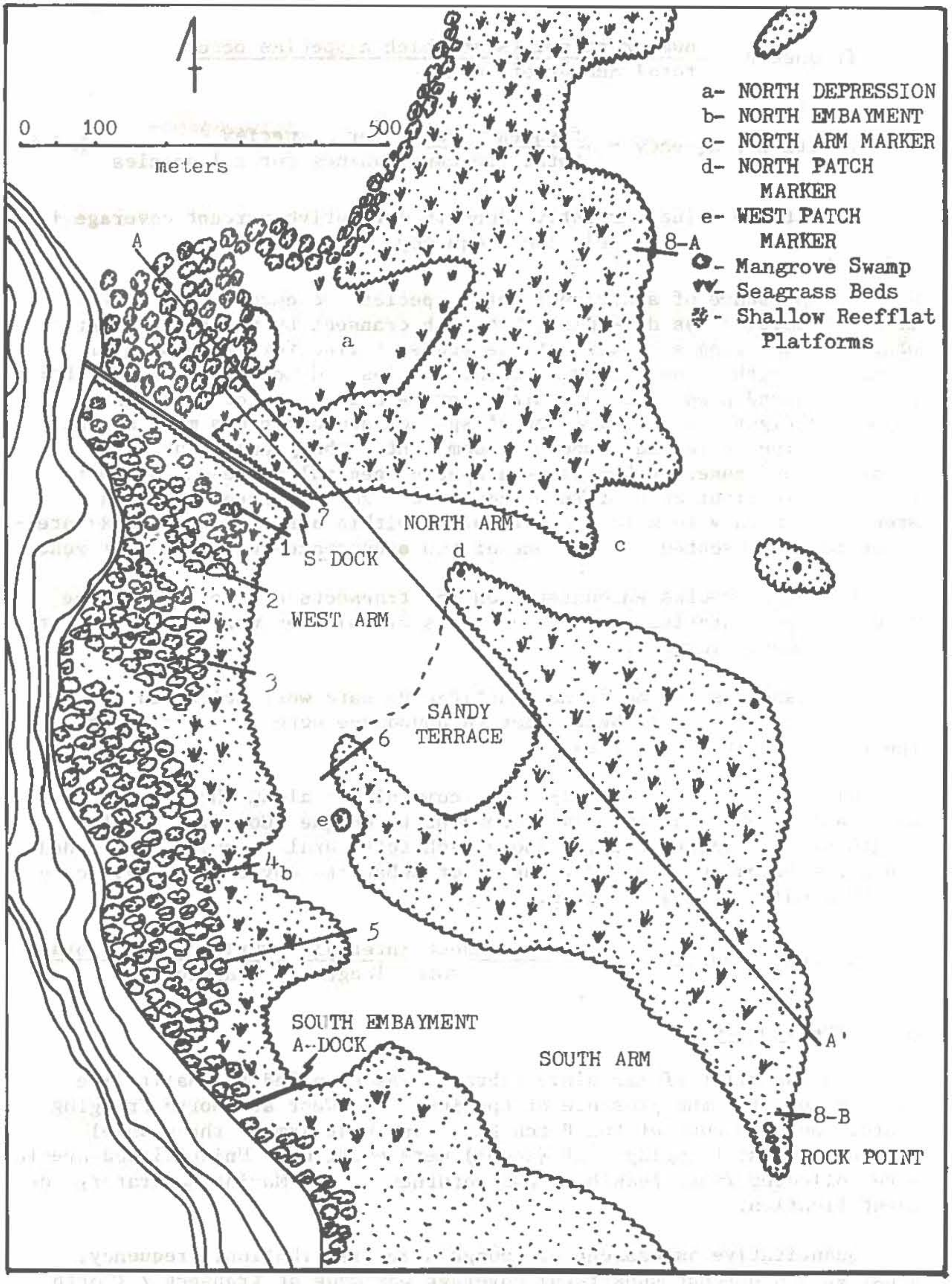

Fig. 4. Distribution of mangrove swamp sea grass beds, the Profile A-A´ and Biological Transects 1-7, 8A, and 8B.

Fishes

Seven transects were used to describe the distribution and relative abundances of the fishes found on the reefs within the study area. Fishes were identified and counted if they were observed within 1 m of either side of the transect lines. These observations were complemented by random swims through the study area, so that a more complete checklist of resident species could be compiled. Snorkeling gear was used on all of the transect counts, and all but two of the random swims. Scuba was used on these two swims to record some of the deeper-living fishes found near the channel wall of the West Fringing Reef Flat and the channel wall of the southwestern side of the Patch Reef.

Zooplankton

Three night and four daytime zooplankton tows were made in the channel adjacent to the proposed cannery site (Fig. 5) on December 20-21, 1977. A plankton net with a diameter of 0.5 m and a sieve mesh of 0.35 mm was used for all tows. The net was towed at a distance of 20 m behind the stern of the boat for night tows and 25 m for day tows. The net was towed slightly below the water surface. A tow speed of approximately 2 knots was maintained for all tows. The tow lengths in the channel (Fig. 5) were determined from a detailed map of the area. Mappable landmarks were used for starting and stopping points. The durations of the tows were recorded. The length of the tow along the North Fringing Reef margin (Fig. 5) was determined by releasing dye patches from the stern of the boat and recording the time it took for the dye patch to reach the mouth of the net. Four dye releases were made and the mean time was used in calculations. The duration of the tow was also recorded. From this data it was possible to calculate the distance towed. The volume of water filtered for all tows was calculated from the tow length and diameter of the plankton net.

The day/night channel tows were performed to evaluate day/night changes in the composition of the zooplankton communities. The north fringing tow was performed to determine the composition of zooplankton transported into the study area.

The zooplankton were preserved in 2-5% formalin for later identification. Two subsamples consisting of at least 1,000 zooplankters were counted in the laboratory. Displacement volume of the entire catch was also determined for each sample.

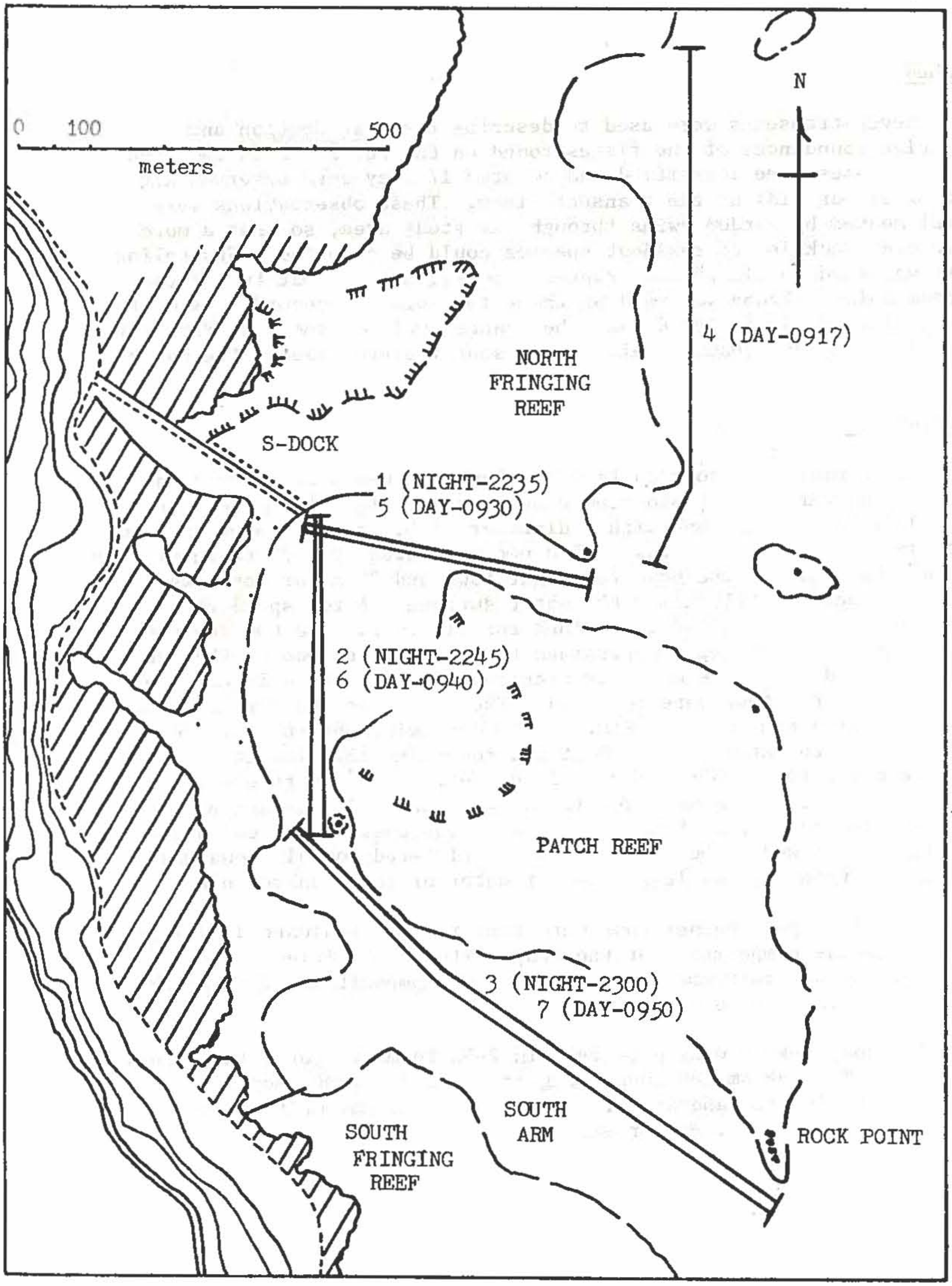

Fig. 5. Zooplankton tow paths, December 20 and 21, 1977.

RESULTS AND DISCUSSION

Water Circulation

Drogue observations are plotted in Figs. 6 - 9 , and additional information is given in Table 1 . Field observations indicated that the drogue paths were usually influenced by the prevailing wind, which was generally from the NNE at 6-22 knots. Drift directions of the 1-m drogues followed the wind more closely than those of the 6-m drogues.

Drogue movement was generally from north to south except for paths D, E, and G, which went south to north (Fig. 7). Drogue paths D, E, and G occurred during a rising tide. The 6-m drogue of path D moved northward following the curvature of West Arm and North Arm channels until it had passed the North Arm Marker. After clearing the marker the drogue was driven southward into the patch reef. The 1-m drogue of path D moved northward ca. 100 m before it reversed directions and caught on the West Fringing Reef. The 6-m drogues of paths E and G showed a similar pattern to the 1-m drogue of path D. Drogue paths N, O, and P (Fig. 9) reflect a rising tide of similar magnitude as occurred during drogue drifts D, E, and G. However, during these drogue tracks no reverse in direction was indicated. The reverse water mass movement as indicated by paths D, E, and G may be an intermittent phenomenon.

The general trend of water movement in the channels, during both rising and falling tides, is from the North Arm to South Arm channel, following the channel topography (Fig. 10). The movement of water across the Patch Reef, North Fringing Reef, and West Fringing Reef was from NNE to SSW (Fig. 10).

Water from the North Fringing Reef flows around S-dock and strikes the West Fringing Reef between S-dock and the 100-m station. This water was typically muddy, appearing to have originated in the North Fringing Reef mangrove zone. This flushing phenomenon was seen to occur on an almost daily basis. Flow of water on the West Fringing Reef was always southward, following the curvature of the reef. The fastest water velocity was usually along the reef margin, with a low velocity typical of the mangrove zone.

Drogues tended to move into the North and South Embayments near the narrow portion of the West Arm channel. (Fig. 6, paths B and C; Fig. 7, paths E and F; Fig. 8, H to M; Fig. 9, path O). As indicated by the drogue movement the North Embayment should receive the heaviest siltation load. Construction activities on either the North Fringing Reef or West Fringing Reef will cause considerable stress on the biological communities in the North Embayment. The South Embayment can potentially receive a considerable silt load but the impact should be less. The silt impact on the South Fringing Reef should be minimal, although the biological communities will undoubtably be somewhat stressed.

Table 1. Drift distance, time, and speed of current drogues, direction and speed of wind during time of drogue drift, and tidal change from December 18 to 21, 1977.

DATE AND FIG.	DROGUE CAST	TIME IN	DROGUE TIME (min)	DRIFT DISTANCE (m)	SPEED (m/hr.)	WIND TIME IN	WIND DIRECTION (°)	WIND SPEED (kts)	TIDE* TIME IN	TIDE* READING (ft)	Δ CHANGE	REMARKS
18/12/77	A 1m	1230	15	100	400	1130	000	12-14	0900	2.75		Moderate
	6m		15	90	360				1130	3.0	+ .25	Rising Tide
Fig.	B 1m	1252	73	540	444	1310	030	11-15	1300	3.3	+ .3	(+ 0.6)
	6m		73	538	196							
	C 1m	1410	95	523	333	1410	010	10-15	1410	3.35	+ .05	Tide Change-1614
	6m		55	123	134	1605	020	12	1605	3.25	- .1	
19/12/77	D 1m	0958	28	246	527	0930	035	11-12	0935	3.0		Moderate
	6m		77	746	581							Rising Tide
Fig.	E 1m	1210	45	112	149	1155	030	13-17	1155	3.4	+ .4	(+ 0.5)
	6m		45	62	82							
	F 1m	1300	30	238	477	1308	030	10				
	6m		30	238	477							
	G 1m	1335	15	132	528	1325	030	11-12				Tide Change-1577
	6m		15	130	520	1445	030	10	1445	3.5	+ .1	
20/12/77	H 1m	1445	105	662	378	1445	040	6-7	1445	3.4		Tide Change-1437
	6m		105	438	251							Moderately strong
Fig.	I 1m	1635	80	462	346	1645	030	8	1600	3.2	- .2	Dropping Tide
	6m		80	462	346				1645	3.0	- .2	(- 1.0)
	J 1m	1800	65	462	426	1815	035	7-8	1810	2.4	- .6	
	6m		65	508	569				1840	2.55	+ .15	
	K 1m	1915	60	446	446	1915	035	6-7				
	6m		60	446	446				2000	2.4	- .15	
	L 1m	2025	50	362	434	2130	042	6-7				
	6m		50	323	388				2130	2.2	- .2	
	M 1m	2230	45	346	462	2330	000	12-13				
	6m		45	346	462				2330	2.2	0	Tide Change-2321
21/12/77	N 1m	0645	45	365	486	0645	030	18-22	0645	2.7		Moderate
	6m		60	338	338							Rising Tide
Fig.	O 1m	0750	57	462	486	0800	015	15-17	0800	2.8	- .1	(+ 0.6)
	6m		70	427	366							
	P 1m	0905	60	631	631	0855	020	16-17	0855	3.0	+ .2	
	6m		60	670	670	1015	025	14-16	1015	3.3	+ .3	

*Arbitrary 0 datum, not related to actual tidal heights as recorded for Moen Island.

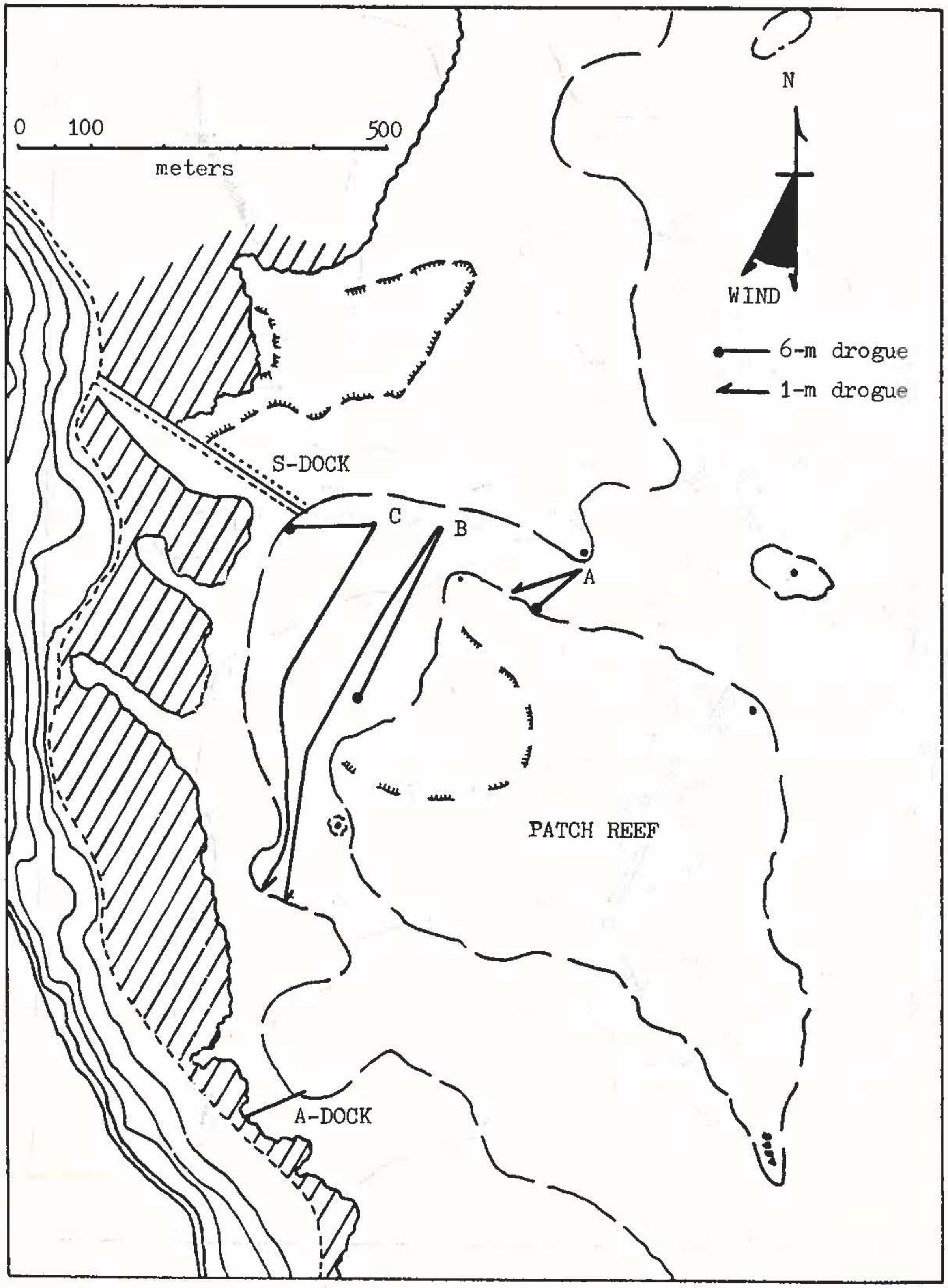

Fig. 6. Drift drogue paths for December 18, 1977. The tide was rising, runs A and B, and falling during run C.

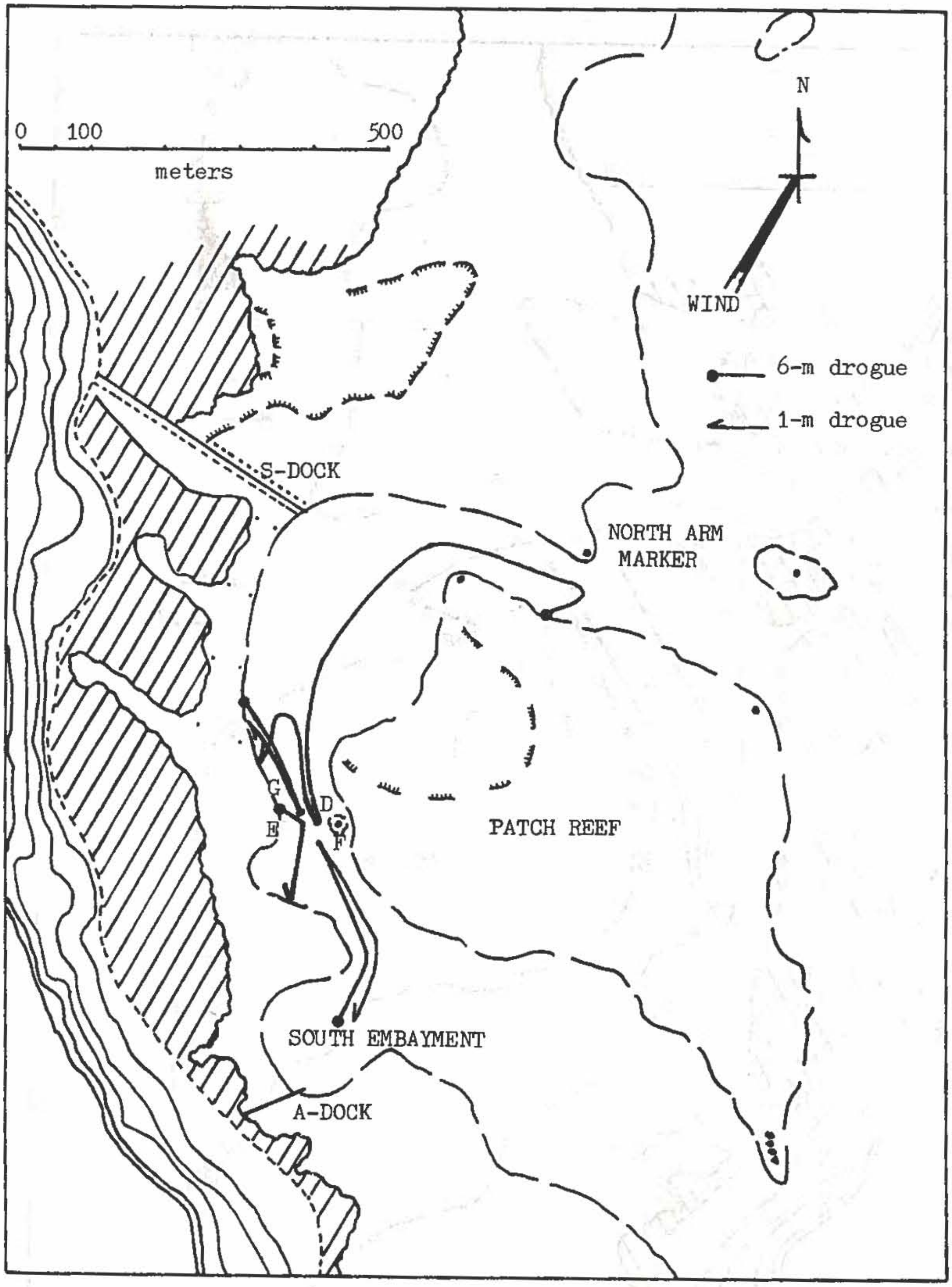

Fig. 7. Drift drogue paths, December 19, 1977. The tide was rising during drogue runs D through G.

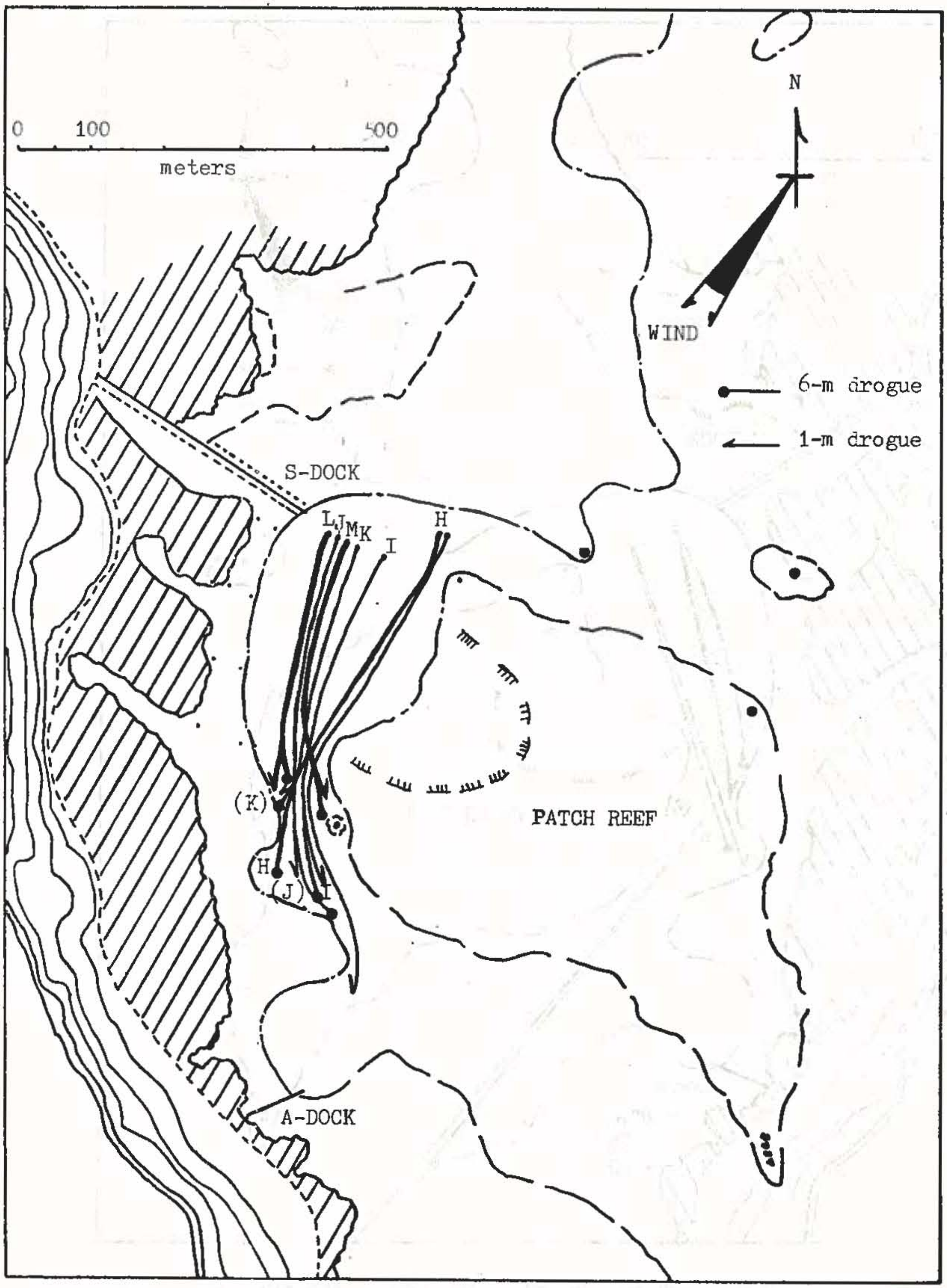

Fig. 8 . Drift drogue paths, December 20, 1977. The tide was strongly falling during drogue runs H through L and slack during drogue run M.

