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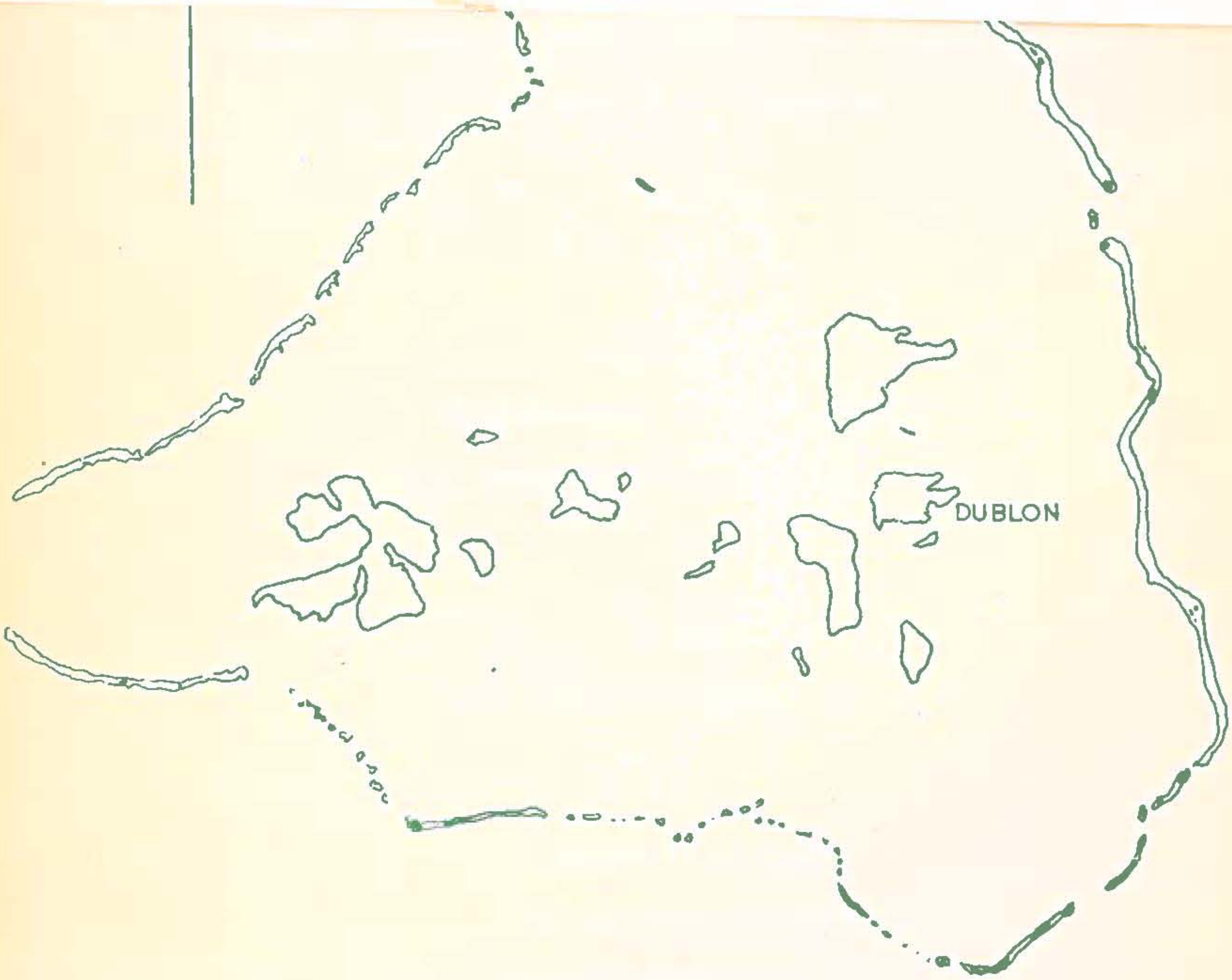
Transmitted herewith for your information is a copy of our Technical Report No. 36, "Limited Current and Underwater Biological Survey of Proposed Truk Tuna Fishery Complex, Dublon Island, Truk." This report was prepared for the Environmental Protection Board, Trust Territory of the Pacific Islands, to assist them in assessing the potential environmental impact of the cannery.

I hope that you find the report informative and will be happy to