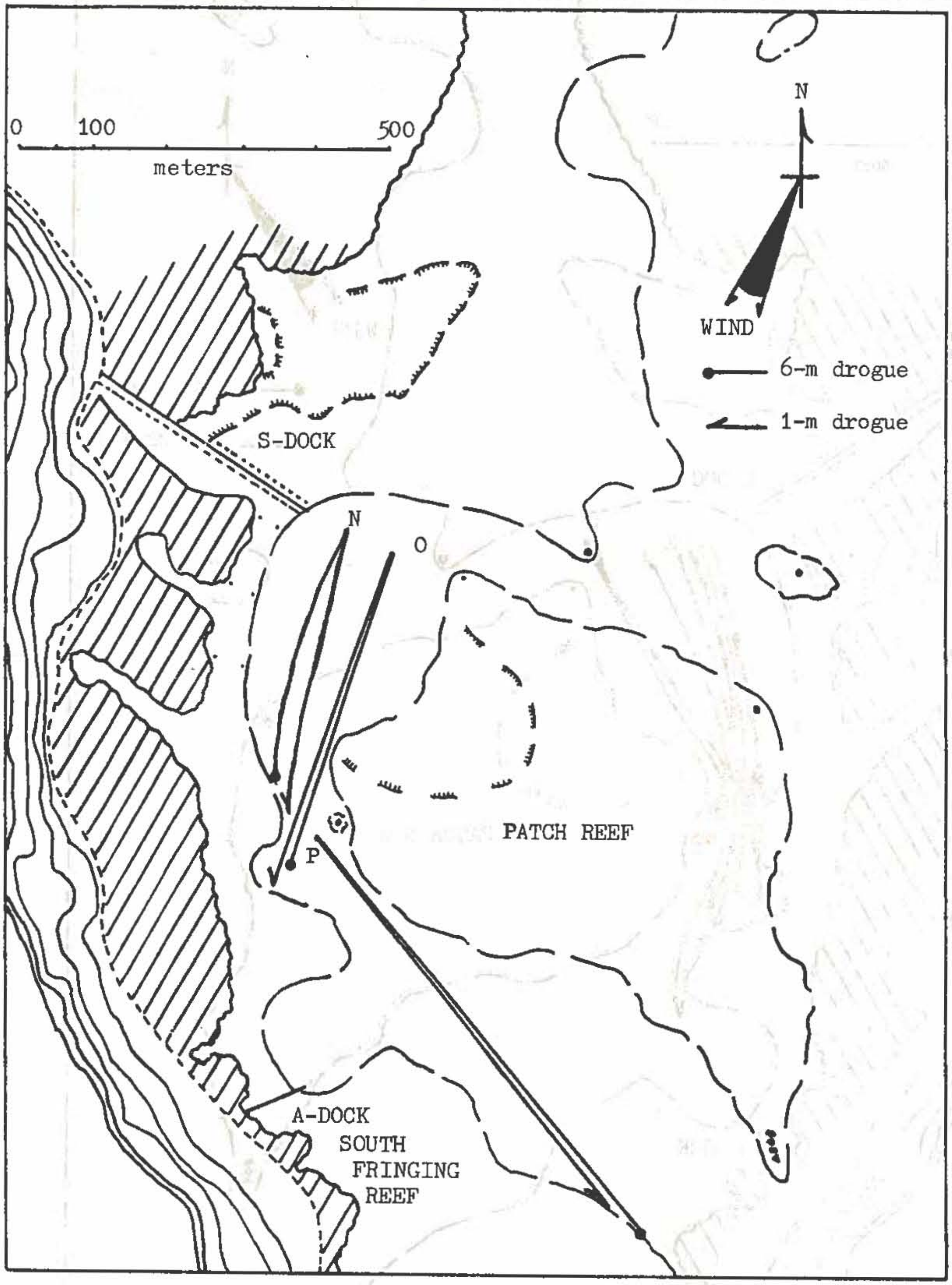

Fig. 9. Drift drogue paths for December 21, 1977. The tide was rising during drogue runs O through P.

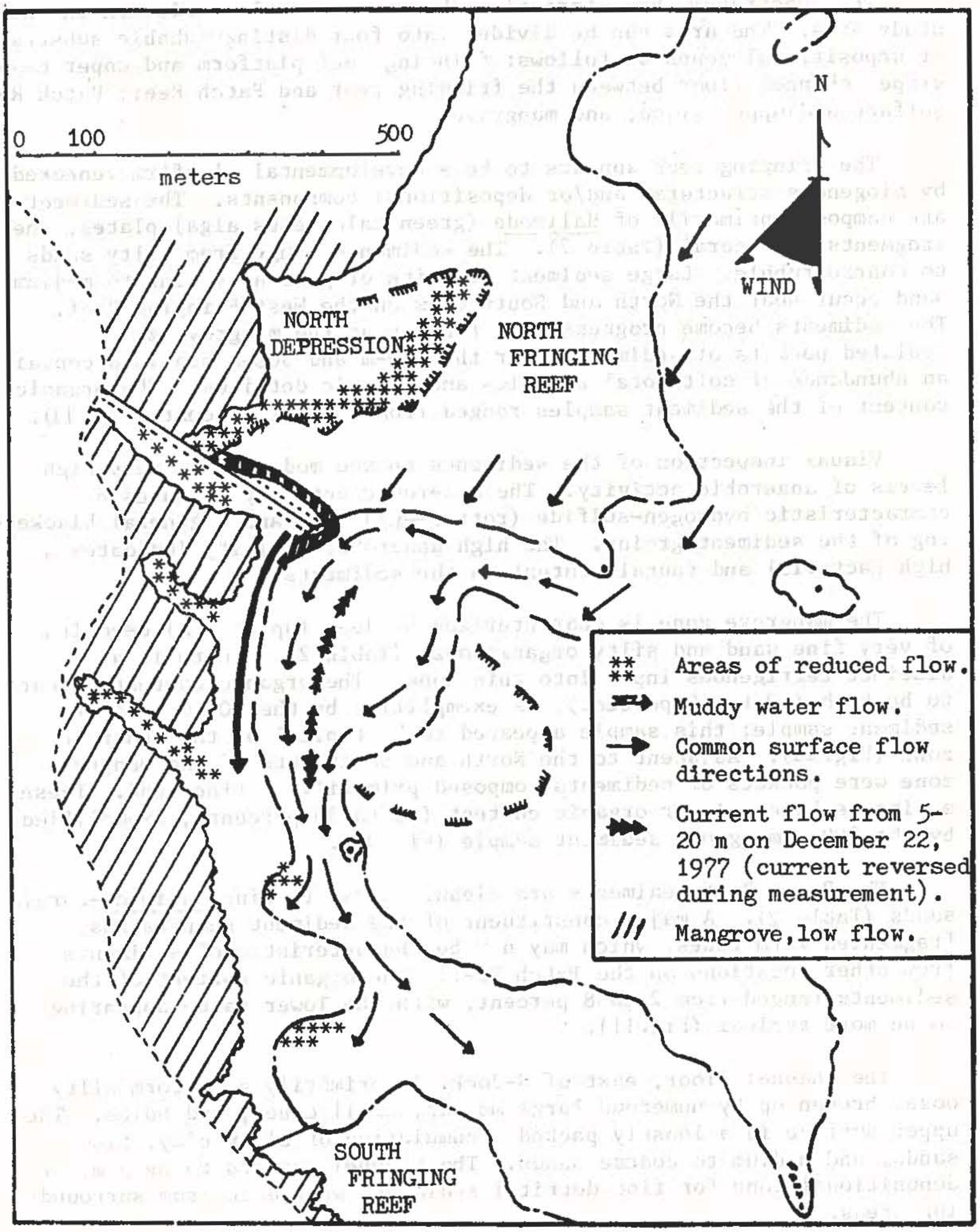

Fig. 10. General current trends from December 17 to 22, 1977. The predominant surface flow directions, as indicated above, are regarded as being the most probable water circulation patterns.

Substrata Characterizations

The substratam characteristics show considerable variation in the study area. The area can be divided into four distinguishable substratum or depositional zones as follows: fringing reef platform and upper channel slope; channel floor between the fringing reef and Patch Reef; Patch Reef surface and upper slope; and mangrove.

The fringing reef appears to be a developmental platform veneered by biogenous structural and/or depositional components. The sediments are composed primarily of Halimeda (green calcareous alga) plates, shell fragments, and coral (Table 2). The sediments range from silty sands to coarse rubble. Large sediment deposits of generally fine to medium sand occur near the North and South Cuts on the West Fringing Reef. The sediments become progressively finer near the mangrove zone. Isolated pockets of sediments near the 200-m and 300-m stations contain an abundance of soft coral spicules and organic detritus. The organic content of the sediment samples ranged from 5 to 11 percent (Fig. 11).

Visual inspection of the sediments showed moderate to very high levels of anaerobic activity. The anaerobic activity produces a characteristic hydrogen-sulfide (rotten-egg) odor and a general blackening of the sediment grains. The high anaerobic activity indicates a high bacterial and faunal content in the sediments.

The mangrove zone is characterized by deep (up to 1 m) deposits of very fine sand and silty organic ooze (Table 2). There is a distinct terrigenous input into this zone. The organic content appears to be high (50 to 60 percent), as exemplified by the 100-m mangrove sediment sample; this sample appeared to be typical of the mangrove zone (Fig. 11). Adjacent to the North and South Cuts of the mangrove zone were pockets of sediments composed primarily of fine sand. These sediments have a lower organic content (20 to 30 percent), exemplified by the 300-m mangrove sediment sample (Fig. 11).

The Patch Reef sediments are clean, coarse to fine Halimeda-coral sands (Table 2). A major constituent of the sediment samples was fragmented worm tubes, which may not be characteristic of sediments from other locations on the Patch Reef. The organic content of the sediments ranged from 2 to 8 percent, with the lower value appearing to be more typical (Fig.11).

The channel floor, east of S-dock, is primarily a uniform silty ooze, broken up by numerous large mounds, small cones, and holes. The upper surface is a loosely packed accumulation of silty clay, fine sands, and medium to coarse sands. The channel appears to be a major depositional zone for fine detrital sediments washed in from surrounding areas.

Table 2. Sediment characteristics of the fringing reef and patch reef. See Fig. 3 for station locations.

	PERCENT ORGANICS	GENERAL PARTICLE CLASSIFICATION	RELATIVE ANAEROBIC ACTIVITY	MAJOR SEDIMENT CONSTITUENTS
CENTRAL REEF FLAT				
0-m Station	5	Coarse-medium sand	Moderate	Coral/shell fragments/Halimeda
100-m Station	8	Fine-medium sand	Moderate	Coral/Halimeda/shell fragments
200-m Station	11*	Fine-medium sand	Very high	Coral/Halimeda/organic detritus
300-m Station	7	Coarse-medium sand	High	Coral/Halimeda/spicules/shell fragments
IN MANGROVE ZONE				
100-m Station	56	Silts	High	Organic detritus
300-m Station	27	Very fine sand	Low	Organic detritus/coral
NORTH-CUT				
320-m Station	5	Fine sand	Low	Coral/spicules/shell fragments
EASTERN PATCH REEF				
Surface	2	Coarse sand	Moderate	Coral/Halimeda/worm tubes
Slope at 6.1 m depth	8	Coarse sand w/fine sand	Low	Halimeda/coral/worm tubes

*Sample contained numerous annelid worms.

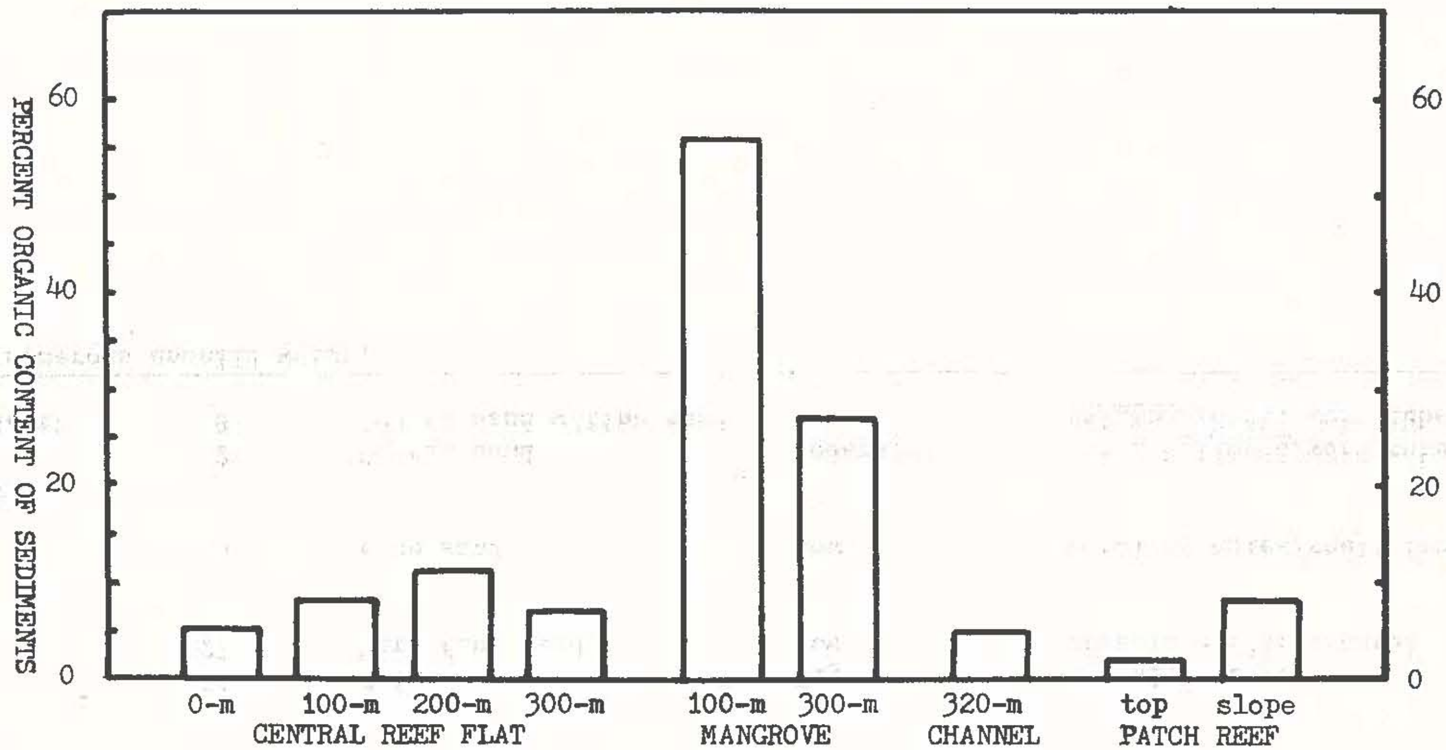

Fig. 11. Organic content of bulk sediment samples.

Living interstitial animals, meiofauna, were observed in the sediment samples from the West Fringing Reef and Patch Reef. No organisms were observed in the two mangrove samples. Benthic nematodes and copepods were the most notable meiofauna with polychaeta, and a kinorkynch-like organism observed in the 100-m and 200-m samples.

Sedimentation

The amounts of sediment accumulation over a 5-day period in each of 10 sedimentation tubes are presented in Table 3. A histogram showing the sediment accumulation in the sedimentation tubes is presented in Fig. 12. The accumulation value for the sedimentation tube adjacent to S-dock is probably artificially high. During the study period a large tuna boat docked and in the process resuspended a large quantity of bottom sediments. The higher sedimentation rate at the 100-m upper channel station is caused by a river-like flow of murky water that originates near the North Depression. This plume was observed to move eastward down the small boat channel to the seaward end of S-dock, sweep south in the channel and strike the West Fringing Reef 50 to 100-m south of S-dock. This phenomenon occurred on a daily basis during the study period. The 100-m and 200-m mangrove stations showed very high sedimentation rates (Fig. 12). These values may not be realistic, since it was observed that any activity on the reef flat tended to stir up silty sediments which were carried by the reef flat current to these stations.

The suspended sediments in all the sedimentation tubes contained a considerable fraction of organic detritus (Table 3). The organic content of the suspended sediments tended to be higher than the surrounding substratum sediments. This suggests that the organic content of the suspended sediments is being utilized by fauna or is washed away by strong currents. Organic content of the upper channel slope and outer reef flat suspended sediments ranged from 28 to 48 percent (Fig. 12). The suspended sediments near the mangrove zone tended to have a higher percentage of organic detritus, ranging from 42 to 67 percent (Fig. 12). The organic fraction appeared to be a gelatinous aggregate bound together by numerous small algal filaments.

Nutrients and Salinity

Table 4 shows orthophosphate (also known as phosphate-phosphorus, PO_4-P), nitrite-nitrogen (NO_2-N) and nitrate-nitrogen (NO_3-N) values for the various sampling stations. The two values designated by asterisks may have been contaminated samples and were not included in the calculation of means. Many of the samples, primarily from the West Fringing Reef, had barely detectable levels of nitrite-nitrogen. The values for nitrate-nitrogen (NO_3-N) are more variable between sampling stations than the orthophosphate values, as is usual. The variability is not surprising in view of the fact that several different ecosystem types were sampled. The nitrogen and phosphorus values are generally low and are characteristic of what might be expected for non-polluted tropical ecosystems.

Table 3. Five-day sedimentation rates on the fringing reef. See Fig. 3 for station locations.

	SEDIMENTATION TIME (HOURS)	ACCUMULATED SEDIMENTS (g)	SEDIMENTATION GRAMS/m^2	PERCENT ORGANIC	APPEARANCE OF WASH (< 45 MICRONS)
UPPER CHANNEL SLOPE					
North Patch Reef	122.4	.0479	77.79	32	Numerous filaments Trace of aggregate
Seaward End Dock	122.2	.1339	217.46	29	Rare filaments Trace of aggregate
0-m Station	122.1	.0423	68.70	44	Rare filaments Trace of aggregate
100-m Station	121.8	.0837	135.93	28	Common filaments Trace of aggregate
OUTER REEF FLAT					
0-m Station	122.0	.0718	116.61	32	No filaments Trace of aggregate
100-m Station	121.8	.0715	116.12	48	Blennie; small quanity of aggregate
300-m Station	121.4	.0736	119.53	43	Trace of aggregate; Rare filaments
NEAR MANGROVE					
0-m Station	122.0	.0601	97.61	42	Small quanity of aggregate Brown silts, nomerous filaments
100-m Station	121.8	.2497	405.52	67	Small quanity of brown silt; Trace of aggregate; numerous filaments
300-m Station	123.2	.4114	668.13	55	Small quanity of brown silt; Trace of aggregate; numerous filaments

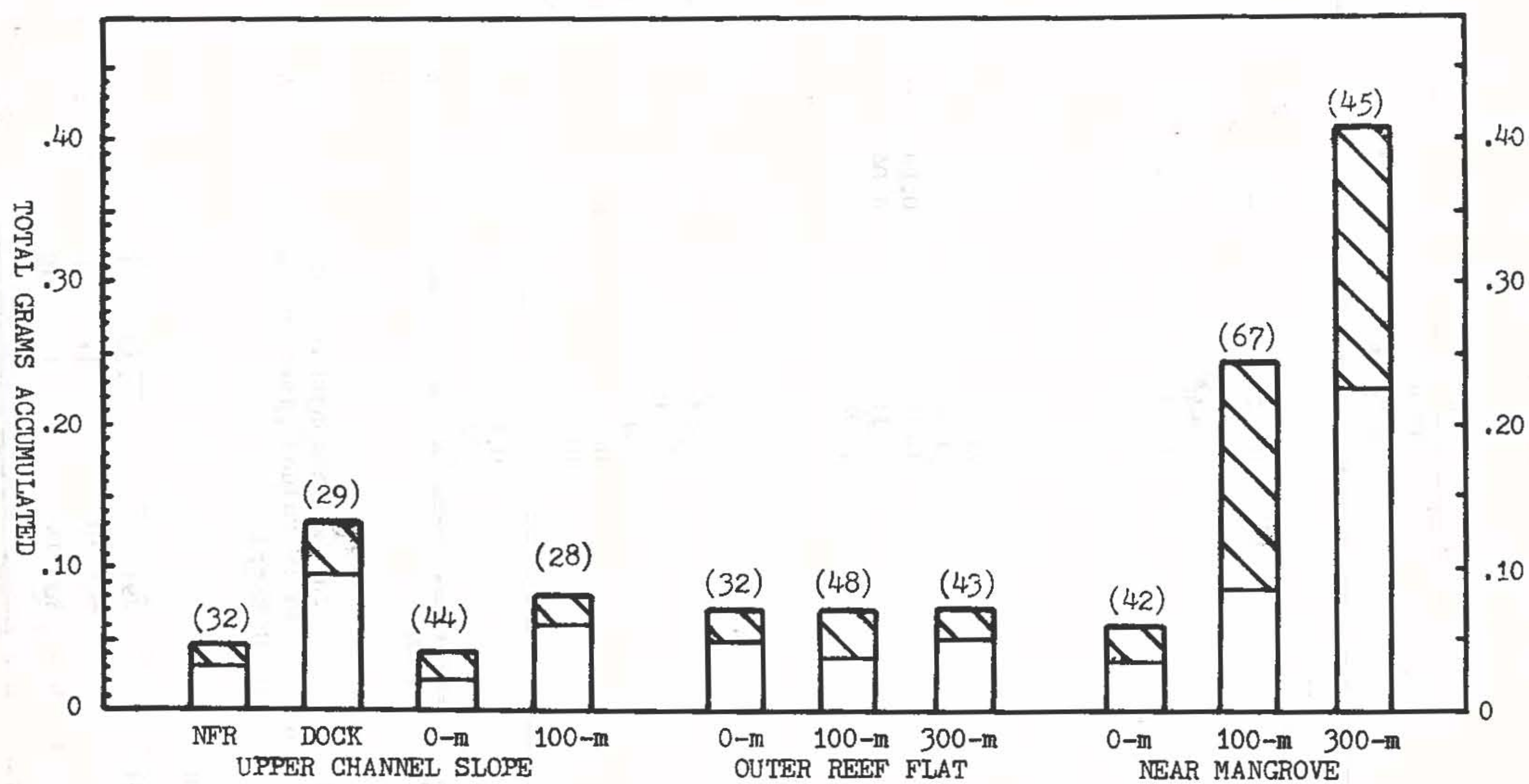

Fig. 12. Grams of sediment accumulated in sedimentation tubes by zones. The slashed area represents percent (numbers in parentheses) of total accumulated that was organic.

Table 4. Orthophosphate, nitrite and nitrate-nitrogen concentrations, December 22, 1977. See Fig. 3 for station locations.

	PO_4-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l
NORTH FRINGING REEF			
1 (East Edge)	0.12	-0-	0.31
2 (Depression)	0.14	-0-	0.38
2 (3-m, Depth)	0.64*	0.02	0.58
3 (South Edge)	0.23	-0-	0.33
WEST FRINGING REEF			
6 (0-m Sta.)	0.14	0.02	0.24
7 (100-m Sta.)	0.20	0.02	1.05*
8 (North cut)	0.16	0.04	0.38
9 (200-m Sta.)	0.18	0.04	0.24
10 (300-m Sta.)	0.17	0.04	0.18
11 (South cut)	0.28	0.07	0.47
WEST CHANNEL			
4 (Dock)	0.13	-0-	0.27
5 (Surface)	0.14	-0-	0.07
5 (10-m, Depth)	0.12	-0-	0.58
12 (Surface)	0.13	0.02	0.07
12 (10-m, Depth)	0.15	-0-	0.22
MEAN ($\bar{X}$)	0.16	0.02	0.31
STANDARD DEVIATION	0.04	0.02	0.16

*not used in computation of mean.

Table 5. A comparison of nitrogen and phosphorus concentrations at study sites on Moen, Dublon, and Tol. Values given are means $\pm$ 1 standard deviation, ranges, and number of samples.

	NO_3-N	PO_4-P
Moen	.27 ± .019; .25 - .29; 5	.23 ± .012; .22 - .25; 5
Dublon	.27 ± .17 ; .12 - .68; 10	.17 ± .029; .12 - .20; 10
Tol	.31 ± .16 ; .07 - .58; 14	.17 ± .047; .12 - .28; 14

Table 5 presents a comparison between nitrate and phosphate values for the Tol study and those found in earlier studies at Point Gabert, Moen (Tsuda et al., 1975), and at the site of a proposed fishery complex on Dublon (Amesbury et al., 1977). The mean nitrate value at Tol is slightly higher than the mean values at Meon and Dublon. The variability (as indicated by the standard deviations) is similar at the Tol and Dublon sites and is an order of magnitude higher than at the Moen site. This is not surprising since the Moen samples were from a generally homogenous water mass, whereas the Tol and Dublon samples were not from a homogenous area. The orthophosphate means are similar for the Dublon and Tol sites, which are lower than the Moen site. As with the nitrate values, the phosphate values are least variable at the Moen site. The Tol site is the only one where detectable nitrite-nitrogen values were found.

Salinity values ranged from 33.3 to 35.0 parts per thousand (ppt) and mostly fell in the range 33.9-34.5 ppt. These values are close to normal seawater salinity and indicate that the Tol site was not strongly influenced by runoff of fresh water from terrestrial areas at the time of our study.

Productivity

Table 6 shows the observed current speeds, depths, and oxygen concentrations at different dates and times at stations on both transects. Water temperatures are not shown, but those measured before the thermometer was broken ranged from 28.8° to 30.3° Celsius and included the morning and afternoon samples. Water movement across the reef flat was generally quite slow, and current speeds rarely exceeded 0.1 meter per second (m/sec). This indicates that a given water mass generally took at least an hour to cover the 300-m distance of the study transects and often much longer. A water mass along the outer transect was timed, using continuous dye tracking, at 76 minutes. During the single nighttime low tide when observations were made, there was little or no water movement across the study area. Table 6 shows that water movement was slower on the inner transect than on the outer transect.

Observed oxygen concentrations ranged from 1.17 milligrams per liter (mg/l) for a nighttime sample to 8.88 mg/l for an afternoon sample, or from 18% to 144% of saturation values. This indicates that the natural community in the study area is metabolically quite active. In general, there was a daytime increase and a nighttime decrease in oxygen concentrations as water flowed along the study transects; the most noteworthy exception is the late-afternoon decrease on both transects on December 20.

Table 7 shows calculated community productivity and respiration values derived from the data in Table 6 . The flow respirometry calculations employed here require that there be significant water flow between sampling stations as well as a significant change in oxygen concentration between these stations. Furthermore, changes in concentration between successive transect segments should consistently either increase or decrease, normally increasing in the daytime and decreasing at night.

Since these conditions were not met in all cases, the calculated productivity data in Table 7 are derived from only a portion of the data in Table 6. No distinction was made between the various segments within a given transect, and different segments were therefore lumped to give an average productivity value for each transect as a whole.

Table 6 shows the rather unexpected result that in the late afternoon hours after 1700 of December 20 oxygen concentrations actually decreased as water flowed across the transects. This indicates that the photosynthetic productivity of the natural community was not meeting its metabolic demands at this time of day. This is in contrast to most productivity studies of tropical marine communities, which show such heterotrophic metabolism only during the dark hours. Hence, as the available light energy decreased in the late afternoon community respiration exceeded community production on the West Fringing Reef. The late-afternoon values were lumped with the nighttime values in calculating the average community respiration reported in Table 7 for the inner transect and provide the only community respiration values for the outer transect.

If we assume that there is net community productivity (i.e., net increase in dissolved oxygen for waters flowing across the transects) for 10 hours during the daylight and that the respiration rate is constant for 24 hours per day, then we may calculate total daytime net production, total daily respiration, and total daily gross production; these values are also reported in Table 7. The most striking thing about such values is that total daytime production is not sufficient to meet the 24-hour respiration demands of the community. In other words, the natural community is not self-sustaining but must derive part of its energy demands from imported sources such as organic detritus. In fact, the 24-hour ratio of gross production to respiration is only 0.76 for the community traversed by the outer transect and 0.68 for the inner transect. The conclusion that the West Fringing Reef community is heterotrophic is supported by the observation of daytime oxygen decreases during the late afternoon hours, by the observation of large numbers of filter-feeding organisms (e.g., sponges) in the study area, by the anaerobic conditions frequently found at the sediment-water interface, by the high organic content of sediments (especially suspended sediments), and by observations of plumes of silt- and detritus-laden water flowing southward around S-dock and onto the study transects (Fig. 10).

The heterotrophic character of the West Fringing Reef community is in marked contrast to the autotrophic character of most other Pacific reef communities that have been studied, for example those studied by Marsh (1974) on Guam and by Smith and Marsh (1973) at Enewetak. Heterotrophic metabolism has been reported for only one other Pacific reef community, that in Kaneohe Bay, Hawaii (Gordon and Kelly, 1962). The West Fringing Reef community is unique among those studied in that it has significant standing crops not only of corals and macroalgae but also of seagrasses. Furthermore, it lies immediately adjacent to an

Table 6. Current speeds, depths, and dissolved oxygen concentrations (DO) on the productivity transects.

STATION	Time of Day	OUTER TRANSECT Current Speed (m/sec)	Depth (m)	DO (mg/l)	INNER TRANSECT Current Speed (m/sec)	Depth (m)	DO (mg/l)
December 17							
0 m	1448	.071	1.1	6.45			
100 m	1510	.12	1.3	6.85			
200 m	1522	.13	.79	6.87			
300 m	1530	.55	1.1	7.68			
December 18							
0 m	0930	.065	.85	6.29	.046	.52	7.16
100 m	1000	.069	1.0	7.03	.043	.61	7.45
200 m	1035	.041	.61	7.70			
300 m	1100	.024	.88	7.29	.048	.43	8.54
0 m	1545	.045	.64	6.74	.062	1.0	7.03
100 m	1525	.061	1.2	6.91	.046	.64	8.53
200 m	1510	.077	.73	7.66	.036	.55	8.50
300 m	1445	.042	1.1	8.21	.061	.52	8.88
December 19							
0 m	1135	.052	1.1	6.82	.040	.67	7.83
100 m	1115	.074	.91	6.95	.056	.58	8.16
200 m	1050	.023	.67	7.45	.048	.55	7.87
300 m	1025	.016	1.2	7.03	.089	.46	8.21
0 m	1430	.032	1.0	6.82	.070	.76	7.20
100 m	1416	.055	1.1	7.37	.032	.61	7.54
200 m	1358	.057	.79	7.66	.036	.61	8.50
300 m	1345	.055	1.2	8.21	.037	.61	8.88

Table 6 . continued

		OUTER TRANSECT			INNTER TRANSECT		
STATION	of Day	Current Speed (m/sec)	Depth (m)	DO (mg/l)	Current Speed (m/sec)	Depth (m)	DO (mg/l)
December 20							
0 m	1700	.029	.58	8.84	.037	.94	7.03
100 m	1728	.048	.94	6.53	.020	.40	5.28
200 m	1748	.032	.55	6.16	.018	.37	3.68
300 m	1815	.036	1.0	5.82	.044	.30	3.77
0 m	2010				.029	.40	4.48
100 m	2025				.0094	.30	1.34
200 m	2050				.018	.15	1.34
300 m	2135				.0076	.27	1.17
December 20-21							
0 m	2340				.0079	.37	5.36
100 m	2350				.012	.40	1.42
200 m	0005				.0071	.21	3.01
300 m	0025				.0066	.24	1.34
December 21							
0 m	0625				.057	-	5.86
100 m	0617				.099	.30	4.40
200 m	0610				.054	.44	4.44
300 m	0605				.048	.46	4.06

Table 7. Net community productivity (Net P), respiration (R), and gross community productivity (Gross P) for two transects on the West Fringing Reef Flat. Values are expressed as grams O_2 per m^2. The number of observations are given in parentheses for the variables actually measured; other quantities are calculated from the measured variables.

	Outer Transect	Inner Transect
Hourly Net P	.97 (13)	.45 (9)
Hourly R	1.2 (3)	.73 (4)
Hourly Gross P.	2.2	1.2
Daytime Gross P (10-hr day)	22	12
24-hr R	29	18
24-hr Gross P:R	.76	.68

extensive mangrove stand and probably has its metabolism affected by organic material washed out from the mangroves or brought in from upstream (northern) areas. The large standing crop of filter-feeding organisms is probably a reflection of such import of organic materials.

Another noteworthy feature is that the gross productivity values are higher than those for autotrophic reef communities studied elsewhere in the Pacific. However, the West Fringing Reef community has a lower gross productivity than the hetrotrophic Hawaiian reef of Gordon and Kelly (1962). It is clear that the West Fringing Reef has a high metabolic activity sustained in part by energy imported from adjacent communities.

Marine Plants

A total of 68 species of marine benthic plants (Table 8) was collected or observed at the study site. This compared favorably with the 63 species reported previously (Amesbury et al, 1977) at the proposed fish cannery site on Dublon Island. Forty-six species were common to both areas (coefficient of community = 57%). Although this represents considerable diversity, algal cover was generally low, averaging approximately 30-40 percent across the seven transects.

By far the most conspicuous species were the seagrasses. Enhalus acoroides, Cymodocea rotundata, Thalassia hemprichii and Halophila ovalis were interspersed with extensive patches of the green alga Halimeda, of which ten species were recorded along with the red coralline alga, Metagoniolithon. The generally low cover of benthic algae was attributed to the high percentage of sand and general lack of a hard substrate. The aforementioned genera, having large rhizoidal holdfasts or rhizomes, are able to prosper; and these were by far the most abundant.

The proposed fill area south of S-dock was characterized by a fairly wide mangrove band (approximately 50-100 m) adjacent to the shoreline. Rhizophora stylosa was the principle mangrove species. Grading seaward from the mangroves, well developed seagrass beds extended half to three-quarters of the way across the West Fringing Reef. A short rubble and sand zone characterized by a scant turf algal community and a few corals gave way to a margin and slope zone of rich soft coral development.

The histograms presented in Fig. 13 are based on 10 tosses per 5- or 10-m increment along each transect. A summary histogram (Fig. 14) of each transect is also shown. Species were lumped according to three functional groups: turf (algae less than 2 cm high), macroalgae (fleshy, erect), and seagrasses. Two additional groups, sand/rubble and corals, are also depicted. A heavy black line partitions these two groups from the others in the summary histogram. It should also be noted that the summary histogram is of the same format as that used for the Dublon site (Amesbury et al, 1977), thus facilitating comparison.

Table 8. Checklist of marine plants recorded from the vicinity of Transects 1 through 7, proposed fish cannery site, Tol Island, Truk, December 1977. Asterisks indicate those species not observed at the Dublon site. (Amesbury et al., 1977).

SPECIES	TRANSECTS 7	1	2	3	4	5	6
CYANOPHYTA (Blue-Green Algae)							
Anacystis sp.	X	X	X	X	X	X	
Hormothamnion enteromorphoides	X	X	X	X	X	X	
Microcoleus lyngbyaceus	X	XX	XX	X	X	X	X
Schizothrix calcicola	X	X	X	X	X	X	
Schizothrix mexicana	X	X	X	X	X	X	X
CHLOROPHYTA (Green Algae)							
Avrainvillea obscura	X					X	
**Boergesenia forbesii*					X		
Boodlea composita						X	X
Caulerpa brachypus							X
Caulerpa cupressoides				X	X	X	X
Caulerpa filicoides			X	X			
**Caulerpa lentillifera*							X
Caulerpa racemosa	X	X	X	X	X	X	X
Caulerpa serrulata		X	X	X		X	X
**Caulerpa taxifolia*							X
**Caulerpa urvilliana*	X	X	X	X	X		
**Caulerpa verticillata*			XX	X	X	X	
**Chlorodesmis fastigiata*							X
Dictyosphaeria cavernosa		X	X	X	X	X	X
Enteromorpha clathrata	X						
Halimeda cylindracea	X	X	X	X	X	X	X
Halimeda discoidea		X	X	X			X
Halimeda gigas	X	X	X	X	X	X	X
Halimeda incrassata	X	X	X	X	X	X	X
Halimeda macroloba	X	X	X	X	X	X	X
Halimeda macrophysa	X	X	X	X	X	X	
Halimeda micronesica	X	X	X	X	X	X	X
Halimeda opuntia	XX	XX	XX	XX	XX	XX	XX
**Halimeda simulans*					X	X	X
**Halimeda velasquezii*							X
**Neomeris annulata*				X			X
Rhipilia orientalis			X	X	X	X	
Tydemannia expeditionis				X	X	X	X
Udotea argentea	X	X	X	X	X	X	
Udotea geppii							X
**Ulothrix* sp.	X	X					
**Valonia ventricosa*	X	X					

Table 8. continued.

SPECIES	7	1	2	3	4	5	6
				TRANSECTS			
PHAEOPHYTA (brown algae)							
Dictyota bartayresii				X	X	X	X
*Dictyota divaricata				X	X	X	X
Dictyota patens							X
Hydroclathrus clathrata			X	X	X	X	
Lobophora variegata	X	X	X	X	X	X	X
Padina jonesii							X
Padina tenuis	X	X	X	X	X	X	
Rosenvingea orientalis		X					
*Sargassum polycystum							X
Turbinaria ornata		X	X	X	X	X	X
RHODOPHYTA (red algae)							
Actinotrichia fragilis						X	
*Antithamnion sp.							X
Amphiroa foliacea			X	X	X	X	X
Amphiroa fragilissima			X	X	X	X	
*Callithamnion marshallensis		X	X	X	X	X	
Centroceras clavulatum	X	X	X	X	X	X	
Ceramium sp.	X	X	X	X	X	X	X
*Champia parvula	X	X	X	X	XX	X	X
Gelidium divaricatum						X	X
Hypnea pannosa							X
Jania capillacea	X						X
*Metagoniolithon sp.	X	X	X	X	X	X	X
*Neogoniolithon sp.	X	X	X	X	X	X	X
Peyssonelia rubra			X	X	X	X	X
*Polysiphonia scopulorum				X	X	X	X
Porolithon sp.	X	X	X	X	X	X	X
Tolypiocladia glomerulata							XX
ANTHOPHYTA (seagrasses)							
*Cymodocea rotundata	X	X	X	X	X	X	X
Enhalus acoroides	X	X	X	X	X	X	X
Holophia ovalis	X	X	X	X	X	X	X
Thalassia hemprichii	X	X	X	X	X	X	X
NUMBER OF SPECIES PER TRANSECT OR IN IMMEDIATE VICINITY	32	35	39	45	44	46	47
TOTAL NUMBER OF GENERA	45						
TOTAL NUMBER OF SPECIES	68						

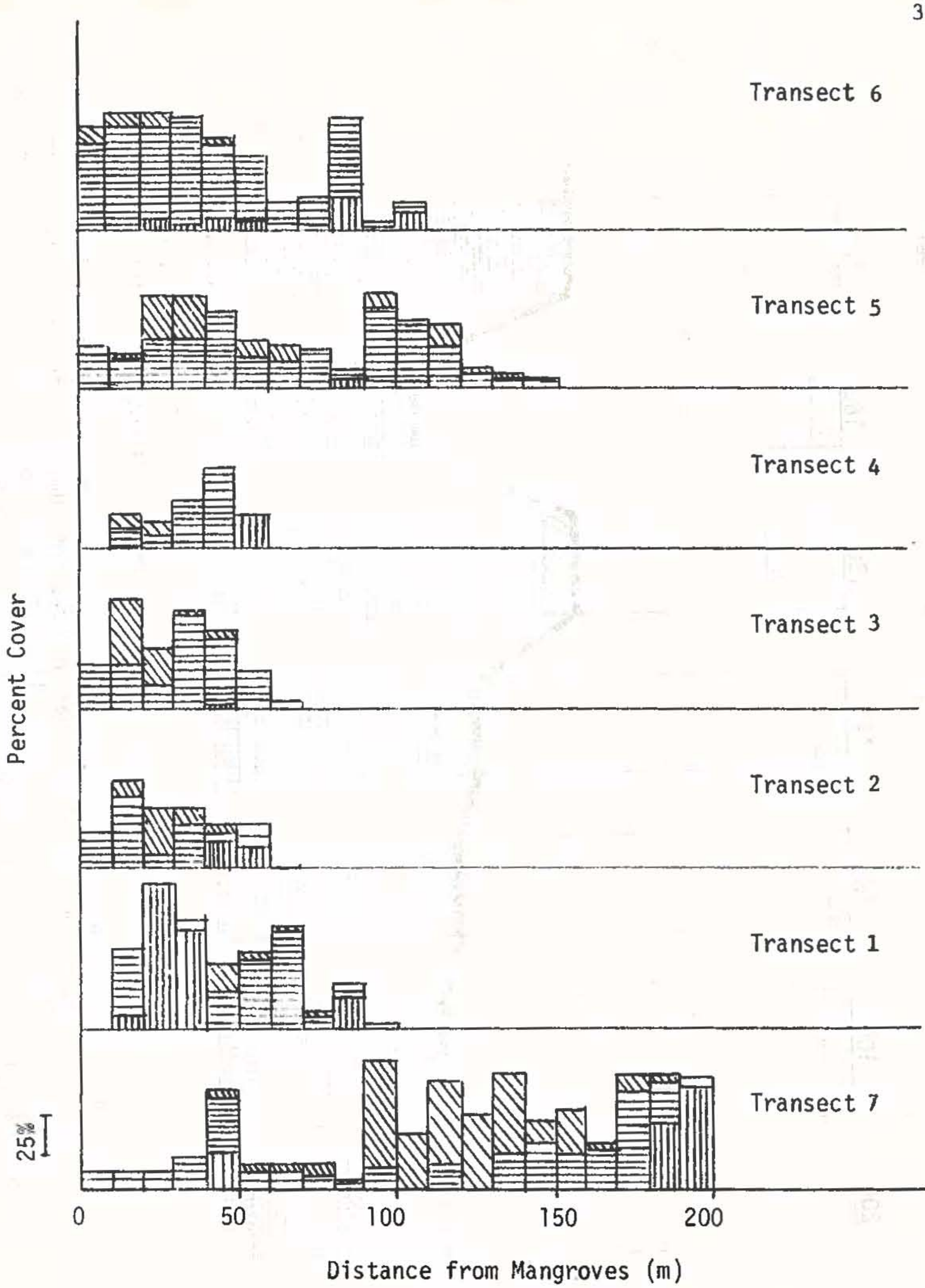

Figure 13. Percent cover of each functional group of marine plants quantified along 10-m segments along seven transects. The number presented above each segment denotes at least 10 tosses on which the analyses are based. Vertical hatching = turf; horizontal hatching = macroalgae; down-right hatching = seagrasses.

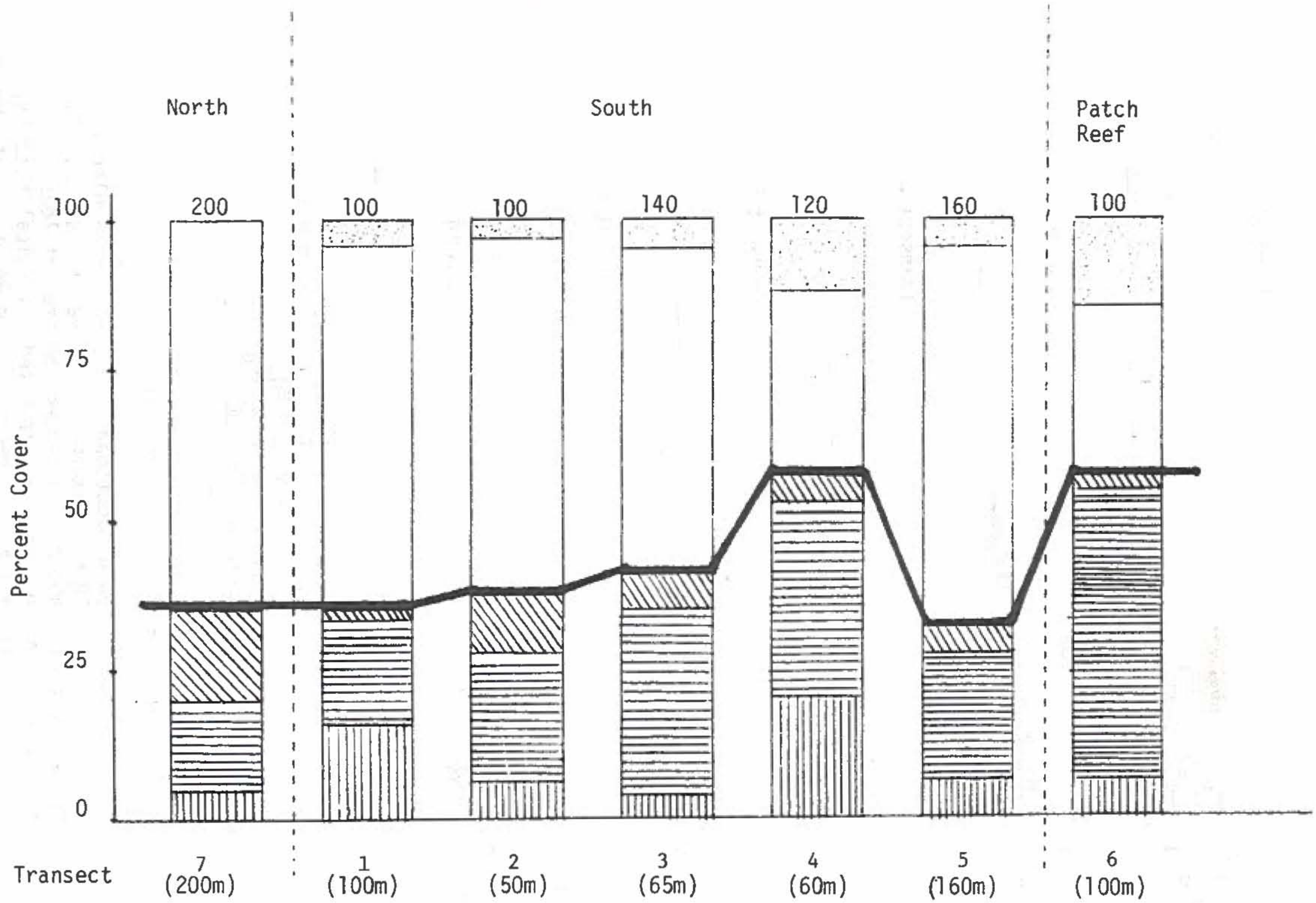

Figure 14. Percent cover of each functional group of marine plants, quantified along the seven transects. The number above each bar denotes the number of tosses on which the analyses are based. The heavy black line separates marine plants from sand and coral. Vertical hatching = turf; horizontal hatching = macroalgae; down-right hatching = seagrass; unshaded = sand/rubble; dotted = coral.

Corals

General Setting

On the basis of overall gross morphology the reefs in the study area can be divided into three principal physiographic divisions consisting of the reef-flat platform, lagoon slope, and lagoon floor. A brief description and a generalized vertical profile (Fig. 2) showing the gross morphology of these divisions are given in the introductory chapter.

In terms of coral distribution some of the three physiographic divisions were further divided into a number of conspicuous zones on the basis of the presence or absence of corals, substrate characteristics, and other dominant communities present. In general each of the zones is characterized by the dominance of hard and soft corals, seagrasses, benthic algae, and a particular type of substrate. The various transects, reef divisions, and zones discriminated are mapped in Fig. 4 and shown in vertical profile in Figs. 15 and 16.

A species list of hard corals along with their relative abundance is compiled in Table 9 for each transect and the size distribution, frequency, density per m^2, and percentage of bottom coverage for hard corals is given for each transect zone in Table 10. Percentage of bottom coverage by soft corals is given for the various transect zones in Table 11.

Transect 1

Three zones were discriminated along this transect, which extends outward from a mangrove fringe to a depth of 5 m on the lagoon slope. The transect is located about 50 m south of S-dock and is 95 m long. Being in the immediate vicinity of S-dock and adjacent to the boat channel, the area shows considerable evidence of physical disturbance.

The innermost part of the reef flat consists of a sand and algal turf zone 31 m wide. Principally because of bottom exposure during low spring tides this zone is devoid of corals. The bottom consists mostly of a plastic sandy mud, intermixed with shell and rock fragments, that is dominated by a low turf of fleshy algae and scattered seagrass patches.

A seagrass and scattered coral zone occupies the outer part of the reef flat from 31 to 78 m. This middle zone is slightly deeper and is dominated mostly by seagrasses, with a few scattered _Porites lutea_ nodules, and small stunted _Pocillopora damicornis_ clumps. Coral density was 1.24 colonies per m^2, coral coverage .13% and average colony size 3.2 cm. No soft corals were encountered along the transect in this zone.

On the outer part of the transect, from 78 to 95 m, a coral zone occupies the upper lagoon slope. The bottom here is mostly sand and rubble with a little mud intermixed in the upper part of the slope, becoming more sandy with increased mud deposition deeper down slope. The most conspicuous community here is the soft corals which occupy 5.3% of the bottom while hard coral coverage accounts for only 39%. Common corals observed were small colonies of Alveopora verrilliana, Pocillopora damicornis, Millepora exaesa, and Porites lutea. Although coral density is the same here (1.24 per m) as in the seagrass and scattered coral zone, the coral coverage of .39% is slightly higher, principally because the average colony size of 6.3 cm was slightly greater.

A total of 16 coral species and 10 genera were recorded from the transect, and when compared to the overall study area it ranks seventh in total species diversity.

Transect 2

Two zones were discriminated along this transect which extends outward from a wide mangrove swamp to a depth of 5 m on the lagoon slope. It is located 100 m south of S-dock and is 50 m long.

A seagrass and scattered coral zone occupies the inner 31 m of the transect of the reef-flat platform. Most of this zone is covered by seagrasses and generally lacks corals because of low tide exposure. A few depressed regions contained some small Porites lutea nodules and small clumps of Pocillopora damicornis. None of these corals however were encountered on the transect line itself. Soft corals were not observed within the zone. The bottom consists mostly of sand and some silt with conspicuous amounts of loose organic detritus on the surface.

The upper lagoon slope, from 31 to 50 m, forms a coral zone along the outer part of the transect. The bottom here is similar to that described for the coral zone at transect 1, but some area is occupied by consolidated reef deposits. Most of the consolidated surface consists of dead Porites microatolls and irregular columnar deposits of soft coral spicule rock. Coral density was 1.35 colonies per m^2, bottom coverage 1.74%, and average colony size 12.1 cm. The most common corals encountered were Goniopora lobata, Porites lutea, Alveopora verriliana, and Millepora exaesa. Although Goniopora lobata did not occur on the transect line proper, it dominated a localized area immediately south of the transect line; and about 35 m south of the transect a large elongate area on the upper lagoon slope, 55 m long and 8 m wide, is completely covered by this species. Although coral diversity, surface coverage, and average colony size was greater here than for the same zone at transect 1, soft corals again dominated the lagoon slope with an overall surface coverage of 9.7%.

A total of 23 coral species and 17 genera were recorded in the general vicinity of the transect. In comparison to the entire study area, transect 2 ranks fifth in total species diversity.

Transect 3

This transect is located 200 m south of S-dock where it extends 70 m outward from a mangrove swamp to a depth of 5 m on the lagoon slope. The transect was divided into a seagrass and scattered coral zone on the reef-flat platform and a coral zone on the lagoon slope.

The reef-flat platform is 47 m wide and consists of seagrass and scattered coral zones. The bottom is composed mostly of sand and silt with some intermixed rubble. Although seagrasses dominate this zone a few stunted colonies of *Pocillopora damicornis* and *Porites lutea* were observed in a depressed pocket that retained water during low tides. Only three colonies were encountered on the transect points, giving an overall coral density of .007 colonies per m^2, bottom coverage of .002% and an average colony size of 5.0 cm. Soft corals were absent from the zone.

The coral zone occupies the upper part of the lagoon slope from 47 to 70 m. The bottom is very irregular with a relief of a meter or more at places. Most of the irregularity results from columnar soft coral spicule rock, dead coral microatolls on the shallower part of the slope and scattered coral knobs and mounds on the deeper part. Soft corals completely dominate the shallower part of the zone and have an overall bottom coverage of 18.7%, while the hard coral coverage is only .191%. Where soft corals are abundant *Millepora exaesa* is the most commonly encountered coral and encrusts the lower part of the soft coral spicule rock columns. *Alveopora verrilliana* and *Goniopora lobata* form various sized clumps over much of the zone, and ramose clumps of *Hydnophora rigida* are conspicuous where the coral zone grades into the seagrass and scattered coral zone on the reef flat. Conspicuous corals on the deeper part of the lagoon slope are ramose patches of *Porites andrewsi*, large rounded heads of *Porites lutea*, and smaller rounded masses of *Goniastrea spectabilis*. Although not abundant, *Favia* species are widely scattered throughout the zone. Overall coral density in the coral zone was .051 per m^2, bottom coverage .191%, and average colony size 17.5 cm. The low coral density and bottom coverage values are a result of competition from soft corals which abundantly cover much of the substrate.

In comparison with the entire study area the transect ranks fourth in species diversity with 29 species and 16 genera being recorded from the general transect area.

Transect 4

This transect is located 300 m north of A-dock at a small reef indentation called the North Embayment. It is 50 m long and divided into two zones.

A seagrass and scattered coral zone occupies the inner 28 m of the transect on the reef-flat platform. A seagrass community dominates most of the zone and no corals were encountered on the transect line, although a few small colonies of Pocillopora damicornis were observed in the general vicinity. The bottom consists of a sand and silt mixture intermixed with Halimeda segments and abundant loose surface organic detritus. Along the mangrove swamp the sediments for a gritty plastic mud.

Along the outer part of the transect, from 28 to 50 m, a coral zone occupies the upper part of the lagoon slope. The surface topography is irregular and similar to that described for the coral zone at transect 3. Soft corals dominate the zone with a surface coverage of 19.2%. In comparison, coral surface coverage was an insignificant .147%, the lowest recorded for the lagoon slope coral zone. The lowest coral density (.047 colonies per m^2) was also recorded from this zone, although the average colony size of 20.0 cm is relatively large for the West Fringing Reef. Soft corals seem to favor the shallower part of the lagoon slope where corals are somewhat cryptic among the basal parts of their spicular rock columns. Millepora exaesa was commonly found encrusting the lower part of these spicule rock columns. Also fairly common in these cryptic habitats were small encrusting patches of Stylocoeniella armata and scattered small rounded Favia amicorum colonies. Although soft corals were still dominant on the deeper part of the lagoon slope, hard corals were more diverse, abundant, and colony size larger than on the shallower upper part. Common corals observed on the deeper slope were Alveopora verrilliana, Porites lutea, Porites (Synaraea) iwayamaensis and Pavona (Polyastra) obtusata.

A total of 17 coral species and 12 genera were recorded in the general vicinity of the transect. In comparison to the entire study area transect 4 ranks sixth in total species diversity.

Transect 5

This transect is located on the north side of the South Embayment about 180 m north of A-dock. Three zones were discriminated along its 160-m length, which extends from a narrow mangrove fringe to a depth of 5 m on the lagoon slope.

The innermost 75 m of the reef-flat platform consists of a seagrass zone. Bottom sediments in this zone are similar to those described for the seagrass and scattered coral zone at transect 3. The zone appears to be mostly exposed during low spring tides. No corals were observed within the general vicinity of the transect.

The outer part of the reef-flat platform, from 75 to 122, consists of the seagrass and scattered coral zone. Seagrasses dominate most of this zone, but become somewhat patchy at the outer portion where rubble patches occupy extensive areas. Sand intermixed with a little silt, rubble, and Halimeda segments is found on the bottom over the remaining part of the zone. Coral density was .021 colonies per m^2, bottom coverage .007%, and average colony size 4.6 cm. These values are somewhat similar to those found in this zone on other West Fringing Reef transects, but the species composition is quite different. A few widely scattered colonies of Acropora, Montipora, and Pavona begin to appear in low depressions along the outer part of this zone. The most conspicuous species were Acropora formosa and Pavona decussata. Other corals observed were Porites lutea, Pocillopora damicornis, and Porites andrewsi.

A coral zone, on the upper part of the lagoon slope, occupies the outer 122 to 160 m of the transect. The bottom consists mostly of large stable coral rubble or consolidated reef deposits in the shallow part of the zone and sand and rubble in the deeper areas. This type of substrate is more favorable for coral development than the predominantly sandy substrates found on the other West Fringing Reef transects. Coral density was 1.16 colonies per m^2, bottom coverage 1.79%, and average colony size 12.0 cm. Although the percentage of coral coverage was higher here than anywhere else along the West Fringing Reef, soft corals dominated the bottom with 6.8% coverage. Soft corals were distinctly more abundant in the shallow parts of the zone and hard corals more abundant in the deeper parts. Except for a single occurrence of Acropora formosa at transect 2 and the rare occurrence of three Montipora species on transect 3 and one on transect 2, this is the first significant presence of these two genera on the West Fringing Reef. Eight species of Acropora and three of Montipora were observed along this transect. Other genera occurring for the first time on West Fringing Reef are Asteropora, Leptoria, Montastrea, Psammocora, Favites, Diploastrea, and Physogyra. This sudden increase in generic and species diversity signalizes the presence of more optimum conditions for coral growth. Of note also is the sudden decrease in soft coral coverage from 19.2% a short distance to the north on transect 4 to 6.8% on this transect. It appears that the less optimum conditions for coral development favor the presence of soft corals. Soft corals were significantly less well developed at transect 6 on the Patch Reef and at transect 8 along more exposed outer lagoon slopes, where greater coral species diversity and bottom coverage occur than at this transect. This might well be the best transect to evaluate the effect of the cannery effluent on the marine environment because of its position downstream of S-dock in the path of the net current flow in the channel and the presence of many coral species that require more optimum environmental conditions.

A total of 66 species and 29 genera were recorded in the general vicinity of the transect. In comparison to the entire study area transect 5 ranks third in total species diversity. Actually there is not significant difference in species diversity between this transect and transect 6 directly across the channel except when dominance is considered. Dominance is considerably higher at the latter locale.

Transect 6

This transect is located on the southwest side of the Patch Reef on a small projecting point north of the West Patch Marker. The northern end of the transect is located on the sandy floor of a shallow terrace. The transect then extends southward up a short lagoon slope and across a reef-flat platform, ending on the lagoon slope of the South Arm channel.

The north lagoon slope consists of a coral and sand zone 18 m wide, covered by extensive patches of *Acropora aspera*. At the bottom of the slope these patches abruptly terminate onto a barren sand-floored terrace about 4 m deep. A few small colonies of *Porites andrewsi* and *Acropora formosa* were scattered in the shallower part of the slope, but none were encountered on the transect itself. Density of the *Acropora aspera* colonies was 1.95 colonies per m^2, bottom coverage 8.27%, and average colony size 16.5 cm, which is, for the most part, considerably higher than the same parameters found on the lagoon slope zones of the West Fringing Reef. The bottom along this zone consists mostly of bioclastic sand with coral-algal rubble. No sediments of terrestrial origin were visually noticed in the sediments. This indicates that the adjacent channel acts as barrier to the transport of sand-sized terrestrial sediments that were a common depositional component along the West Fringing Reef zones.

A coral and rubble zone is developed along the middle part of the transect, 18 to 67 m where the transect crosses the reef-flat platform. Corals were more diverse in this zone, although coral density (.26 colonies per m^2) and bottom coverage (.84%) were considerably lower than that found on the adjacent north lagoon slope zone. The substratum consists of consolidated reef deposits with scattered veneering patches of coarse bioclastic sand and coral-algal rubble. Conspicuous corals in this zone are *Acropora acuminata*, *Acropora formosa*, *Pocillopora meandrina*, and *Pocillopora damicornis*. Shallow water during low tides prevents the development of extensive coral growth in this zone, but even so, the average colony size was 16.2 cm. This was primarily a result of the presence of low, spreading arborescent *Acropora* patches. Toward the south lagoon slope the reef flat is slightly deeper and coral diversity is somewhat greater.

A coral zone occupies the south end of the transect, 67 to 90 m where it extends downward across the upper lagoon slope to a depth of 5 m. Coral diversity and development is considerably greater here than on the north lagoon slope. Large coral knolls and mounds, up to 4 m high and across, are developed on the slope. Some of these consist of single colonies of *Porites (Synaraea) convexa*, *Porites andrewsi*, and *Porites lutea* while others are composed of an aggregate of species. Between coral colonies the bottom is mostly composed of consolidated reef deposits on the upper slope and bioclastic sand and coral-algal rubble on the deeper slope. Extensive coral development extended much farther down the slope than 5 m, but it was not quantitatively analyzed below that depth. Within the zone overall coral density was 1.27 colonies per m^2, bottpm coverage 7.95%, and average colony size 22.8 cm. Except for coral density these values are higher than for any other transect that was quantitatively analyzed. Coral density would be expected to be lower because of the large size of the individual colonies. The most striking differences between this transect and those located on the West Fringing Reef are the large size of the colonies, abundance of Acropora species, the extension of a well developed coral community on the lower lagoon slope, greater bottom coverage, less terrigenous sediment, and less bottom coverage by soft corals.

A total of 67 species and 27 genera were recorded along and within the general vicinity at the transect. In comparison to the overal study area, transect 6 ranks second in species diversity.

Transect 7

This transect is located 20 to 100 m north of S-dock on the broad North Fringing Reef. It is 205 m long and extends from the mangrove zone across a narrow extension of the North Depression and a shallow reef-flat platform to a depth of 4 m on the lagoon slope.

A mud flat zone extends 47 m from the mangrove border across the narrow extension of the North Depression. This zone is about a meter deeper than the adjacent reef-flat platform and has a bottom consisting of black plastic mud intermixed with Halimeda segments. Except for a few scattered patches of algae and seagrass where it grades into the reef-flat, the zone is quite barren of corals and other conspicuous organisms. Deeper parts of the depression were investigated about 200 m north of the transect where several coral patches were observed. One of these patches consisted of a cluster of Porites lutea colonies, one of which was more than a meter in diameter. This large colony size is surprising, considering that visibility in the locality was less than 1 m and soft plastic mud prevailed over the bottom.

A seagrass zone extends from 47 to 177 m across the reef-flat platform. Although no corals were encountered on the transect a few small nodules of Porites lutea and small clumps of Pocillopora damicornis were found in occasional depressed regions which retain water during low tides. The most commonly encountered organism in this zone was a small finger-shaped brown sponge. This brown finger sponge was quantitatively analyzed by using the point-centered technique (see Table 14). The bottom along the entire zone is sand with scattered rubble and silt, the latter increasing toward the mangroves and North Depression.

A scattered coral zone occupies the upper part of the lagoon slope, 177 to 205 m. This zone is located at the seaward end of S-dock and shows evidence of considerable disturbance. Corals were mostly absent along the transect except for a few scattered colonies of Favia amicorum, Favites virens and Porites lutea toward the deeper part of the slope. The bottom consists of a mixture of sand, rubble, and boulders, the latter probably derived from filling and dredging operations along S-dock. Coral density was 1.11 colonies per m^2, bottom coverage .42%, and average colony size 6.7 cm. A few scattered Pocillopora damicornis, Goniastrea spectabilis, and Millepora exaesa colonies were observed along the outer third of the channel on the north side of S-dock.

A total of 7 coral species and 6 genera were observed in the vicinity of the transect, the lowest recorded for any transect.

Transect 8

This transect was evaluated by making a snorkel assessment of the coral communities observed on the outer reef-flat platforms and upper lagoon slopes of North Fringing Reef and the lagoon side and outer channel regions of the Patch Reef (Fig. 4). A quantitative assessment of the coral community along this transect was not made, but visual estimates indicate that in most locations it possesses greater species diversity, bottom coverage and average colony size than any of the more protected transect locations (1-7) on the North and West Fringing Reefs and the west side of the Patch Reef. The major differences in the community structure of corals between transects 1-7 and this transect were the presence of a more diverse coral community on the outer fringe of the reef-flat platform, a greater variance in colony size in all the outer reef zones, and the dominance of Acropora and Montipora species on the upper lagoon slopes. Additionally, extensive regions of the lagoon slope along the southern half of the Patch Reef were covered almost exclusively by arborescent Acropora formosa thickets, (Vertical Profile 8A).

The principal physical differences between this transect and the more protected transects (1-7) were the presence of a distinct steep to vertical faced ledge, at many places on the upper lagoon slope, (Vertical Profile 8B) increased water movement and agitation from waves generated in the long fetch of Truk Lagoon, lower turbidity, less influence from terrestrial sediments and surface drainage from Tol Island, more consolidated reef deposit surface area and a deeper lagoon slope with larger topographical relief features developed upon the surface.

A total of 120 species and 36 genera was observed along this transect. In comparison to the overall study area it shows the greatest diversity. Even though transect 8 covers a much greater reef area than any of the other transects, observations indicated that a comparison of equal areas at any place along its length would most likely reveal a greater species diversity. A total of 36 species were recorded on transect 8 that were not observed on transects 1-7, and only 5 species were present on transects 1-7 that were not found on transect 8. Of the 36 species observed only on transect 8, 22 were Acropora and Montipora species.

Table 9 . List of corals observed along transects 1-8. The following symbols indicate their relative abundance: D=dominant, A=abundant, C=common, O=occasional, and R=rare.

	TRANSECTS							
CORALS	1	2	3	4	5	6	7	8
CLASS - ANTHOZOA								
ORDER - SCLERACTINIA								
SUBORDER - ASTROCOENIINA								
FAMILY - ASTROCOENIIDAE								
Stylocoeniella armada (Ehrenberg)	O	O	O	O	O	C		C
FAMILY - THAMNASTERIIDAE								
Psammocora contigua (Esper)					O	R		O
Psammocora digitata Milne-Edwards and Haime					R	R		O
Psammocora profundacella Gardiner								R
Psammocora samoensis Hoffmeister								R
FAMILY - POCILLOPORIDAE								
Stylophora mordax (Dana)								R
Seriatopora hystrix Dana								C
Pocillopora damicornis (Linnaeus)	O	O	O	O	C	C	R	C
Pocillopora danae Verrill	R		R		O	O		C
Pocillopora eydouxi Milne-Edwards and Haime								O
Pocillopora ligulata Dana					R	R		C
Pocillopora meandrina Dana					O	C		C
Pocillopora (Ramose sp. 1)					R			O
FAMILY - ACROPORIDAE								
Acropora acuminata Verrill					C	C		A
Acropora arbuscula (Dana)								O
Acropora aspera (Dana)						A		A
Acropora complanata (Brook)								O
Acropora cymbicyathus (Brook)								O
Acropora danai (Milne-Edwards and Haime)								O
Acropora formosa (Dana)		R			O	C		A

Table 9. continued

CORALS	TRANSECTS 1	2	3	4	5	6	7	8
FAMILY - ACROPORIDAE (continued)								
Acropora humilis (Dana)								O
Acropora hyacinthus (Dana)					R	O		C
Acropora hebes (Dana)					O	C		A
Acropora hystrix (Brook)								O
Acropora irregularis (Brook)								O
Acropora kenti (Brook)					R	O		O
Acropora nasuta (Dana)					R	C		C
Acropora patula (Brook)					R			C
Acropora polymorpha (Brook)					O	A		A
Acropora reticulata (Brook)								O
Acropora rotumana (Gardiner)								O
Acropora sp. cf. *A. squamosa* (Brook)						R		
Acropora syringodes (Brook)								A
Acropora valida (Dana)								O
Acropora (Ramose sp. 1)								O
Astreopora gracilis Bernard					R			R
Astreopora myriophthalma (Lamarck)					R	R		R
Astreopora (Massive sp. 1)					R			R
Montipora ehrenbergii Verrill								O
Montipora foveolata (Dana)								O
Montipora hoffmeisteri Wells								O
Montipora sp. cf. *M. informis* Bernard								O
Montipora lobulata Bernard			R		O	O		C
Montipora patula Verrill						R		O
Montipora prolifera Bernard					R	O		C
Montipora sinensis Bernard								O
Montipora socialis Bernard					R			O
Montipora trabeculata Bernard								R
Montipora tuberculosa (Lamarck)								O
Montipora venosa (Ehrenberg)					R			
Montipora verrilli Vaughan								O
Montipora verrucosa (Lamarck)								O
Montipora (Glabrous sp. 1)		R	R					
Montipora (Papillate sp. 2)								R
Montipora (Papillate sp. 3)			R					R

Table 9. continued

CORALS	TRANSECTS 1	2	3	4	5	6	7	8
SUBORDER - FUNGIINA								
FAMILY - AGARICIIDAE								
Pavona decussata Dana					O	O		O
Pavona (Polyastra) obtusata (Quelch)		O	O	O	C	C		C
Pavona (Polyastra) venosa Ehrenberg		R						O
Pachyseris rugosa (Lamarck)		R			R	R		O
Pachyseris speciosa (Dana)					R			R
FAMILY - FUNGIIDAE								
Fungia (Verrillofungia) concinna Verrill				O	O			O
Fungia (Ctenactis) echinata (Pallas)						O		O
Fungia (Fungia) fungites (Linnaeus)					O	C		C
Herpolitha limax (Esper)	R	R	R		R			O
FAMILY - PORITIDAE								
Goniopora arbuscula Umbgrove			O			R		O
Goniopora columna Dana						O		O
Goniopora lobata Milne-Edwards and Haime		D	O	O	O	R		R
Goniopora tenuidens (Quelch)		R						O
Porites andrewsi Vaughan	O	O	O	R	A	A		A
Porites annae Crossland					R	O		C
Porites australiensis Vaughan					R	O		O
Porites cocosensis Wells				R	R	R		C
Porites lutea Milne-Edwards and Haime	D	O	C	O	D	D	R	D
Porites murrayensis Vaughan	R				R	R		O
Porites superfusa Gardiner						O		
Porites ? (Massive sp. 1)	R							O
Porites (Synaraea) convexa Verrill			O		C	C		A
Porites (Synaraea) horizontalata Hoffmeister			R			O		O
Porites (Synaraea) iwayamaensis Eguchi				O	C	C		C
Porites (Synaraea) vaughani Crossland						O		O
Alveopora verrilliana Dana	O	C	D	O	O	O		O

Table 9. continued

CORALS	TRANSECTS 1	2	3	4	5	6	7	8
SUBORDER - FAVIINA								
FAMILY - FAVIIDAE								
Favia amicorum (Milne-Edwards and Haime)	R	O	O	O	O	O	R	O
Favia favus (Forskaal)			R			R		R
Favia laxa (Klunzinger)	O	O			O	O		O
Favia matthai Vaughan					O	O		O
Favia pallida (Dana)	R	R	R		R		R	O
Favia rotulosa (Ellis and Solander)		R				O		O
Favia rotumana (Gardiner)			R		R	R		R
Favia speciosa (Dana)			R	R				R
Favia stelligera (Dana)								O
Favites acuticollis (Ortmann)					R			R
Favites fluxuosa (Dana)					R	R		R
Favites russelli (Wells)					R	O		O
Favites virens (Dana)					R		R	O
Goniastrea édwardsi Chevalier					R	R		O
Goniastrea favulus (Dana)			R		R	R		O
Goniastrea pectinata (Ehrenberg)								O
Goniastrea retiformis (Lamarck)								O
Goniastrea spectabilis (Verrill)	O		O	O	O	O	R	C
Platygyra daedalea (Ellis and Solander)					O	R		O
Platygyra lamellina (Ehrenberg)		O				O		O
Leptoria phrygia (Ellis and Solander)					R	R		O
Hydnophora rigida (Dana)	O	O	O		O	O		O
Montastrea curta (Dana)					R			O
Diploastrea heliopora (Lamarck)					R			O
Leptastrea bottae (Milne-Edwards and Haime)	O		R					
Leptastrea purpurea (Dana)		O			R	O		O
Cyphastrea serailia (Forskaal)								O
FAMILY - OCULINIDAE								
Galaxea fascicularis (Linnaeus)			R		R	O		O

Table 9. continued

CORALS	TRANSECTS 1	2	3	4	5	6	7	8
FAMILY - MUSSIDAE								
<u>Lobophyllia corymbosa</u> (Forskaal)					R			O
<u>Lobophyllia costata</u> (Dana)			O			O		O
<u>Lobophyllia hemprichii</u> (Ehrenberg)		R	R			R		O
<u>Symphyllia nobilis</u> (Dana)					R	R		R
<u>Symphillia valenciennesii</u> Milne-Edwards & Haime						R		R
FAMILY - PECTINIIDAE								
<u>Echinophyllia aspera</u> (Ellis and Solanders)								R
<u>Pectinia lactuca</u> (Pallas)		R	R			O		O
SUBORDER - CARYOPHYLLIINA								
FAMILY - CARYOPHYLLIIDAE								
<u>Euphyllia fimbriata</u> (Spengler)				R	R	O		R
<u>Physogyra lichtensteini</u> Milne-Edwards and Haime					R	R		O
SUBORDER - DENDROPHYLLIINA								
FAMILY - DENDROPHYLLIIDAE								
<u>Turbinaria</u> (Foliaceous sp. 1)								O
ORDER - COENOTHECALIA								
FAMILY - HELIOPORIDAE								
<u>Heliopora coerulea</u> (Pallas)								R
CLASS - HYDROZOA								
ORDER - MILLEPORINA								
FAMILY - MILLEPORIDAE								
<u>Millepora dichotoma</u> Forskaal								R
<u>Millepora exaesa</u> Forskaal	O	O	O	D	O	C	D	A
<u>Millepora platyphylla</u> Hemprich and Ehrenberg								R

Table 9. continued

CORALS	TRANSECTS 1	2	3	4	5	6	7	8
ORDER - STYLASTERINA								
FAMILY - STYLASTERIDAE								
Distichopora violacea (Pallas)				R	O	C		C
Distichopora (Orange sp. 1)				R	O	C		C
TOTAL GENERA	10	17	16	12	29	27	6	36
TOTAL SPECIES	16	23	29	17	66	67	7	120
Total Genera for Study Site 36								
Total Species for Study Site 125								

Table 10. Size distribution, frequency, density, and percent of substrate covered by corals on the reef flat and lagoon slope and floor zones at the study site. Relative values of frequency, density, and percent of substrate covered are also given and an importance value is calculated from the sum of these three values. The symbols under "Size Distribution" represent the number of observations (n) and the mean ($\bar{Y}$), standard deviation (s), and range (w) of colony diameters.

CORALS	Size Distribution of Colonies, Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Relative Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover	Importance Value
TRANSECT 1											
Reef Flat 0-31 meters (sand and algal turf zone)											
No corals											
Reef Flat 31-78 meters (sea grass and scattered coral zone)											
Porites lutea	5	2.8	1.8	1-5	.33	42.9	.68	55.6	.06	46.2	144.7
Leptastrea bottae	2	4.0	0.0	4-4	.22	28.5	.28	22.2	.04	30.7	81.4
Stylocoeniella armata	1	5.0	-	-	.11	14.3	.14	11.1	.02	15.4	40.8
Pocillopora damicornis	1	1.0	-	-	.11	14.3	.14	11.1	.01	7.7	33.1
Overall Density 1.24 per m^2											
Percent Substrate Coverage .13%											
Lagoon Slope 78-95 meters (coral zone)											
Porites lutea	1	<8.0	-	-	.25	25.0	.31	25.0	.15	38.5	88.5
Favia amicorum	1	8.0	-	-	.25	25.0	.31	25.0	.14	35.8	85.8
Alveopora verrilliana	1	5.0	-	-	.25	25.0	.31	25.0	.06	15.4	65.4
Porites murrayensis	1	4.0	-	-	.25	25.0	.31	25.0	.04	10.3	60.8
Overall Density 1.24											
Percent Substrate Coverage .39%											

Table 10. continued

CORALS	Size Distribution of Colonies, Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Relative Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover	Importance Value
TRANSECT 2											
Reef Flat 0-31 meters (sea grass and scattered coral zone)											
No corals											
Lagoon Slope 31-50 meters (coral zone)											
<u>Porites lutea</u>	2	15.0	12.7	6-24	.50	33.3	.39	28.5	.94	54.0	115.8
<u>Alveopora verrilliana</u>	3	4.3	1.5	3-6	.50	33.3	.58	42.9	.09	5.2	81.4
<u>Favia pallida</u>	1	9.0	-	-	.25	16.7	.19	14.3	.59	33.9	64.9
<u>Millepora exaesa</u>	1	20.0	-	-	.25	16.7	.19	14.3	.12	6.9	37.9
Overall Density 1.35 per m^2											
Percent Substrate Coverage 1.74%											

Table 10. continued

CORALS	Size Distribution of Colonies, Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Relative Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover	Importance Value
TRANSECT 3											
Reef Flat 0-47 meters (sea grass and scattered corals zone)											
<u>Pocillopora</u> <u>damicornis</u>	1	7.0	-	-	.11	33.3	>.002	33.3	<.001	54.7	121.3
<u>Porites</u> <u>lutea</u>	1	6.0	-	-	.11	33.3	>.002	33.3	<.001	40.6	107.2
<u>Stylocoeniella</u> <u>armata</u>	1	2.0	-	-	.11	33.3	>.002	33.3	<.001	4.7	71.3
Overal Density >.007 per m^2											
Percent Substrate Coverage .002%											
Lagoon Slope 47-70 meters (coral zone)											
<u>Millepora</u> <u>exaesa</u>	2	27.5	7.8	22.33	.40	50.0	.025	50.0	.158	82.7	182.7
<u>Alveopora</u> <u>verrilliana</u>	1	14.0	-	-	.20	25.0	.013	25.0	.020	10.5	60.5
<u>Lobophyllia</u> <u>costata</u>	1	11.0	-	-	.20	25.0	.013	25.0	.013	6.8	56.8
Overall Density <.051											
Percent Substrate Coverage .191%											

Table 10. continued

CORALS	Size Distribution of Colonies, Diameters (cm) n	$\bar{Y}$	s	$\bar{w}$	Frequency	Relative Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover	Importance Value
TRANSECT 4											
Reef Flat 0-28 meters (sea grass and scattered coral zone)											
No corals encountered											
Lagoon Slope 28-50 meters (coral zone)											
Favia speciosa	1	22.0	-	-	.20	50.0	.016	33.3	.061	41.0	124.3
Goniastrea aspera	1	19.0	-	-	.20	50.0	.016	33.3	.044	29.5	112.8
Porites lutea	1	18.9	-	-	.20	50.0	.016	33.3	.044	29.5	112.8
Overal Density .047 per m^2											
Percent Substrate Coverage .149%											

Table 10. continued

CORALS	Size Distribution of Colonies, Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Relative Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover	Importance Value
TRANSECT 5											
Reef Flat 0-75 meters (sea grass zone)											
No corals encountered											
Reef Flat 75-122 meters (sea grass and scattered coral zone)											
Porites lutea	3	6.0	6.1	2-13	.33	60.0	.013	60.0	.006	85.6	205.6
Acropora formosa	1	5.0	-	-	.11	20.0	.004	20.0	<.001	10.4	50.4
Porites cocosensis	1	3.0	-	-	.11	20.0	.004	20.0	<.001	4.0	44.0
Overall Density .021 per m^2											
Percent Substrate Coverage .007											
Lagoon Slope 122-160 meters (coral zone)											
Pavona (Polyastra) obtusata	2	22.0	22.6	6-38	.13	6.0	.106	9.1	.615	34.3	49.4
Acropora acuminata	2	17.0	19.8	3-31	.25	11.6	.106	9.1	.402	22.5	43.2
Pocillopora damicornis	3	10.7	7.1	3-17	.25	11.6	.159	13.7	.184	10.3	35.6
Millepora exaesa	4	4.3	1.3	3-6	.25	11.6	.212	18.3	.032	1.8	31.7
Porites andrewsi	2	8.5	0.7	8-9	.25	11.6	.106	9.1	.060	3.4	24.1
Favia pallida	2	7.0	4.2	4-10	.25	11.6	.106	9.1	.049	2.7	23.4
Pocillopora damae	1	19.0	-	-	.13	6.0	.052	4.5	.147	8.2	18.7
Pocillopora meandrina	2	5.5	2.1	4-7	.13	6.0	.106	9.1	.027	1.5	16.6
Hydnophora rigida	1	16.0	-	-	.13	6.0	.052	4.5	.104	5.8	16.3
Porites lutea	1	14.0	-	-	.13	6.0	.052	4.5	.081	4.5	15.0
Herpolitha limax	1	11.0	-	-	.13	6.0	.052	4.5	.048	2.7	13.2
Goniastrea sp.	1	10.0	-	-	.13	6.0	.052	4.5	.041	2.7	12.8
Overall Density 1.16 per m^2											
Percent Substrate Coverage 1.79%											

Table 10. continued

CORALS	Size Distribution of Colonies, Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Relative Frequency	Density per m^2	Relative Density	Percent of Cover	Relative Percent of Cover	Importance Value
TRANSECT 6 (Patch Reef)											
Lagoon Slope (North Side) - 0.18 meters (coral and sand zone)											
Acropora aspera	13	16.5	17.0	3-61	1.0	100.0	1.95	100.0	8.27	100.0	300.0
Overall Density 1.95 per m^2											
Percent Substrate Coverage 8.27%											
Reef Flat 18-67 meters (coral and rubble zone)											
Acropora acuminata	5	18.8	20.3	4.47	.30	35.0	.08	31.3	.43	51.2	107.5
Pocillopora meandrina	5	10.2	4.7	6.18	.30	25.0	.08	31.3	.08	9.5	65.8
Acropora formosa	2	25.5	21.9	10.41	.20	16.7	.03	12.5	.21	25.0	54.2
Pocillopora damicornis	2	7.0	1.4	6-8	.20	16.7	.03	12.5	.01	1.2	30.4
Porites lutea	1	23.0	-	-	.10	8.3	.02	6.2	.08	9.5	24.0
Montipora lobulata	1	13.0	-	-	.10	8.3	.02	6.2	.03	3.6	18.1
Overall Density .26 per m^2											
Percent Substrate Coverage .84%											
Lagoon Slope (South Side) 67-90 meters (coral zone)											
Porites andrewsi	3	33.0	17.1	15-49	.21	21.2	.27	21.4	2.74	34.5	77.1
Pocillopora damicornis	4	13.3	4.3	8-18	.29	29.2	.36	28.6	.54	6.7	64.5
Porites (Synaraea) convexa	2	39.0	24.0	22-56	.14	14.1	.18	14.3	2.57	32.3	60.7
Porites lutea	1	43.0	-	-	.07	7.1	.09	7.1	1.32	16.6	30.8
Pectinia lactuca	1	27.0	-	-	.07	7.1	.09	7.1	.53	6.7	20.9
Acropora acuminata	1	17.0	-	-	.07	7.1	.09	7.1	.21	2.6	16.8
Fungia echinata	1	7.0	-	-	.07	7.1	.09	7.1	.04	.5	14.7
Stylocoeniella armata	1	3.0	-	-	.07	7.1	.09	7.1	.01	.1	14.3
Overall Density 1.27 per m^2											
Percent Substrate Coverage 7.95%											

Table 10. continued

CORALS	Size Distribution of Colonies, Diameters (cm) n	$\bar{Y}$	s	w	Frequency	Relative Frequency	Density Per m^2	Relative Density	Percent of Cover	Relative Percent of Cover	Importance Value
TRANSECT 7											
Reef Flat 0-47 meters (mud flat zone)											
No Corals											
Lagoon Slope 177-205 meters (scattered coral zone)											
<u>Favia amicorum</u>	1	9.0	-	-	.17	33.3	.37	33.3	.24	57.1	123.7
<u>Favia pallida</u>	1	6.0	-	-	.17	33.3	.37	33.3	.11	26.2	92.8
<u>Porites lutea</u>	1	5.0	-	-	.17	33.3	.37	33.3	.07	16.7	83.3
Overall Density 1.11 per m^2											
Overall Substrate Coverage .42%											
TRANSECT 8											
No Quantitative Data Collected											
See Table for List of Corals Observed											

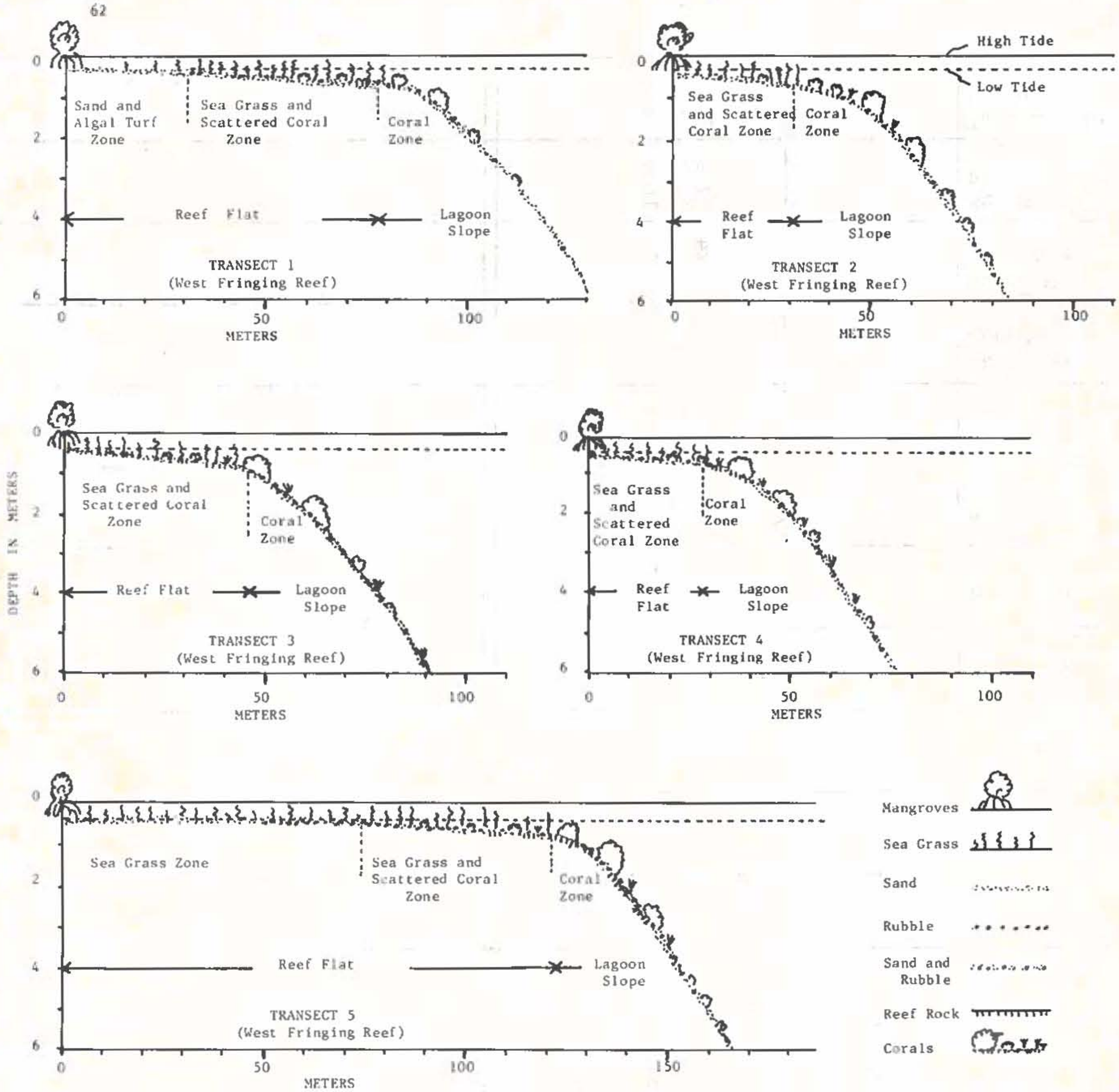

Fig. 15. Vertical profiles of transects 1-5. Vertical exaggeration is X 10.

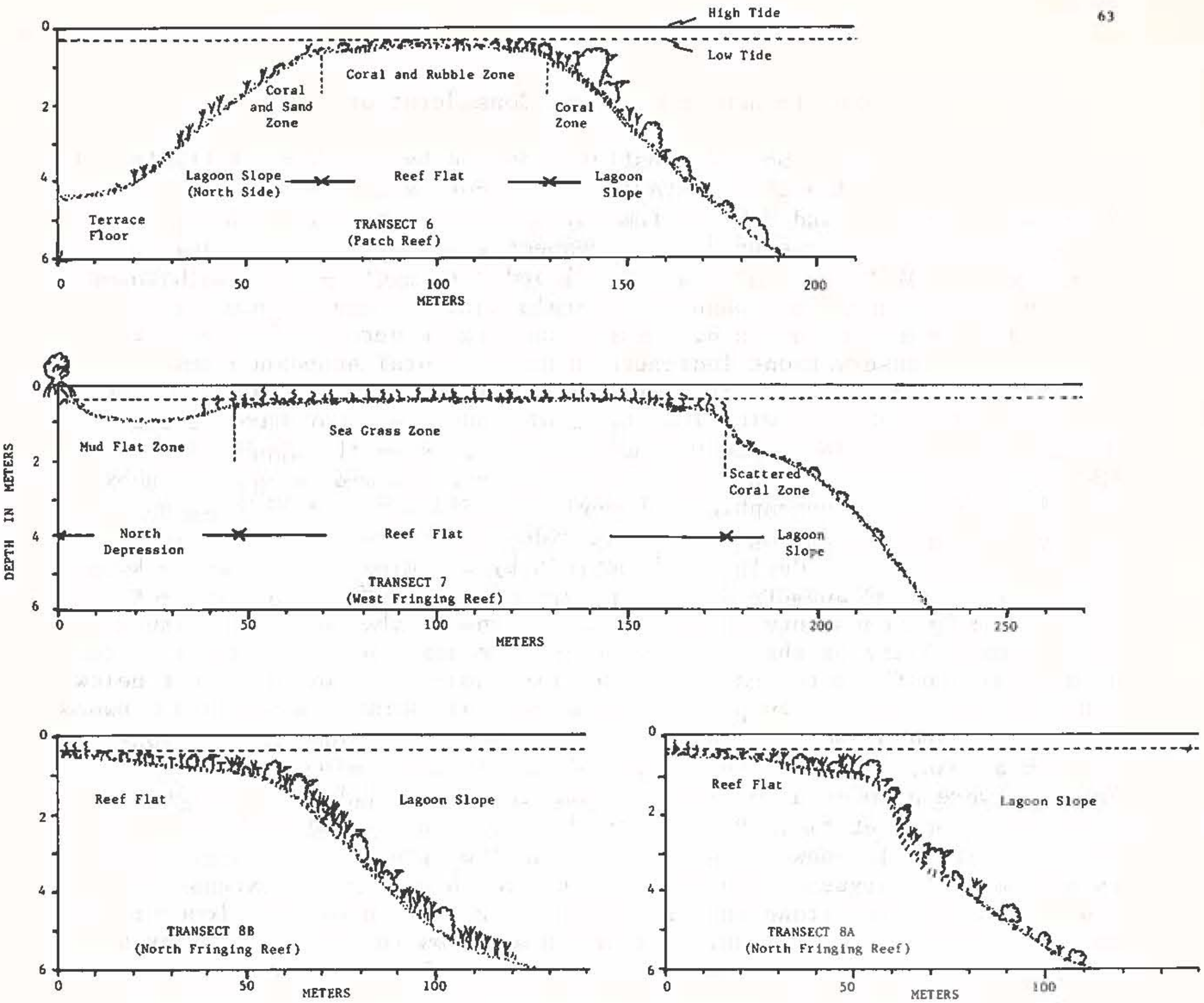

Fig. 16. Vertical profiles of transects 6, 7, 8A, and 8B. Vertical exaggeration is X 10.

Coral Transects: General Considerations

The percentage of bottom substrate covered by soft corals (Table 11) varied indirectly with the coverage by hard corals at most transect locations (Tables 9 and 10). Bottom coverage by soft corals ranged from 18.7% to 19.2% at transects 3 and 4 respectively, with lowest hard coral coverage to 5.3% to 6.8% at transects 1 and 5 respectively, with highest hard coral coverage. Although soft corals were not quantitatively analyzed at transects 6 and 8, where hard coral coverage was considerable greater, observations indicated that soft coral abundance was distinctly lower. It appears that soft corals are able to more successfully colonize habitats with less optimum conditions than hard corals. Optimum soft coral development generally occurred on the upper part of the lagoon slope coral zones, where the colonies formed an upper canopy by colonizing the topographic high regions. These topographic highs are subject to exposure during low spring tides. Soft corals can reduce their overall heights during such periods by becoming flacid, which keeps part of the colony submerged. The polyps of soft corals are also very long, extending deep into the cortical regions of the submerged colony stem. The ability of the soft corals to form this canopy layer relegates hard corals to the more shaded and cryptic habitats of deeper water below. A major exception to this pattern of soft coral dominance was found between transects 2 and 3, where a large colony of _Goniopora lobata_, 55 m long and 8 m across, dominated the upper lagoon slope. Similar _G. lobata_ colonies were also occasionally observed in similar habitats at Dublon Island (Amesbury et al., 1977) and in Ponape (Tsuda et al., 1974). Although little is known of _G. lobata_ adaptive strategy, it is well known that the polyps are quite toxic and capable of great extension, and it may exhibit strong aggressive behavior through extracoelenteric messenterial extension as well. This would allow the coral to favorably compete for space with the soft corals once it become established.

The reefs within the entire study area support a moderately diverse coral community consisting of 125 species and 36 genera. Other fringing reef systems studied in Truk Lagoon have coral communities consisting of 61 species and 26 genera on the west side of Moen Island (Site A), 103 species and 35 genera on the southeast side of Moen Island (Site B), and 32 species and 13 genera on the northeast side of Moen Island (Site C) (See Table 1 in Appendix A). A study of a lagoon fringing reef system on the south side of Dublon Island revealed 102 species and 35 genera (Amesbury et al., 1977). The highest coral diversity for a localized lagoon fringing reef system in Micronesia was found at Malakal Island, Palau, where 163 species and 48 genera were recorded (Birkeland et al., 1977). At all the referenced localities the reefs were located in regions of some previous disturbance and the total species diversity would probably be higher in more pristine habitats.

Fishes

A total of 136 species of fish was recorded within the study area (Table 12). More species were observed on the Patch Reef (110 spp.)

Table 11. Percent substrate covered by soft corals on transects 1-8.

TRANSECT NO.	REEF FLAT PLATFORM	LAGOON SLOPE
1	None encountered	5.3%
2	"	9.7%
3	"	18.7%
4	"	19.2%
5	"	6.8%
6	Soft Corals Not Analyzed	
7	None Encountered	None Encountered
8	Soft Corals Not Analyzed	

than on the fringing reefs (101 spp.), but both areas appeared to be quite diverse.

On the fringing reefs the highest species diversity was encountered near the reef margins, within approximately the last 30% of the transect lengths. Species belonging to the families Pomacentridae (20%), Labridae (16%) and the Lutjanidae (11%) accounted for 47% of the total number of species observed on the transects within this zone. The number of species observed along these transect segments ranged from 11 to 26 ($\bar{X}$ = 19). The most relatively abundant species found were the damselfishes Chromis atripectoralis and Amblyglyphidodon curacao, which normally occurred in dense aggregations around coral outcroppings. Other predominant species seen along the fringing reef margins included the eleotrid Ptereleotris microlepis, the labrids Stethojulis bandanensis and Halichoeres hoeveni, and the acanthurids Acanthurus xanthopterus and Ctenochaetus striatus. Occasionally, mixed schools of Caesio caerulaureus, C. chrysozonus, and small unidentified atherinids were seen in mid-water just outside of the reef margins.

Over the inner segments of the fringing reef transects, 42% of the total number of observed species belonged to the families Labridae (17%) Gobiidae (12.5%), and Acanthuridae (12.5%). The gobiids clearly dominated most of the sand-silt-algae zone between the mangroves and the reef margin. The wrasse Stethojulis bandanensis was also seen as a common resident in this area. Sizable feeding aggregations composed largely of the rabbitfish Siganus spinus were observed only along transect 7, on the north side of S-dock. A mean number of 18 individuals of this species was noted per aggregation, and the largest aggregation seen contained approximately 40 individuals. Associated with healthy algal beds, S. spinus is a popular and easily accessible food fish.

Unlike the fringing reef transects, the patch reef transect (6) ran nearly parallel to the reef margin. Therefore, the observed species diversity was consistently high along most of its length. Nearly 56% of the species seen on this transect were representatives of the following three families: Labridae (27%), Pomacentridae (16%), and Acanthuridae (13%). The species with greatest relative abundances on this transect were the damselfishes Amblyglyphidodon curacao, Chromis atripectoralis, C. caerulea, and Pomacentrus pavo. A school of Caesio caerulaureus was encountered in mid-water just beyond the reef margin south of the West Patch Marker. Also, the labrid Stethojulis bandonensis was found to be common on the shallower parts of the reef.

As stated previously, more species of fish were found on the Patch Reef than on the fringing reefs. Just over 37% of those seen on the Patch Reef were not found on the fringing reefs. Likewise, approximately 34% of the species seen on the fringing reefs were not observed on the Patch Reef. Thus, although the respective faunas for the two reefs are more similar than not, a considerable difference appears to exist. This difference may be partially explained by the manner in which the

Table 12. Checklist and transect counts of fishes observed in the vicinity of the proposed Tol tuna fishery complex. The letters refer to general study site locations; A=North and South Fringing Reefs. B=Path Reef near West Patch Marker. The underlined numerals 1 - 5 and 7 are fringing reef transect numbers. Transect 6 is the Patch Reef transect. Following these are the 10-meter intervals within which fishes were observed, and in parentheses, the number of individuals counted. See Fig. 4 for transect locations.

ACANTHURIDAE (Surgeonfishes)

Acanthurus lineatus (Linnaeus) A; B-6:60-70(1)
A. nigrofuscus (Forskal) A-1:70-80(1); B-6:60-70(5)
A. pyroferus Kittliz A-7:170-180(2)
A. triostegus (Linnaeus) A-4:110-120(1); B-6:60-70(3)
A. xanthopterus (Cuvier & Valenciennes) A-1:70-80(1), 80-90(5), 90-95(5) A-3:50-60(4); A-4:70-80(1), 130-140(3), 140-140(2), 150-160(1); A-7:170-180(2), 190-205(1); B-6:50-60(1), 60-70(1), 70-80(1), 80-90(3)
Ctenochaetus striatus (Quoy & Gaimard) A-2:30-40(2); A-3:50-60(2), 60-70(2); A-4:120-130(1), 140-150(3), 150-160(5); B-6:50-60(4), 60-70(6), 70-80(3)
C. xanthrum (Blythe) A-3:40-50(1)
Naso brevirostris (Cuvier & Valenciennes) A; B
Zebrasoma scopas (Cuvier) B-6:60-70(1)
Z. veliferum (Bloch) A-2:30-40(1); A-3:50-60(1); A-4:140-150(2); B-6:80-90(2)

APOGONIDAE (Cardinalfishes)

Apogon aroubiensis Hombron & Jacquinot A-4:120-130(1); B
A. aureus (Lacepede) A-2:30-40(2)
A. leptacanthus Bleeker B-6:80-90(12)
A. novemfasciatus Cuvier & Valenciennes A-1:90-95(3); A-2:30-40(2); A-3:50-60(1), 60-70(2); A-5:30-40(3), 40-50(2); B-6:50-60(1)

ATHERINIDAE (Silversides)

Unidentified atherinids A-1:70-80(60); A-4:90-100(15); A-7:180-190(25)

BALISTIDAE (Triggerfishes)

Balistapus undulatus (Mungo Park) A-1:90-95(1); B
Pseudobalistes viridescens (Bloch & Schneider) A-7:180-190(1)
Rhinecanthus acculeatus (Linnaeus) A-3:30-40(1)
Sufflamen chrysopterus (Bloch & Schneider) A-5:40-50(1); B

BLENNIIDAE (Blennies)

Exallias brevis (Kner) B
Meicanthus atrodorsalis (Gunther) A-1:70-80(1); A-3:50-60(1), 60-70(2); B-6:60-70(1), 80-90(1)

Table 12. continued

Plagiotremus rhynorynchus (Bleeker) A; B
Unidentified blenniids A-4:130-140(2); A-7:10-20(7), 190-205(1)

BOTHIDAE (Left-eye Flounders)

Bothus mancus (Broussonet) A-7:70-80(1)

CANTHIGASTERIDAE (Sharp-back Puffers)

Canthigaster bennetti (Bleeker) A-4:80-90(1)
C. solandri (Richardson) A-3:60-70(2); A-7:0-10(1)

CARANGIDAE (Jacks)

Caranx melampygus Cuvier A-1:80-90(1); A-4:150-160(1); B-6:60-70(1)

CARCHARHINIDAE (Requiem Sharks)

Carcharhinus albimarginatus (Ruppell) A
C. melanopterus (Quoy & Gaimard) B
C. menisorrah (Muller & Henle) A

CENTRISCIDAE (Shrimpfishes)

Aeoliscus strigatus (Gunther) A

CHANIDAE (Milkfishes)

Chanos chanos (Forskal) A-2:10-20(1)

CHAETODONTIDAE (Butterflyfishes)

Chaetodon auriga Forskal A-1:50-60(1), 60-70(1); A-2:30-40(1); A-3:40-50(1); A-4:130-140(1); A-7:170-180(1), 180-190(1); B-6:10-20(2)
C. ephippium Cuvier & Valenciennes A; B-6:0-10(2)
C. citrinellis Cuvier & Valenciennes A-3:60-70(1); A-4:130-140(1); B-6:60-70(1)
C. kleini Bloch A; B-6:10-20(1)
C. lineolatus Cuvier & Valenciennes A-2:30-40(1)
C. lunula (Lacepede) A
C. melanotus Bloch & Schneider B
C. plebius Cuvier & Valenciennes B
C. rafflesi Bennet B
C. semeion Bleeker B
C. trifascialis Quoy & Gaimard A; B
C. trifasciatus Mungo Park A; B-6:60-70(1), 70-80(1)
C. ulientensis Cuvier A; B
C. unimaculatus Bloch B
C. vagabundus Linnaeus A; B
Heniochus acuminatus Linnaeus A
H. chrysostomus Cuvier & Valenciennes A; B-6:60-70(1)

Table 12. continued

ELEOTRIDAE (Sleepers)

Ptereleotris microlepis Bleeker A-2:40-50(8); A-5:40-50(3); A-7:190-205(15)

FISTULARIDAE (Coronetfishes)

Fistularia petimba Lacepede B

GOBIIDAE (Gobies)

Amblygobius albimaculatus (Ruppell) A-4:40-50(1), 50-60(1), 80-90(2); A-7:0-10(2), 60-70(1), 80-90(1); B-6:0-10(1)

A. phaelena (Cuvier & Valenciennes) A-1:40-50(2), 50-60(2), 60-70(7), 70-80(4), 80-90(2); A-2:20-30(2), 30-40(2), 40-50(2); A-3:20-30(1), 40-50(3); A-7:170-180(2), 180-190(7), 190-205(2)

Unidentified gobiids A-1:40-50(2), 50-60(8), 60-70(7); A-2:10-20(4), 20-30(8), 30-40(5), 40-50(6); A-3:10-20(5), 20-30(12), 30-40(9), 40-50(7), 50-60(8), 60-70(3); A-4:20-30(2), 30-40(1), 40-50(2), 50-60(1), 60-70(2), 70-80(2), 80-90(2), 90-100(3), 100-110(2), 130-140(2), 140-150(1), 150-160(2); A-7:0-10(12), 10-20(10), 20-30(2), 30-40(6), 40-50(8), 50-60(9), 60-70(8), 70-80(5), 80-90(7), 90-100(1), 100-110(2), 110-120(3), 120-130(2), 130-140(2), 140-150(4), 150-160(7), 160-170(8), 170-180(3), 180-190(4), 190-205(6); B-6:0-10(1), 10-20(2), 20-30(2), 30-40(3), 40-50(2)

HOLOCENTRIDAE (Squirrelfishes)

Adioryx diadema (Lacepede) A

A. spinnifer (Forskal) A

Flammeo sammara (Forskal) A-4:120-130(1); B

Myrpristis murdjan (Forskal) A; B

Myrpristis sp. B

KYPHOSIDAE (Rudderfishes)

Kyphosus cinerascens (Forskal) A

LABRIDAE (Wrasses)

Cheilinus chlorourus (Bloch) A-1:80-90(1); A-5:30-40(1); B-6:60-70(2)

C. fasciatus (Bloch) B-6:80-90(1)

C. trilobatus Lacepede A-1:50-60(1), 80-90(1); A-2:30-40(1); A-4:130-140(1); B-6:20-30(2), 50-60(1), 60-70(1), 80-90(2)

Cheilinus sp. B

Gomphosus varius Lacepede B-6:50-60(1), 60-70(3)

Table 12. continued.

Halichoeres hoeveni (Bleeker) A-1:70-80(1), 90-95(2); A-2:30-40(2); A-3:50-60(2), 60-70(3); A-4:120-130(1), 140-150(4), 150-160(1); A-5:20-30(1), 30-40(2); B-6:0-10(2), 40-50(2), 50-60(3), 80-90(3)
H. margaritaceus (Cuvier & Valenciennes) A-4:110-120(1), 120-130(2) 130-140(4); B-6:60-70(1)
H. marginatus Ruppell A-4:120-130(1); B-6:50-60(2)
H. trimaculatus (Quoy & Gaimard) B-6:0-10(3), 40-50(2)
Hemigymnus melapterus (Bloch) B-6:50-60(1), 60-70(2)
Hologymnosus semidiscus (Lacepede) A-3:50-60(1); B-6:40-50(2), 50-60(1)
Labrichthys unilineata Bleeker B
Labroides dimidiatus (Cuvier & Valenciennes) A; B-6:80-90(2)
Macropharyngodon meleagris (Cuvier & Valenciennes) B
Stethojulis bandanensis (Bleeker) A-1:50-60(3), 70-80(1); A-3:50-60(5); A-4:30-40(1), 40-50(1), 50-60(2), 70-80(2), 80-90(5), 90-100(1), 110-120(1), 120-130(8), 130-140(4), 140-150(2), 150-160(2); A-5:20-30(5), 30-40(2); A-7:170-180(3), 180-190(1); B-6:0-10(2), 10-20(6), 20-30(5), 30-40(2), 40-50(5), 50-60(1)
S. strigiventer (Bleeker) A-3:50-60(2); B-6:10-20(1), 30-40(1), 40-50(3), 50-60(3)
Thalassoma amblycephalus (Bleeker) A
T. hardwickei B-6:60-70(1)
T. janseni (Bleeker) B
T. lutescens (Lay & Bennett) B
T. quinquevittata (Lay & Bennett) B
Thalassoma sp. B-6:40-50(3), 50-60(2), 60-70(2)

LUTJANIDAE (Snappers)

Caesio caerulaureus Lacepede A-4:150-160(30); B-6:80-90(50)
C. chrysozonus Cuvier & Valenciennes A-1:90-95(5)
Gnathodentex aureolineatus (Lacepede) A-3:60-70(1); B
Lutjanus fulvus (Bloch & Schneider) A-7:190-205(2); B-6:0-10(2)
L. monostigmus (Cuiver & Valenciennes) A-7:110-120(2); B
L. semicinctus (Quoy & Gaimard) A; B
L. vaigiensis (Quoy & Gaimard) A-1:40-50(1), 60-70(1), 70-80(2); A-7:0-10(1), 130-140(3), 140-150(1); B
Monotaxis grandoculus (Forskal) A-1:80-90(3), 90-95(4); A-5:30-40(1); B-6:70-80(2), 80-90(2)
Scolopsis cancellatus (Cuvier & Valenciennes) B-6:20-30(2), 30-40(1), 50-60(2), 60-70(5)

MONACANTHIDAE (Filefishes)

Oxymonacanthus longirostris (Block & Schneider) B

MULLIDAE (Goatfishes)

Mulloidichthys samoensis (Gunther) A-2:40-50(2); A-7:130-140(2), 140-150(1), 150-160(5), 160-170(4); B-6:40-50(1)

Table 12. continued.

Parupeneus barberinus (Lacepede) A-1:30-40(1); B
P. bifasciatus (Lacepede) B
P. trifasciatus (Lacepede) A-2:30-40(1); A-4:130-140(3), 150-160(1); A-5:30-40(1); B-6:0-10(3)

MURAENIDAE (Moray eels)

Gymnothorax sp. A

OSTRACIONTIDAE (Boxfishes)

Ostracion cubicus Linnaeus A; B

POMACANTHIDAE (Angelfishes)

Centropyge bicolor (Bloch) A
C. vrolicki (Bleeker) B

POMACENTRIDAE (Damselfishes)

Abudefduf coelestinus (Cuvier) A; B
A. sordidus (Forskal) A
Amblygliphidodon curacao (Bloch) A-1:70-80(4), 90-95(6); A-2:30-40(3); A-3:50-60(2); A-4:130-140(4), 150-160(2); A-5:30-40(1); A-7:180-190(3), 190-205(2); B-6:0-10(5), 50-60(2), 60-70(7), 70-80(27)
Amphiprion melanopus Bleeker B
A. perideraion Bleeker B
Chromis atripectoralis Welander & Schultz A-1:80-90(7), 90-95(35); A-4:140-150(16), 150-160(14); B-6:60-70(12), 80-90(65)
C. caerulea Cuvier B-6:80-90(35)
C. margaritifer Fowler A-1:90-95(5); A-4:150-160(3); B
Dascyllus aruanus (Linnaeus) A-1:70-80(1); B-6:0-10(1), 80-90(4)
Eupomacentrus albifasciatus (Schlegel & Muller) A-4:120-130(2), 130-140(4); B-6:50-60(1)
E. lividus (Bloch & Schneider) A-4:140-150(1), 150-160(1); B-6:70-80(4)
E. nigricans (Lacepede) A-2:30-40(2); A-4:140-150(3); B-6:50-60(2), 60-70(2), 70-80(2), 80-90(3)
Glyphidodontops biocellatus (Quoy & Gaimard) B
G. leucopomus (Lesson) A-5:50-60(3); B
Plectroglyphidodon lacrymatus (Quoy & Gaimard) B
P. leucozona (Bleeker) A-3:40-50(1); A-4:80-90(2), 110-120(2), 120-130(7), 130-140(5); B-6:0-10(3), 20-30(3), 30-40(1), 40-50(5), 50-60(1)
Pomacentrus moluccensis Bleeker A-2:30-40(1); A-3:50-60(1), 60-70(1); A-5:30-40(4), 40-50(1); B
P. pavo (Bloch) A-4:140-150(5); A-5:40-50(4); A-7:180-190(10); B-6:0-10(4), 70-80(5), 80-90(45)
P. tripunctatus Cuvier B
P. vaiuli Jordon & Seale A-4:140-150(3); B

Table 12. continued.

SCARIDAE (Parrotfishes)

Bolbometopon muricatus (Cuvier & Valenciennes) B
Scarops rubrioviolaceus (Bleeker) B
Scarus ghobban Forskal A-2:40-50(1); B
S. scaber (Cuvier & Valenciennes) B-6:80-90(4)
S. sordidus Forskal B-6:0-10(1), 50-60(1)
S. troscheli Bleeker A; B
S. venosus Bleeker B-6:80-90(2)
Unidentified scarids A-2:30-40(1); B-6:0-10(7), 50-60(9), 60-70(3), 80-90(2)

SCORPAENIDAE (Scorpionfishes)

Pterois volitans (Linnaeus) A

SERRANIDAE (Groupers)

Epinephalus caeruleopunctatus (Bloch) B
E. megachir (Richardson) A
E. merra Bloch A-1:90-95(1); A-7:180-190(1); B
Cephalopholis miniatus (Forskal) B
Variola louti (Forskal) B

SIGANIDAE (Rabbitfishes)

Siganus puellus (Schlegel) A; B-6:60-70(1)
S. spinus (Linnaeus) A-7:130-140(20), 140-150(8), 150-160(44), 160-170(22), 170-180(3)
S. virgatus (Cuvier & Valenciennes) A; B-6:60-70(1)
S. vulpinis (Schlegel & Muller) A; B

SPHYRAENIDAE (Barracudas)

Sphyraena barracuda (Walbaum) A

SYGNATHIDAE (Piperfishes)

Corythoichthys schultzi Herald A; B-6:60-70(1)

SYNODONTIDAE (Lizardfishes)

Synodus variegatus (Lacepede) A

TETRAODONTIDAE (Pufferfishes)

Arothron hispidus (Linnaeus) A

ZANCLIDAE (Moorish idols)

Zanclus cornutus (Linnaeus) B-6:60-70(1)

TOTAL NUMBER INDIVIDUALS COUNTED ON TRANSECTS = 1430
TOTAL NUMBER FAMILIES OBSERVED = 34
TOTAL NUMBER SPECIES OBSERVED = 136

transects were laid out, perpendicular to the reef margin on the fringing reef and generally parallel to the margin on the patch reef. However, a more likely explanation is the different physical and biological characteristics of each type of ecological unit. Yet, in general, both reefs appears to support rich fish faunas which may be interpreted as indicative of flourishing community situations.

Macroinvertebrates

Sponges, soft corals (Alcyonacea), bivalves (Ostreidae and Spondylidae), corallmorpharia, hydroids, and the ascidian tunicate Didemnum ternatanum were common throughout the study area (excluding the mangrove zone). See Table 13 for checklist of macroinvertebrates.

The most prevalent fauna occurring on the fringing reefs were sponges. A minimum of fourteen larger distinctive types, both in growth form and color, were frequently observed. The mangrove and adjacent mud flat zones contained scattered sponges, usually limited to small or cryptic types. The predominant sponges associated with the seagrass or seagrass-Halimeda zone was a creeping stolonform type, characterized by upright finger-like projections and ranging in color from tan to orange-brown. A density of 3.4 brown finger sponges per m^2 was measured for the seagrass zone of transect 7 (Table 14). The brown finger sponge appeared to have a similar density in the seagrass zone of the West Fringing Reef.

The predominant organisms occurring in the mangrove zone were an intertidal snail, Cerithium sp., the edible oyster Saxostrea mordax, and a snapping shrimp of the family Alpheidae.

The cushion star Culcita novaeguinea frequented the upper channel slopes and outer fringing reef margins. The urchins Toxopneustes pileolus and Tripneustes gratilla were common in the seagrass-Halimeda zone of the North Fringing Reef. Three species of crinoids, Comanthus bennetti, C. schlegeli, and Comaster multifidus, were observed along outer fringing reef margins. The cryptic or noturnal habits of crinoids prevented an accurate accounting. Twelve species of holothurians (sea-cucumbers) were distributed throughout the study area. Generally, the largest populations were in the seagrass beds and along the fringing reef margins.

Few organisms were observed along the West Arm channel below ca. 10 m. The most conspicuous fauna were sponges, the small oyster Lopha cristagalli, the large jagged tooth oyster Dendostraes hyotis, the pearl oyster Finctada margaritifera, hydroids, soft corals, and sea whips (Antipatharia).

Table 13 . List of macroinvertebrates on fringing and patch reefs. The numbers in parentheses represent the approximate number of unidentified species observed. The gastropods include both living and dead specimens.

PORIFERA

Sponge spp. (14)

CNIDARIA
- Hydrozoa
  - *Physalia* sp.
  - Hydroid sp.
- Scyphozoa
  - *Cassiopeia* sp.
  - *Aurelia* sp.
- Anthozoa
  - Actiniaria
    - unidentified spp. (2)
  - Alcyonacea
    - Alcyoniidae
      - *Lobophytum* sp.
      - *Sarcophyton* sp.
      - *Sinularia* sp.
    - Nephtheidae
      - unidentified spp. (3)
    - Xenidae
      - *Xenia* sp.
      - unidentified sp.
  - Antipatharia
    - unidentified sp.
  - Corallimorpharia
    - unidentified sp.
  - Zoanthiniaria
    - Zoanthidae
      - *Zoanthus pacificus* Walsh and Bowers

NEMATODA

unidentified sp.

ANNELIDA
- Polychaeta
  - Sabellidae
    - unidentified spp. (3+)

MOLLUSCA
- Cephalopoda
  - *Ocotpus* sp.
- Gastropoda
  - Bursidae
    - *Bursa* sp.
  - Cassidae
    - *Casmaria erinaceus* Linnaeus

Table 13. continued

Cerithiidae
- Cerithium nodulosum (Bruguiere)
- Cerithium sp.*

Conidae
- Conus capitaneus Linnaeus
- Conus coronatus Gmelin
- Conus flavidus Lamarck
- Conus imperialis Linnaeus
- Conus litteratus Linnaeus
- Conus magus Linnaeus
- Conus marmoreus Linnaeus
- Conus miles Linnaeus
- Conus cf. obscurus Sowerby
- Conus pulicarius Hwass (in) Bruguiere
- Conus rattus Hwass
- Conus cf. sanquinolentus Quoy and Gaimard
- Conus cf. vexillum Gmelin

Cypraeidae
- Cypraea annulus Linnaeus
- Cypraea arabica Linnaeus
- Cypraea argus Linnaeus
- Cypraea histrio Gmelin
- Cypraea lynx Linnaeus
- Cypraea mauritiana Linnaeus
- Cypraea moneta Linnaeus
- Cypraea tigris Linnaeus
- Cypraea vitellus Linnaeus

Fasiolariidae
- Latirus sp.

Fissurellidae
- unidentified sp.

Littorinidae
- Littorina sp.

Mitridae
- Mitra cucumerina Lamarck
- Mitra litterata Linnaeus
- Mitra variabiles Reeve
- Strigatella sp.
- Vexillum plicarium Linnaeus

Muricidae
- Boreotrophon tenisculptus (Carpenter)
- Chicoreus sp.
- Morula sp.
- Thais sp.

Nassariidae
- Parcanassa sp.

Naticidae
- Mamilla opaca (Recluz)

Neritidae
- Nerita sp.

Table 13. continued

Olividae
Oliva sp.
Potamididae
Terebralia sulcata Brugiere
Strombidae
Lambis (Lambis) lambis Linnaeus
Strombus (Conomurex) luhuanus Linnaeus
Strombus (Gibberulus) gibberulus Linnaeus
Terebridae
Terebra maculata Linnaeus
Terebra subulata Linnaeus
Trochidae
Euchelus sp.
Trochus (Trochus) niloticus Linnaeus
Vasidae
Vasum sp.

Bivalvia
Chamidae
Chama sp.
Isognominidae
Isognomon sp.
Limidae
Mantellum orientalis (Adams and Reeve)**
Mytilidae
Malleus albus (Lamarck)
Ostreidae
Dendostraes hyotis (Linnaeus)
Lopha crista-galli (Linnaeus)
Saxostrea mordax (Gould)
Pinnidae
Atrina (Atrina) vexillum (Born)
Pinna muricata Linnaeus
Pteriidae
Pinctada margaritifera (Linnaeus)
Spondylidae
Spondylus barbatus Reeve
Spondylus ducalis Roeding
Spondylus spp. (2)
Tridacnidae
Hippopus hippopus (Linnaeus)
Tridacna gigas (Linnaeus)***
Tridacna maxima (Roeding)
Tridacna squamosa Lamarck

ARTHROPODA

Crustacea
Alpheidae
unidentified sp.
Diogenidae
Dardanus guttatus (Oliver)
Dardanus megistos (Herbst)
Dardanus scutellatus (H. Milne Edwards)

Table 13. continued

Parthenopidae
Daldorfia horrida Linnaeus
Pontoniinae
unidentified sp.

ECHINODERMATA
Asteroidea
Acanthasteridae
Acanthaster planci (Linnaeus)
Ophidiasteridae
Linckia laevigata (Linnaeus
Oreasteridae
Culcita novaeguineae Muller and Troschel
Ophiuroidae
unidentified sp.
Echinoidea
Brissidae
Brissus latecarinatus (Leske)
Diadematidae
Diadema sp.
Echniothrix sp.
Laganidae
Laganum laganum (Leske)
Toxopneustidae
Toxopneustes pileolus (Lamarck)
Tripneustes gratilla (Linnaeus
Holothuroidea
Holothuriidae
Bohadschia argus Jaeger
Bohadschia marmorata Jaeger
Holothuria (*Halodeima*) *atra* Jaeger
Holothuria (*Halodeima*) *edulis* Lesson
Holothuria (*Thymiosycia*) *hilla* Lesson
Holothuria (*Thymiosycia*) *impatiens* (Forskal)
Stichopodidae
Stichopus chloronotus Brandt
Stichopus variegatus Semper
Synaptidae
Euapta godeffroyi (Semper)
Synapta maculata (Chamisso and Eysenhardt)
unidentified species
sp. 1 (black and yellow rings)
sp. 2 (large solid mustard colored, smooth)
Crinoidea
Comanthus bennetti (Muller)
Comanthus schlegeli (Carpenter)
Comaster multifidus (Muller)

Table 13. continued

CHORDATA
- Ascidiacea
  - *Ascidia gemmata* Sluiter
  - *Didemnum* (*Didemnum*) *moseleyi* (Herdman)
  - *Didemnum ternatanum* Gottschaldt
  - unidentified sp. (2+)

*abundant in mangrove area
**common under clumps of *Halimeda opuntia* (L.) Lamx.
***eroded values

Table 14. Size distribution, frequency and coverage of brown finger sponge along transect 7.

	Size Distribution of Colonies, Diameter (cm) n	$\bar{Y}$	s	w	Frequency	Relative Frequency	Density Per m^2	Percent Cover	Relative Percent Cover	Importance Value
Reef Flat, 0-47 meters (mud flat zone)										
No sponges encountered										
Reef Flat, 47-177 meters (seagrass zone)										
Brown finger sponge	91	2.42	1.29	1-6	.96	100	3.41	.20	100.0	300.0
Overall density 3.41 per m^2										
Overall substrate coverage .20%										
Lagoon Slope, 177-205 meters (scattered coral zone)										
No sponge encountered										

Foraminifera

The benthic and planktonic foraminiferal species recorded for the study site are generally consistant with the lagoonal fauna recorded for Bikini Atoll (Cushman, Todd, and Ruth, 1954). However, considerably fewer species were recorded for the Tol site. Thirty benthic and 11 planktonic species were identified (Table 15). The 20-m channel sample, collected away from the West Fringing Reef slope in oozy channel sediments, showed the greatest species diversity. The predominate genus, in terms of both species and abundance, was Quinqueloculina.

The most conspicuous foraminiferan was Marginopora vertebralis. This species was extremely abundant on the North Fringing Reef and periphery of the Patch Reef. It had limited occurrence on the West Fringing Reef. Large aggregates of living M. vertebralis were frequently observed in clumps of Halimeda opuntia, found in the clearer waters of the North Fringing Reef and Patch Reef. Individuals were observed to be firmly attached and usually oriented horizontal to the substratum. The larger specimens, some up to 2 cm, were usually attached higher in the H. opuntia clumps. Individuals of all sizes tended to be aggregated on the northeastern edges of the H. opuntia clump. This was especially true of clumps found on the eastern portion of the North Fringing Reef. Since M. vertebralis feeds on minute plankton, it would be positioned in the clump to face the oncoming water mass. Therefore, this aggregation behavior suggests that water movement across the reef flat is typically from the northeast.

Other species found in relative abundance in the study site were Amphistegina lessonii, Homotrema rubrum, Heterostegina depressa, and Quinqueloculina seminulum.

Planktonic foraminifera were a minor component of the collected zooplankton (Table 16). The number of individuals per cubic meter of water filtered ranged from 0.18 to 1.37. Species were recorded in all tows, with the highest occurences in the night tows. Globigerina cf. eggeri and Globigerina bulloides were the predominant planktonic species. Tretomphalus planus was quantified in four tows and observed in all tows except the two West Arm tows. According to Johnson (1954) T. planus is endemic to lagoon environments, and as a result it can be useful as an index of past oceanographic conditions of the atoll.

Zooplankton

Zooplankton abundance was low in the study area, as revealed in both day and night net tows (Table 16). The total density of planktonic organisms varied from 23 to 43 individuals per m^3 for day samples and from 82 to 284 individuals per m^3 for night samples. These densities are considerably less than those found in similar lagoon environments elsewhere in Micronesia: 318 plankters per m^3 in daytime tows and 425-1585 per m^3 in night tows at Apra Harbor, Guam (UGML, 1977), 617

Table 15. Benthic and planktonic Foraminiferida. Planktonic species were in the zooplankton tows. See Fig. 3 for sample locations.

	PATCH REEF	CHANNEL 14-20 m	NORTH REEF	WEST REEF
BENTHIC				
Marginopora vertebralis Blainville	X	-	X	X
Marginopora vertebralis Blainville var plicata Dana	X	-	X	X
Sorites marginalis (Lamarck)	X	-	X	X
Peneroplis pertusus (Forskal)	X	-	-	-
Textularia pseudogramen Chapman & Parr	X	X	X	-
Elphidium advena (Cushman)	X	X	-	X
Amphistegina lessonii d'Orbigny	X	X	X	X
Acervalina inhaerens Schultze	X	-	X	X
Homotrema rubrum (Lamarck)	X	X	X	X
Gypsina plana (Carter)	X	-	X	X
Cycloclypeus carpenteri Brady	-	X	-	-
Spiroloculina cf. communis Cushman & Todd	X	X	-	-
Spiroloculina cf. rotunda d'Orbigny	-	X	-	-
Heterostegina depressa d'Orbigny	X	X	X	X
Heterostegina cf. curva Moebius	-	X	-	-
Operculina ammonoides (Gronovius)	-	X	-	-
Quinqueloculina seminulum (Linnaeus)	X	X	X	X
Quinqueloculina bradyana Cushman	X	X	-	X
Quinqueloculina parkeri (Brady)	X	X	-	-
Quinqueloculina cf. amygdaloides (Brady)	-	X	-	-
Quinqueloculina cf. samoaensis Cushman	-	X	-	-
Quinqueloculina cf. bidentata d'Orbigny	X	X	-	X
Quinqueloculina sp.	-	X	-	-
Haverina involuta Cushman	-	X	-	-
Cornuspira involvens Cushman	-	X	-	-
Triloculina cf. oblonga (Montagu)	X	X	-	X
Triloculina sp.	-	X	-	-
Cibicides sp.	-	X	-	-
Miliolinella sp.	X	X	-	-
Nonion sp.	X	X	-	X

PLANKTONIC

- Globigerina cf. eggeri Rhumbler
- Globigerina bulloides d'Orbigny
- Globigerina sp.
- Globorotalia sp.
- Globigerinoides sp.
- Orbulina universa d'Orbigny
- Tretomphalus planus Cushman
- Bolivina sp.
- Planorbulina sp.
- Rosalina sp.
- Acervulina cf. inhaerens Schultze

plankters per m^3 in daytime tows off Ebeye, Kwajelein Atoll (Amesbury et al., 1975a), and 413-710 plankters per m^3 in daytime tows at Tanapag Harbor, Saipan (Amesbury and Doty, 1977). The densities are generally less but more comparable to daytime tows off Dublon, Truk Atoll (Amesbury et al., 1977) (Table 17). The Dublon samples ranged from 24 to 90 plankters per m^3. Although the zooplankton densities were generally higher for the Dublon samples, the diversity was less. Additional zooplankters found in the Tol samples but not in the Dublon samples were mysids, gastropods, radiolarians, echinoderm larvae, stomatopods, polychaete larvae, ostracods, and Lucifer.

The major zooplankton components in common between Dublon and Tol samples were copepods, larvaceans, fish eggs, and foraminifera. The number of fish eggs per m^3 was higher for the Dublon samples. Fish larvae were found in all the Tol samples, ranging from 1.2 to 2.8 per m^3. Fish larvae were found in only one Dublon sample at a density of 0.42 per m^3.

The night-time catches in the North Arm and West Arm tows were considerably greater than daytime catches, 9 and 11 fold, respectively. The night-time catch in the South Arm was double that of the daytime catch. The density of plankton encountered in the North Arm catch was reduced by a factor of 3.5 after moving across the Patch Reef. Copepods were reduced from 155 per m in the North Arm to 30 per m in the South Arm. Additionally, there were fewer predatory chaetognaths, crab zoeae and megalopas, larvaceans, Lucifer and mysids in the South Arm catch. The limited amount of data makes it impossible to ascertain if this was an actual predation reduction in numbers of plankton or merely a sampling artifact.

The zooplankton community in the study area can be considered a lagoonal assemblage, as indicated by the presence of the lagoon endemic foraminiferan Tretomphalus planus.

Table 16. Abundance of zooplankton collected in the vicinity of the study area. Abundance is expressed as number of organisms per cubic meter of water filtered. See Fig. 5 for locations of the tows.

	NIGHT			DAY			
	1 NORTH ARM	2 WEST ARM	3 SOUTH ARM	4 REEF MARGIN	5 NORTH ARM	6 WEST ARM	7* SOUTH ARM
Copepods	155.19	189.75	29.81	11.45	6.53	6.74	7.59
Mysids	21.10	22.26	13.82	1.84	3.87	0.95	4.50
<u>Lucifer</u>	20.28	9.16	9.96	1.87	1.61	0.39	0.41
Larvaceans	25.11	18.95	11.86	2.30	9.65	7.89	7.00
Crab zoeae	25.79	24.92	6.44	2.20	4.23	2.09	11.51
Crab megalopas	7.86	2.17	0.61	0.21	0.64	0.51	2.41
Chaetognaths	5.38	2.54	1.08	0.73	1.51	1.53	2.14
Fish eggs	1.66	1.65	2.78	1.19	1.57	1.97	1.55
Fish larvae	2.21	1.53	1.08	0.08	0.14	0.39	0.50
"Shrimp" larvae**	1.38	5.35	1.69	0.08	0.24	0.64	0.32
Medusae	0.97	1.02	0.27	0.21	0.37	0.25	0.68
Pteropods	0.55	0.26	0.07	0.05	0.24	0.45	0.82
Gastropods	1.66	0.26	0.27	0.26	0.46	0.06	0.82
Foraminiferida	0.85	0.65	1.37	0.14	0.55	0.18	0.56
Globigerina eggeri	-	0.13	0.34	0.10	0.19	-	0.04
Globigerina bulloides	-	0.13	0.27	0.02	0.15	-	0.13
Globigerina sp.	0.14	0.13	0.07	-	-	0.12	-
Globoratalia sp.	0.29	0.13	0.55	-	-	0.06	0.04
Globigerinoides sp.	-	-	0.07	-	-	-	-
Orbulina universa	0.14	0.13	0.07	-	0.06	-	-
Tretomphalus planus	0.14	-	-	0.02	0.15	-	0.13
Bolivina sp.	-	-	-	-	-	-	0.04
Planorbulina sp.	0.14	-	-	-	-	-	0.18
Radiolarians	6.07	0.51	-	0.05	0.18	0.06	0.50
Echinoderm larvae	0.42	-	0.14	0.08	0.27	0.12	0.55
Stomatopods	1.79	1.40	0.07	0.08	0.19	-	0.13
Polychaete	-	0.13	0.07	-	0.06	-	-
Ostracods	-	0.26	-	-	-	0.25	-
Egg mass	0.42	-	-	-	-	-	0.13
Miscellaneous	1.24	0.64	0.21	-	0.06	0.45	0.41
Total Plankton/m^3	279.93	283.30	81.61	22.93	32.35	24.91	42.57
Total Volume Displaced (ml)	16.90	13.60	12.50	6.60	9.00	9.80	7.75
Volume/m^3 (ml)	0.221	0.164	0.080	0.049	0.118	0.118	0.050

*Heavy agregate content

**This category includes all non-crablike zoeae and/or larvae

Table 17. Comparison of selected daytime planktonic organisms collected at Dublon (Amesbury et al., 1977) and Tol Islands, Truk. Abundance is expressed in number of organisms per cubic meter of water filtered.

	OUTSIDE FRINGING REEF		ADJACENT TO FRINGING REEF			
	TOL-4	DUBLON-2	DUBLON-1	TOL-5	DUBLON-4	TOL-6
Copepods	11.45	27.50	12.50	6.53	20.42	6.74
Larvaceans	2.30	16.67	6.67	9.65	25.42	7.89
Crab zoeae	2.20	3.75	-	4.23	0.42	2.09
Chaetognaths	0.73	3.75	-	1.51	-	1.53
Fish eggs	1.19	8.33	3.33	1.57	5.00	1.97
Fish larvae	0.08	0.42	-	0.14	-	0.39
"Shrimp" larvae*	0.08	5.00	-	0.14	1.25	0.64
Foraminifera	0.14	1.25	0.83	0.55	0.42	0.18
Medusae	0.21	0.83	-	0.37	0.42	0.25
Total Number/m^3	22.93	67.92	24.17	32.35	53.33	24.91
Volume/m^3 (ml)	0.049	0.020	0.022	0.118	0.017	0.118

*This category includes all non-crablike zoeae and/or larvae.

SUMMARY AND CONCLUSIONS

Water movement is generally southwestward on the North Fringing Reef and the Patch Reef and southward on the West Fringing Reef. It is generally southward in the surface and deeper layers of the channel; but there can be intermittent reversals, as seen on one rising tide during the course of our study.

The substratum in the mangrove area consists of deep deposits of fine, silty ooze with high organic content. Sediments on the West Fringing Reef are composed of larger particles and show high anaerobic activity, and suspended sediments accumulating in traps on that reef have high percentages of organic matter. The channel bottom consists of unstable silty ooze; and the Patch Reef has clean, coarse-grained sediments.

Water salinity is close to normal oceanic levels in the study area, and nitrate and phosphate levels are low and characteristic of unpolluted systems. Gross community productivity on the West Fringing Reef is high but is supported partially by the import of organic matter from adjacent communities.

Both hard and soft corals are restricted primarily to the outer fringe of the reef-flat platforms and upper lagoon slopes. Seagrasses and benthic algae dominate the remaining parts of the reef-flat platforms, occupying 25-50% of the substrata on most transects surveyed. Seagrasses are by far the most conspicuous plant species. The lower lagoon slopes and lagoon floors are primarily depositional zones where the sediment accumulation rate is high; and corals are widely scattered, patchy, or absent.

Coral diversity, density, size distribution, and percentage of substratum covered varies considerably between transects. Highest diversity occurs along the outer, more exposed parts of the North Fringing Reef and the exposed eastern and southern sides of the large Patch Reef. Conditions for coral growth deteriorate rapidly from the exposed outer edge of North Fringing Reef along the North Arm channel to S-dock and then generally improve southward along the edge of the West Fringing Reef. On the Patch Reef corals are mostly absent along the sandy terrace south of the North Patch Marker and adjoining the West Arm channel. Coral density and percentage of substratum coverage vary directly with coral diversity at most transect locations.

Other organisms are diverse and abundant. There is a rich fish fauna indicative of a thriving natural community. The large number of filter feeders, particularly sponges, is a noteworthy feature of the macroinvertebrate assemblages. Foraminiferans and zooplankton are generally characteristic of lagoonal assemblages, although there is a relatively low abundance of zooplankton.

Overall, development of the proposed fishery complex will result in the permanent loss of approximately 47,000 m^2 of mangrove area and approximately 41,000 m^2 of additional fringing reef flat (Fig. 17). Assuming a uniform depth in the fill area of -1 m, and further assuming that a total fill to 3 m above the existing substratum level (2 m above mean low water) will be required, we can estimate that at least 264,000 m^3 of fill material will be necessary. We understand that this material is to be dredged from the North Fringing Reef in an area adjacent to S-dock. The total dredge area will depend upon the type of dredging operation, and the depth to which dredging takes place.

Filling operations on the West Fringing Reef and dredging on the North Fringing Reef will result in the suspension of large quantities of sand-to-clay-sized particles. The coarser sand fraction will settle in the vicinity of the construction activities. The finer silt and clay fractions will be transported by the prevailing currents to outlying areas. This silt-clay suspension can cause considerable stress on biological communities. The circulation patterns observed in this study indicate that dredging and filling operations will profoundly affect the biological communities on the western Patch Reef, southern North Fringing Reef (in the vicinity of the North Arm Marker), North and South Embayments, and portions of the South Fringing Reef (Fig. 17). The faunal communities in the North and South Arm channel floors will probably remain in much the same state as at present.

If disruption occurs from increased sedimentation in outlying areas, it is probable that a faunal community similar to the present one will become reestablished in time. The amount of silty ooze currently found in the West Arm channel will be greatly increased, thereby providing a long-term source of unstable sediments. As a result, it is unlikely that an extensive faunal community will be able to reestablish in this area. The anticipated major siltation or sedimentation zone is shown in Fig. 17. The boundary is, of course, only an approximation since exact predictions cannot be made. It is not expected that the northern portion of the North Fringing Reef, eastern portion of the Patch Reef, and southern portion of the South Fringing Reef will be heavily affected by sedimentation. If minor sedimentation occurs in these areas, the biological communities will probably be able to accommodate to the stress with little or no damage.

Currents and tidal flushing in the channel are probably of sufficient magnitude to provide a reasonable dilution and dispersion of treated cannery wastes when the proposed facility becomes operational. This, of course, depends upon the magnitude of the operation itself and the volume of discharge, factors for which we have no quantitative estimates. We would anticipate that any power-plant discharge, particularly waste heat, would be sufficiently dispersed quickly enough that there would be only a very localized effect. Additional information from the developer will be required when the plans are more specific.

The Scope of Work for this study calls for a comparison of the environmental impact of the Dublon Fishery site and the Tol Fishery site in terms of temporary and permanent physical and biological damage. The Dublon project would require the filling of an estimated 5,000 m^2 of marine habitat with material derived from a terrestrial site, while the Tol project would involve the filling of approximately 88,000 m^2 and substantial dredging of additional marine habitat. This consideration alone makes it clear that the impact of the Tol project on the marine environment would be considerably greater than the impact of the Dublon project. The Dublon project would involve no loss of mangrove area, whereas the loss of an extensive, relatively unaltered mangrove area would result from the proposed Tol project. Mangrove swamps are generally considered to be important nursery areas for fish and crustaceans, although evaluation of this consideration specifically for the Tol site is considerably beyond the scope of the present study. There are large expanses of mangrove swamps on Tol, and the area lost through the proposed fishery project would be a small percentage of the total. Both proposed projects would involve permanent loss of natural fringing reef flat communities, but this would be much more extensive on Tol. The impact of construction-related sedimentation on adjacent fringing reef flat communities would also probably be greater on Tol. This study and an earlier one (Amesbury et al., 1977) indicate that coral and plant diversity are similar at the two sites, but considerably more fish species were observed at the Tol Site (136 spp.) than at the Dublon Site (ca. 65 spp.).

Because the proposed Dublon site is adjacent to a wide, deep channel with strong currents, its water-circulation and dispersion characteristics are better than the Tol site, which nevertheless has moderate water-circulation and dispersion characteristics of its own. We would expect that temporary siltation stress caused by construction would be less severe at the Dublon site and that long-term impact caused by discharge of cannery wastes and power-plant effluent would also be less severe at that site (assuming that all discharges would be at some depth in Takeshima Channel). The proposed Tol site, however, is not entirely unreasonable; and we realize that there are other considerations besides the impact on the marine environment.

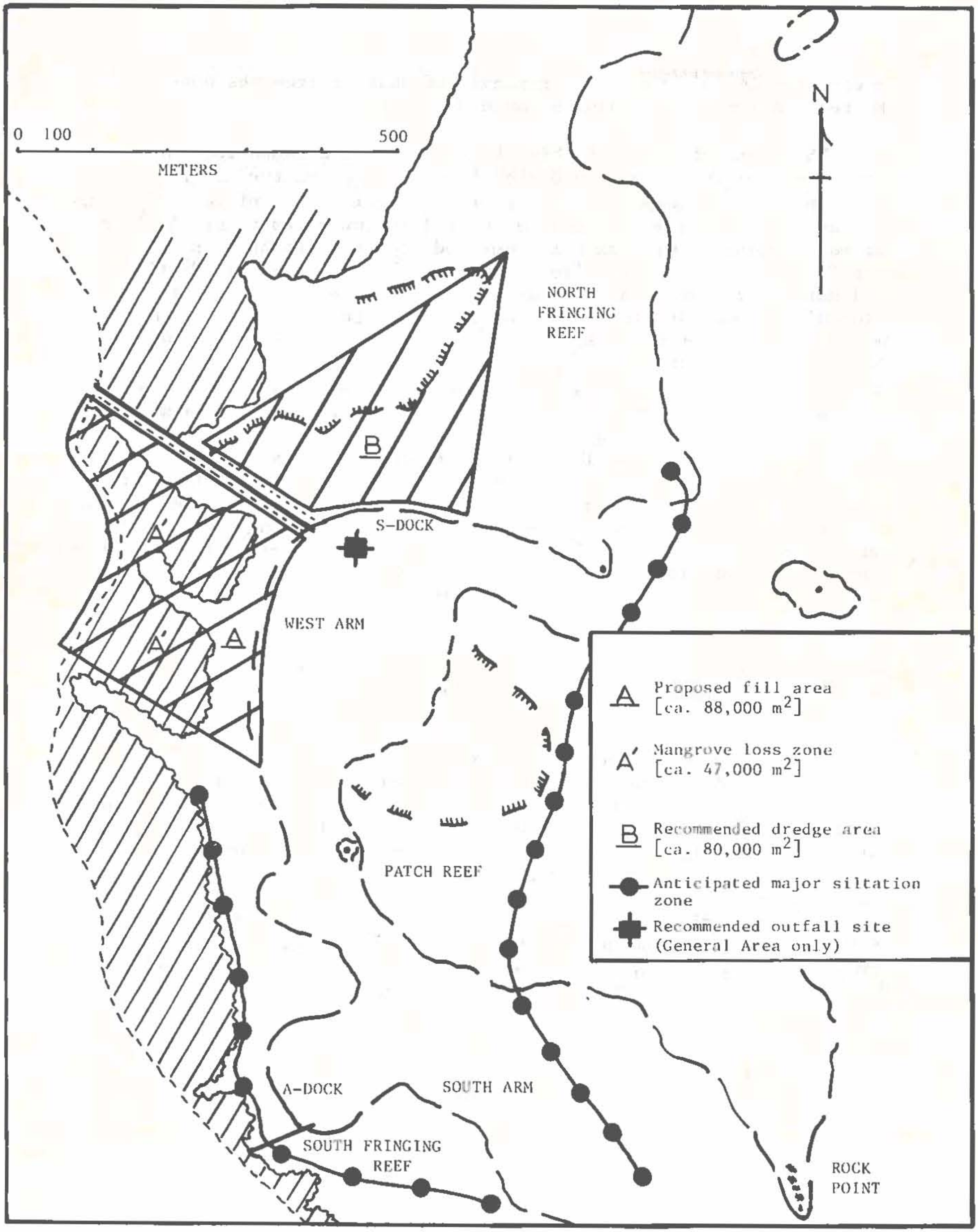

Fig. 17. Proposed fill area, mangrove loss zone, recommended dredge area, proposed outfall diffuser location, and anticipated major siltation zone for proposed cannery site, Tol Island. The area calculations and boundaries are rough approximations.

RECOMMENDATIONS

Rough calculations of the amount of fill material required for the proposed project were presented in the last section. If this material comes from the North Fringing Reef, a large area will have to be dredged. Recommended approximate boundaries for the dredge area are presented in Fig. 17. These boundaries will allow a sufficient amount of material to be dredged and will confine the operation to an area adjacent to S-dock which is of relatively low biological diversity and already partially disturbed. There are economic advantages in that this will allow dredged material to be moved a minimal possible difference and will allow the use of the dredged area next to the dock for some ship operations. This will also protect the outer, most biologically diverse part of the North Fringing Reef, since it will be upstream of the dredge area. Sediments suspended in the water by the dredging will be carried into areas that are subject to fill or other disturbance anyway.

On the basis of water circulation patterns and the need to minimize biological stress, all liquid wastes from the proposed operation should be directed into an outfall placed off the end of S-dock in the West Arm channel (Fig. 17). The outfall should terminate in a diffuser structure, which should preferably be placed on the channel floor. This should confine the effects of the outfall wastes primarily within the West Arm channel, where water mass exchange will provide maximum dilution and mixing of the effluent.

It would be advisable to conduct a water quality monitoring program during construction activities and after normal operations begin. Of primary concern during construction would be turbidity levels in the North and South Arms of the channel. The focus after normal operations begin should be on suspended solids and oils and grease. Additional monitoring of temperature, salinity, coliform bacteria counts, dissolved oxygen, biological oxygen demand, pH, nitrate-nitrogen, and orthophosphate would be desirable but probably not necessary unless experience dictates otherwise.

The possibility of oil spills should be of particular concern at all times. A contingency plan to deal with even small spills should be developed and periodically updated. Immediate clean-up of any spills that do occur should be a requirement that is rigorously enforced. It is likely that such spills would cause the most severe of any long-term stresses associated with operation of the proposed fishery complex.

It appears as if much of the proposed fill area is planned for housing or other uses that are not marine-related. Such things as development of docks obviously necessitate some disturbance and sacrifice of the marine environment, but there are other activities that might better be developed without massive dredging and filling operations. However, from the standpoint of protecting the environment it is probably more desirable to fill a larger fringing reef area such as that proposed than to string out development projects along an extended stretch of relatively undisturbed mangrove shoreline, and we realize that the availability of naturally level land area is limited on Tol. In any case, a reevaluation of the proposed project with the idea of reducing the large area to be filled would probably be in order.

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APPENDIX A

DESCRIPTION OF THREE FRINGING REEF SITES ON MOEN ISLAND, TRUK LAGOON

Reconnaissance snorkel observations were made at three sites on the fringing reefs of Moen Island, Truk, to evaluate the reef communities as potential dredge sites to obtain fill materials. The locations of these sites are shown in Figure A-1.

Site A - Fringing Reef at Memorial Church on the West Side of Moen Island

The lagoon fringing reef at this site is characterized by a shallow reef-flat platform that extends outward 130 to 150 m from the shoreline to the lagoon slope. The lagoon slope is a narrower region, 20 to 40 m wide, which dips gently or moderately downward to a relatively flat sandy lagoon floor at 5 to 8 m (Fig. A-2).

The water throughout the area was remarkably clear. Four imaginary marine plant transects were traversed using snorkel gear; and three distinct zones were recognized: a mangrove/seagrass band, a transition zone of low relief corals in which _Caulerpa_ and _Halimeda_ species dominated the algal components (and sea cucumbers were common), and finally, an _Acropora/Halimeda_ zone in which the majority of algal species were seen. The area appears to be both rich and diverse with respect to marine plants. Table A-1 gives a checklist of the marine plants observed at this site.

Scattered clumps of mangrove trees and seagrass beds dominate the inner half of the reef flat. The seagrass beds are not continuous, but form a mosaic pattern of distribution with sand and rubble occupying the open places between the patches. Except for a few scattered _Porites lutea_ and tiny (<5 mm dia.) _Stylaraea punctata_ colonies, corals are absent from the inner reef-flat platform. Low tides expose much of this part of the reef flat; this factor restricts coral growth to low depressed regions retaining water. A brown finger sponge is abundant on the sandy substrates in both the seagrass beds and open sandy areas.

The outer half of the reef-flat platform becomes more rubbly with less sand, is deeper and retains water during low tide, and is more abundantly covered by both reef-building and soft corals. Arborescent _Acropora formosa_ (staghorn coral) thickets dominate the outer part of the reef flat at places, and small ramose clumps of the corals _Psammocora contigua_, _Pocillopora damicornis_, and _Porites cocosensis_ are scattered about where the outer reef flat grades into the shallower seagrass beds toward the shore. At other places _Porites lutea_ dominates the outer part of the reef flat.

The lagoon slope has greater coral substrate coverage and diversity than any other part of the fringing reef. Large individual massive corals up to 3 m in diameter give the lagoon slope much of its irregular relief. The upper crest of the slope supports the richest coral growth, particularly in corymbose and arborescent colony forms of various Acropora species. Large massive Porites lutea and columnar Porites (S.) convexa and Porites (S.) iwayamaensis dominate the lower slope. Encrusting Montipora species and soft corals also cover extensive regions of the slope.

On the lagoon floor the substrate becomes sandier and coral growth becomes scattered and patchy. Except for a few mounds of Porites lutea the coral community is more variable and less easily characterized by a few dominant species. Physogyra and Goniopora colonies with their large expanded polyps were conspicuous in the shaded recesses where the lagoon floor grades into the lower part of the lagoon slope.

A total of 61 species of corals representing 26 genera was recorded while snorkeling along the length of three transects that crossed the fringing reef at this locality (Table A-2). This number could perhaps be increased slightly by additional searching within the area between the transects, but it is doubtful that more than 70-75 species occur here.

Fish observations were made across the whole shallow reef-flat platform and part of the lagoon slope on a random swim. A total of 55 species belonging to 13 families was observed at this site (Table A-3). It is felt that further inspection may increase this count by approximately 20 species primarily by the inclusion of those species which are more cryptic or wandering in lifestyle.

Site B - Fringing Reef on the Southeast side of Moen Island

The lagoon fringing reef at this site consists of a shallow reef-flat platform about 200 to 250 m wide and a narrow lagoon slope 10 to 30 m wide which dips moderately-to-steeply downward to a flattened lagoon floor 5 to 8 m deep (Fig. A-2). The reef-flat platform can be divided into a wide inner depressed zone, which at low tide is a meter or more deep in the middle part, and a narrow outer part which is partly exposed during low tide. Considerable variation is found in the physiography of the upper lagoon slope, which may be steep-to-gently sloping or consist of a vertical face which is locally overhanging in some places.

The depressed part of the reef-flat platform consists mostly of sand and rubble with scattered patches of living and dead corals and an occasional clump of seagrass. Toward the shore the substrata becomes sandier, seagrasses more abundant, and corals mostly absent. At places large sandy areas occur where both seagrasses and corals are rare or lacking. Of note also in this part of the reef flat is the presence of many clumps and patches of dead corals. These dead corals are mostly ramose and massive Porites colonies, similar in species composition to the present scattered living community, which suggests that coral dominance by these species was perhaps greater in the recent past. Conspicuous corals in the depressed reef flat zone include colonies of Porites andrewsi, Porites cocosensis, Porites lutea, Psammocora contigua, Pocillopora damicornis, Montipora lobulata, and a few solitary Fungia (F.) fungites.

In contrast to the inner reef-flat platform, the outer part consists of less unconsolidated material, is shallower with depressions here and there which retain water during low tides, and at places is more abundantly populated by a greater variety of coral species, particularly along the outer fringe which is slightly deeper and receives more water agitation from lagoon waves. Various colony forms of Acropora are the most conspicuous corals on the outer reef flat fringe. Other commonly encountered corals are encrusting patches of Montipora and small bushy arborescent Seriatopora hystrix colonies.

The lagoon slope is mostly consolidated reef rock with greater coral coverage and species diversity than at any other region. Massive colony forms of Favia, Platygyra, Favites, Pavona, and Porites species intermixed with various growth forms of Acropora dominate the steeper upper part of the lagoon slope. The lower lagoon slope, where it flattens out and grades into the lagoon floor, is dominated by scattered patches of corals consisting mostly of large arborescent thickets of Acropora and conspicuous isolated mounds, knolls, and knobs of Porites andrewsi, Porites (S.) iwayamaensis, and Porites (S.) convexa. Sand and coral-algal rubble occupies much of the open spaces between these large patchy areas of coral growth. Much coral mucus and seagrass detritus was seen in the water overlying the lagoon slope. Further out onto the lagoon floor the coral cover becomes widely scattered and patchy with sand-sized sediments covering most of the region.

A total of 103 species of corals representing 35 genera was recorded from this reef while snorkeling out to the lagoon slope from the outer part of a stone pier at the east end of the lagoon, and then parallel along the lagoon slope, lagoon floor, and outer reef flat for about a kilometer in a westward direction, and then back to the shore across the entire width of the reef-flat platform (Table A-2). For such a large reef very little of the entire reef area was investigated. With a more thorough search of this large reef area it would not be unreasonable to expect up to 125 species of corals here.

Seagrasses were the dominant plant form, with Halimeda, Padina, and Caulerpa species also abundant. The area is extremely diverse with respect to plant species, particularly along the margin and slope areas (Table A-4).

Fish observations at Site B were restricted to the seagrass beds, small coral patches, and sandy areas of the inner reef-flat platform within 25 m of the stone dock. A total of 62 species representing 16 families was recorded in this zone (Table A-5). Considering the relative absence of living corals and seagrasses in much of the area, this number was somewhat surprising, and indicative of a rather rich fringing-reef community. A more complete investigation, especially along the lagoon slope, would probably increase the number of observed species to over 100 and possibly even double it.

Site C - Fringing Reef on the northeast side of Moen Island

The lagoon fringing reef at this site is characterized by a wide reef-flat platform, 300 to 350 m across, and a steep rubbly lagoon slope grading to the lagoon floor at 10-12 m (Fig. A-2).

The reef-flat platform can be divided into a wider, sand-floored inner part, which forms a shallow moat during low tides and is dominated mostly by seagrass beds, and a narrower, rubbly outer part which is mostly barren and exposed during low tides except for a few depressed zones which retain water. A few scattered colonies of Psammocora contigua, Porites cocosensis, Porites andrewsi, and Pocillopora damicornis were observed where the depressed inner reef flat grades into the more exposed outer part. Extensive rubble patches consisting mostly of broken-up Acropora and Porites branches were the most conspicuous features of the outer part of the reef-flat platform.

The lagoon slope is steep and relatively barren of coral growth in comparison to Sites A and B. Rubble, similar to that formed in patches on the outer part of the reef-flat platform, dominates the entire lagoon slope. The present coral coverage is patchy and sparse, although new recruitment of Acropora species was noticeable at places. It appears that the lagoon slope once supported a much more luxuriant coral community that has been mostly killed, and the colonies of the dominant ramose Acropora and Porites species have mostly disintegrated into rubble. This condition has persisted at this reef for about ten years, since in the summer of 1969 one of the authors (RHR) investigated this same reef and found it be composed mostly of coral rubble with widely scattered live corals.

At a depth of about 10 m the lagoon slope flattens out to a sandy undulating lagoon floor. Rubble still persists here and there but sand becomes conspicuously more abundant and dominates the floor at some distance from the base of the slope. Coral growth is patchy and sparse although a few thickets of Acropora formosa were found at several places.

A total of 32 species of corals representing 13 genera were observed by swimming out from the shore to the lagoon slope and back again (Table A-2). This reef site is considerably more depauperate, both in species diversity and substrate coverage, than either Site A or B. With more extensive searching to find widely scattered or rare species the total number of species at this site could possibly be raised to 40. In relation to corals, this site would be the best place to dredge for fill materials as it supports a far less luxuriant growth of corals than the other two sites.

With respect to marine plants, the area was generally characterized as a wide, seagrass-covered reef flat. Turf algae were dominant. Visually, this site was much less diverse than the other sites (Table A-4).

A very short survey of the fish of the lagoon slope was made at Site C. The relatively barren condition of this area was reflected in the fish fauna observed (Table A-6). Even with more time spent searching in this area, the total number of observed species would probably only be raised by about 10-15 species. As at the other sites, pomacentrids (damselfish) were the dominant fish family, with labrids (wrasses) and acanthurids (surgeonfishes) also contributing heavily to total diversity.

Overall, Site C has a markedly lower biological diversity than the other two sites and is definitely the preferred dredging site from the standpoint of minimizing environmental impact. If the other sites must be dredged, activities should be confined within 75 m of the shoreline.

Figure A-1. Location of fringing reef Sites A, B, and C.

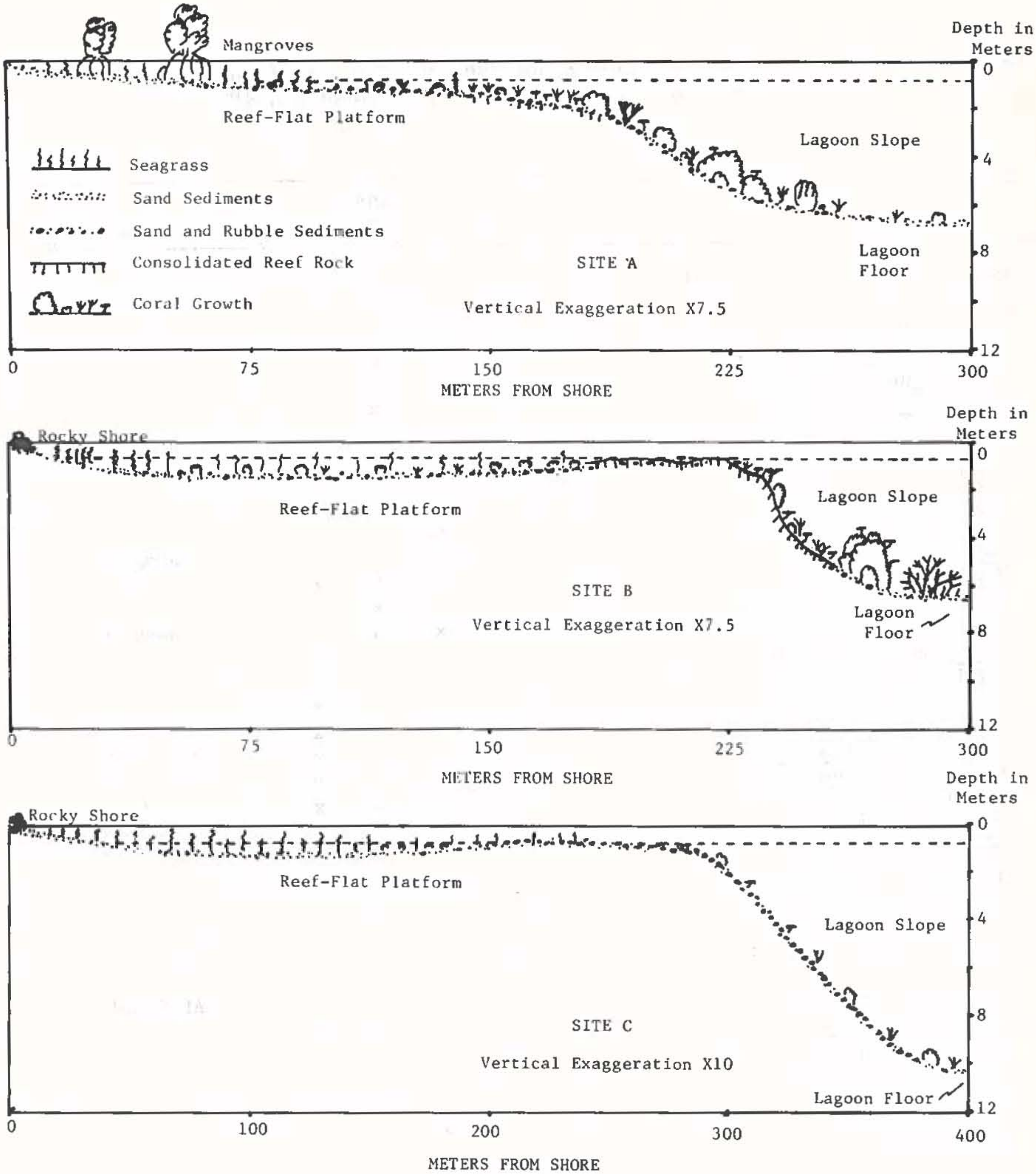

Figure A-2. Vertical profiles of fringing reef Sites A, B, and C. See Figure A-1 for site locations.

Table A-1. Checklist of marine plants observed at Site A in front of Memorial Church on Moen Island, Truk, December 16, 1977.

SPECIES	TRANSECT 1	2	3	Comments
CYANOPHYTA (Blue-Green Algae)				
Anacystis sp.	x			
Microcoleus lyngbyaceus	x	x		
Schizothrix calcicola	x	x	x	
Schizothrix mexicana		x	x	
CHLOROPHYTA (Green Algae)				
Avrainvillea obscura	x			
Caulerpa cupressoides	x	x		
Caulerpa racemosa	x	x		Abundant
Caulerpa serrulata		x	x	
Caulerpa sertularioides		x		
Caulerpa urvilliana	x	x		Abundant
Halimeda cylindracea		x	x	
Halimeda discoidea			x	
Halimeda gigas			x	
Halimeda incrassata			x	
Halimeda macrophysa			x	Abundant
Halimeda micronesica		x	x	
Halimeda opuntia		x	x	Abundant
Halimeda velasquezi			x	
Neomeris annulata		x		
Tydemannia expeditionis			x	
Udotea argentea		x		
PHAEOPHYTA (Brown Algae)				
Dictyota divaricata		x		Abundant
Dictyota patens		x	x	
Hydroclathrus clathratus	x			
Lobophora variegata			x	
Padina jonesii		x		
Padina tenuis	x	x		
Turbinaria ornata		x	x	
RHODOPHYTA (Brown Algae)				
Actinotrichia fragilis			x	
Amphiroa fragilissima			x	
Gelidium divaricatum		x		
Metagoniolithon sp.		x		
Polysiphonia sp.			x	
Porolithon onkodes		x	x	

Table A-1. continued.

SPECIES	TRANSECT 1	2	3	Comments
ANTHOPHYTA (Seagrasses)				
Enhalus acoroides	x			Abundant
Thalassia hemprichii	x	x		Abundant

Table A-2. List of corals observed at Sites A, B, and C. See Figure A-1 for site locations.

CORALS	SITE A	SITE B	SITE C
CLASS - ANTHOZOA			
ORDER - SCLERACTINIA			
SUBORDER - ASTROCOENIINA			
FAMILY - ASTROCOENIIDAE			
Stylocoeniella armada (Ehrenberg)		X	X
FAMILY - THAMNASTERIIDAE			
Psammocora contigua (Esper)	X	X	X
Psammocora digitata Milne-Edwards and Haime	X	X	
FAMILY - POCILLOPORIDAE			
Seriatopora hystrix Dana	X	X	X
Pocillopora damicornis (Linnaeus)	X	X	X
Pocillopora danae Verrill		X	X
Pocillopora elegans Dana		X	X
Pocillopora eydouxi Milne-Edwards and Haime	X	X	
Pocillopora ligulata Dana		X	
Pocillopora meandrina Dana	X	X	X
Pocillopora setchelli Hoffmeister		X	
FAMILY - ACROPORIDAE			
Acropora acuminata Verrill		X	X
Acropora affinis (Brook)		X	X
Acropora aspera (Dana)	X	X	X
Acropora complanata (Brook)		X	X
Acropora delicatula (Brook)		X	
Acropora danai (Milne-Edwards and Haime		X	
Acropora formosa (Dana)	X	X	X
Acropora humilis (Dana)	X	X	
Acropora hyacinthus (Dana)		X	X

CORALS	SITE A	SITE B	SITE C
Acropora hebes (Dana)		X	X
Acropora hystrix (Brook)	X	X	
Acropora irregularis (Brook)		X	
Acropora kenti (Brook)	X		
Acropora nasuta (Dana)	X	X	X
Acropora patula (Brook)		X	X
Acropora polymorpha (Brook)	X		
Acropora reticulata (Brook)		X	X
Acropora rotumana (Gardiner)		X	X
Acropora sp. cf. *A. squamosa* (Brook)	X	X	X
Acropora syringodes (Brook)	X	X	
Acropora valida (Dana)		X	
Acropora (Corymbose sp. 1)		X	X
Astreopora myriophthalma (Lamarck)		X	
Montipora ehrenbergii Verrill		X	
Montipora foveolata (Dana)		X	
Montipora hoffmeisteri Wells	X		
Montipora lobulata Bernard	X	X	X
Montipora patula Verrill	X		
Montipora prolifera Bernard	X		
Montipora socialis Bernard		X	
Montipora tuberculosa (Lamarck)	X	X	
Montipora venosa (Ehrenberg)		X	
Montipora verrilli Vaughan		X	
Montipora verrucosa (Lamarck)	X	X	
Montipora (Glabrous sp. 1)		X	
Montipora (Papillate sp. 2)	X		
Montipora (Foveolate sp. 3)	X		
Montipora (Papillate sp. 4)	X		
SUBORDER - FUNGIINA			
FAMILY - AGARICIIDAE			
Agariciella planulata (Dana)		X	
Pavona decussata Dana		X	X
Pavona divaricata (Lamarck)		X	

Table A-2. continued.

CORALS	SITE A	SITE B	SITE C
Pavona (Polyastra) obtusata (Quelch)	X		
Pavona (Polyastra) venosa Ehrenberg	X		
Pavona (Polyastra) (Encrusting sp. 1)		X	
Pachyseris rugosa (Lamarck)	X		
Pachyseris speciosa (Dana)		X	
FAMILY - SIDERASTREIDAE			
Coscinaraea columna (Dana)		X	
FAMILY - FUNGIIDAE			
Fungia (Verrillofungia) concinna Verrill	X	X	
Fungia (Danafungia) danai Milne-Edwards and Haime		X	
Fungia (Fungia) fungites (Linnaeus)	X	X	
Herpolitha limax (Esper)	X		
FAMILY - PORITIDAE			
Goniopora arbuscula Umbgrove		X	
Goniopora columna Dana	X		
Goniopora lobata Milne-Edwards and Haime	X	X	
Porites andrewsi Vaughan	X	X	X
Porites australiensis Vaughan	X	X	
Porites cocosensis Wells	X	X	X
Porites lutea Milne-Edwards and Haime	X	X	X
Porites murrayensis Vaughan	X	X	
Porites lichen Dana		X	
Porites (Synaraea) convexa Verrill	X	X	X
Porites (Synaraea) iwayamaensis Eguchi	X	X	X
Porites (Synaraea) vaughani Crossland		X	
Stylaraea punctata Klunzinger		X	
Alveopora verrilliana Dana	X		

Coscinaraea columna (Dana)		X	
FAMILY - FUNGIIDAE			
Fungia (Verrillofungia) concinna Verrill	X	X	
Fungia (Danafungia) danai Milne-Edwards and Haime		X	
Fungia (Fungia) fungites (Linnaeus)	X	X	
Herpolitha limax (Esper)	X		
FAMILY - PORITIDAE			
Goniopora arbuscula Umbgrove		X	
Goniopora columna Dana	X		
Goniopora lobata Milne-Edwards and Haime	X	X	
Porites andrewsi Vaughan	X	X	X
Porites australiensis Vaughan	X	X	
Porites cocosensis Wells	X	X	X
Porites lutea Milne-Edwards and Haime	X	X	X
Porites murrayensis Vaughan	X	X	
Porites lichen Dana		X	
Porites (Synaraea) convexa Verrill	X	X	X
Porites (Synaraea) iwayamaensis Eguchi	X	X	X
Porites (Synaraea) vaughani Crossland		X	
Stylaraea punctata Klunzinger		X	
Alveopora verrilliana Dana	X		
FAMILY - ACROPORIDAE			
Acropora acuminata Verrill		X	X
Acropora affinis (Brook)		X	X
Acropora aspera (Dana)	X	X	X
Acropora complanata (Brook)		X	X
Acropora delicatula (Brook)		X	
Acropora danai (Milne-Edwards and Haime		X	
Acropora formosa (Dana)	X	X	X
Acropora humilis (Dana)	X	X	
Acropora hyacinthus (Dana)		X	X

Table A-2. continued.

CORALS	SITE A	SITE B	SITE C
SUBORDER - FAVIINA			
FAMILY - FAVIIDAE			
Favia amicorum (Milne-Edwards and Haime)		X	
Favia favus (Forskaal)	X	X	
Favia laxa (Klunzinger)		X	
Favia matthai Vaughan	X	X	
Favia pallida (Dana)	X	X	
Favia rotulosa (Ellis and Solander)	X		
Favia rotumana (Gardiner)		X	
Favia speciosa (Dana)	X	X	
Favia stelligera (Dana)		X	
Favites abdita (Ellis and Solander)		X	
Favites acuticollis (Ortmann)		X	
Favites flexuosa (Dana)	X		
Favites pentagona (Esper)		X	
Favites virens (Dana)		X	
Oulophyllia crispa (Lamarck)		X	
Goniastrea edwardsi Chevalier		X	
Goniastrea favulus (Dana)		X	
Goniastrea pectinata (Ehrenberg)		X	
Goniastrea retiformis (Lamarck)		X	
Goniastrea spectabilis (Verrill)	X	X	
Platygyra daedalea (Ellis and Solander)	X	X	X
Platygyra lamellina (Ehrenberg)	X	X	
Leptoria phrygia (Ellis and Solander)		X	
Hydnophora microconos (Lamarck)		X	
Hydnophora rigida (Dana)	X	X	
Montastrea curta (Dana)		X	
Diploastrea heliopora (Lamarck)	X	X	
Leptastrea bottae (Milne-Edwards and Haime)			X
Leptastrea purpurea (Dana)	X		
Cyphastrea serailia (Forskaal)		X	
FAMILY - OCULINIDAE			
Galaxea fascicularis (Linnaeus)	X	X	

Table A-2. continued.

CORALS	SITE A	SITE B	SITE C
FAMILY - MUSSIDAE			
Lobophyllia corymbosa (Forskaal)	X	X	
Lobophyllia costata (Dana)	X	X	
Lobophyllia hemprichii (Ehrenberg)	X	X	
Symphyllia nobilis (Dana)	X	X	
Symphillia valenciennesii Milne-Edwards and Haime		X	
FAMILY - PECTINIIDAE			
Echinophyllia aspera (Ellis and Solander)		X	
Pectinia lactuca (Pallas)	X		
SUBORDER - CARYOPHYLLIINA			
FAMILY - CARYOPHYLLIIDAE			
Physogyra lichtensteini Milne-Edwards and Haime	X	X	
SUBORDER - DENDROPHYLLIINA			
FAMILY - DENDROPHYLLIIDAE			
Turbinaria (Foliaceous sp. 1)		X	
ORDER - COENOTHECALIA			
FAMILY - HELIOPHORIDAE			
Heliopora coerulea (Pallas)	X	X	X
CLASS - HYDROZOA			
ORDER - MILLEPORINA			
FAMILY - MILLEPORIDAE			
Millepora dichotoma Forskaal		X	X
Millepora exaesa Forskaal	X	X	X
Millepora platyphylla Hemprich and Ehrenberg		X	

Table A-2. continued.

CORALS	SITE A	SITE B	SITE C
ORDER - STYLASTERINA			
FAMILY - STYLASTERIDAE			
Distichopora violacea (Pallas)		X	
Distichopora (Orange sp. 1)		X	
TOTAL GENERA	26	35	13
TOTAL SPECIES	61	103	32
Total Genera for Moen Island 38			
Total Species for Moen Island 122			

Table A-3. Numbers of species in various fish families observed at Site A on Moen, December 16, 1977. Observations made between 1445 and 1660 hours.

ACANTHURIDAE (Surgeonfishes)		8 spp
APOGONIDAE (Cardinalfishes)		2 spp
ATHERINIDAE (Silversides)		1 sp
BLENNIDAE (Blennies)		2 spp
CANTHIGASTERIDAE (Sharpback Puffers)		1 sp
CHAETODONTIDAE (Butterflyfishes)		6 spp
HOLOCENTRIDAE (Soldierfishes)		2 spp
LABRIDAE (Wrasses)		9 spp
LUTJANIDAE (Snappers)		4 spp
MULLIDAE (Goatfishes)		4 spp
POMACENTRIDAE (Damselfishes)		10 spp
SERRANIDAE (Groupers)		2 spp
SCARIDAE (Parrotfishes)		4 spp
TOTAL NUMBER OF FAMILIES OBSERVED	13	
TOTAL NUMBER OF SPECIES OBSERVED	55	

Table A-4. Checklist of marine plants observed at Sites B and C on Moen Island, Truk, December 21, 1977.

SPECIES	SITE B	SITE C
CYANOPHYTA (Blue-Green Algae)		
Anacystis sp.	x	x
Microcoleus lyngbyaceus	x	x
Schizothrix calcicola	x	x
Schizothrix mexicana	x	x
CHLOROPHYTA (Green Algae)		
Boergesenia forbesii	x	
Caulerpa cupressoides	x	x
Caulerpa racemosa	x	x
Caulerpa serrulata	x	x
Caulerpa taxifolia	x	
Caulerpa urvilliana	x	x
Caulerpa verticillata		x
Chlorodesmis fastigiata		x
Dictyosphaeria cavernosa	x	
Dictyosphaeria versluysii	x	
Enteromorpha sp.	x	
Halimeda cylindracea	x	x
Halimeda gigas	x	x
Halimeda incrassata	x	
Halimeda macroloba	x	x
Halimeda macrophysa	x	
Halimeda micronesica	x	x
Halimeda opuntia	x	x
Halimeda velasquezii	x	
Rhipilia orientalis	x	x
Udotea argentea	x	
PHAEOPHYTA (Brown Algae)		
Dictyota bartayresii	x	x
Dictyota divarticulata	x	x
Dictyota friabilis	x	
Hydroclathrus clathratus	x	x
Padina jonesii	x	
Padina minor	x	x
Sargassum polycystum	x	
Sphacelaria tribuloides	x	
Turbinaria ornata	x	x

Table A-4. continued

SPECIES	SITE B	SITE C
RHODOPHYTA (Red Algae)		
Actinotrichia fragilis	x	
Amphiroa foliacea	x	x
Amphiroa fragilissima	x	
Centroceras sp.	x	x
Ceramium sp.	x	x
Champia parvula	x	
Gelidium divaricatum	x	x
Jania capillacea	x	
Polysiphonia sp.	x	x
Metagoniolithon sp.	x	x
Neogoniolithon sp.	x	x
Tolypiocladia giomerulata	x	
ANTHOPHYTA (Seagrasses)		
Cymodocea rotundata	x	x
Enhalus acoroides	x	x
Syringodium isoetifolium	x	
Thalassia hemprichii	x	x

Table A-5. Numbers of species in various fish families observed at Site B on Moen, December 21, 1977. Observations were restricted to the sandy substrate and patch reef areas within 25 m west of the existing dock between 1530 and 1610 hours.

ACANTHURIDAE (Surgeonfishes)	6 spp
APOGONIDAE (Cardinalfishes)	5 spp
BALISTIDAE (Triggerfishes)	1 sp
BLENNIIDAE (Blennies)	2 sp
CARANGIDAE (Jacks)	1 sp
CHAETODONTIDAE (Butterflyfishes)	3 spp
ELEOTRIDAE (Sleepers)	1 sp
GOBIIDAE (Gobies)	3 spp
HEMIRAMPHIDAE (Halfbeaks)	1 sp
LABRIDAE (Wrasses)	11 spp
LUTJANIDAE (Snappers)	5 spp
MULLIDAE (Goatfishes)	2 spp
POMACENTRIDAE (Damselfishes)	13 spp
SCARIDAE (Parrotfishes)	4 spp
SIGANIDAE (Rabbitfishes)	3 spp
SYGNATHIDAE (Pipefishes)	1 spp

TOTAL NUMBER OF FAMILIES OBSERVED 16

TOTAL NUMBER OF SPECIES OBSERVED 62

Table A-6. Numbers of species in various fish families observed at Site C, Moen, December 21, 1977. Observations made on a random swim over the lagoon slope between 1645 and 1700 hours.

ACANTHURIDAE (Surgeonfishes)	7 spp
CHAETODONTIDAE (Butterflyfishes)	7 spp
LABRIDAE (Wrasses)	9 spp
LUTJANIDAE (Snappers)	3 spp
MULLIDAE (Goatfishes)	3 spp
POMACENTRIDAE (Damselfishes)	10 spp
SCARIDAE (Parrotfishes)	3 spp
SIGANIDAE (Rabbitfishes)	4 spp
ZANCLIDAE (Morrish Idols)	1 sp

TOTAL NUMBER OF FAMILIES OBSERVED 9

TOTAL NUMBER OF SPECIES OBSERVED 47

Table A-2. List of corals observed at Sites A, B, and C. See Figure A-1 for site locations.

CORALS	SITE A	SITE B	SITE C
CLASS - ANTHOZOA			
ORDER - SCLERACTINIA			
SUBORDER - ASTROCOENIINA			
FAMILY - ASTROCOENIIDAE			
Stylocoeniella armada (Ehrenberg)		X	X
FAMILY - THAMNASTERIIDAE			
Psammocora contigua (Esper)	X	X	X
Psammocora digitata Milne-Edwards and Haime	X	X	
FAMILY - POCILLOPORIDAE			
Seriatopora hystrix Dana	X	X	X
Pocillopora damicornis (Linnaeus)	X	X	X
Pocillopora danae Verrill		X	X
Pocillopora elegans Dana		X	X
Pocillopora eydouxi Milne-Edwards and Haime	X	X	
Pocillopora ligulata Dana		X	
Pocillopora meandrina Dana	X	X	X
Pocillopora setchelli Hoffmeister		X	
FAMILY - ACROPORIDAE			
Acropora acuminata Verrill		X	X
Acropora affinis (Brook)		X	X
Acropora aspera (Dana)	X	X	X
Acropora complanata (Brook)		X	X
Acropora delicatula (Brook)		X	
Acropora danai (Milne-Edwards and Haime		X	
Acropora formosa (Dana)	X	X	X
Acropora humilis (Dana)	X	X	
Acropora hyacinthus (Dana)		X	X

CORALS	SITE A	SITE B	SITE C
Acropora hebes (Dana)		X	X
Acropora hystrix (Brook)	X	X	
Acropora irregularis (Brook)		X	
Acropora kenti (Brook)	X		
Acropora nasuta (Dana)	X	X	X
Acropora patula (Brook)		X	X
Acropora polymorpha (Brook)	X		
Acropora reticulata (Brook)		X	X
Acropora rotumana (Gardiner)		X	X
Acropora sp. cf. *A. squamosa* (Brook)	X	X	X
Acropora syringodes (Brook)	X	X	
Acropora valida (Dana)		X	
Acropora (Corymbose sp. 1)		X	X
Astreopora myriophthalma (Lamarck)		X	
Montipora ehrenbergii Verrill		X	
Montipora foveolata (Dana)		X	
Montipora hoffmeisteri Wells	X		
Montipora lobulata Bernard	X	X	X
Montipora patula Verrill	X		
Montipora prolifera Bernard	X		
Montipora socialis Bernard		X	
Montipora tuberculosa (Lamarck)	X	X	
Montipora venosa (Ehrenberg)		X	
Montipora verrilli Vaughan		X	
Montipora verrucosa (Lamarck)	X	X	
Montipora (Glabrous sp. 1)		X	
Montipora (Papillate sp. 2)	X		
Montipora (Foveolate sp. 3)	X		
Montipora (Papillate sp. 4)	X		
SUBORDER - FUNGIINA			
FAMILY - AGARICIIDAE			
Agariciella planulata (Dana)		X	
Pavona decussata Dana		X	X
Pavona divaricata (Lamarck)		X	

Table A-2. continued.

CORALS	SITE A	SITE B	SITE C
Pavona (Polyastra) obtusata (Quelch)	X		
Pavona (Polyastra) venosa Ehrenberg	X		
Pavona (Polyastra) (Encrusting sp. 1)		X	
Pachyseris rugosa (Lamarck)	X		
Pachyseris speciosa (Dana)		X	
FAMILY - SIDERASTREIDAE			
Coscinaraea columna (Dana)		X	
FAMILY - FUNGIIDAE			
Fungia (Verrillofungia) concinna Verrill	X	X	
Fungia (Danafungia) danai Milne-Edwards and Haime		X	
Fungia (Fungia) fungites (Linnaeus)	X	X	
Herpolitha limax (Esper)	X		
FAMILY - PORITIDAE			
Goniopora arbuscula Umbgrove		X	
Goniopora columna Dana	X		
Goniopora lobata Milne-Edwards and Haime	X	X	
Porites andrewsi Vaughan	X	X	X
Porites australiensis Vaughan	X	X	
Porites cocosensis Wells	X	X	X
Porites lutea Milne-Edwards and Haime	X	X	X
Porites murrayensis Vaughan	X	X	
Porites lichen Dana		X	
Porites (Synaraea) convexa Verrill	X	X	X
Porites (Synaraea) iwayamaensis Eguchi	X	X	X
Porites (Synaraea) vaughani Crossland		X	
Stylaraea punctata Klunzinger		X	
Alveopora verrilliana Dana	X		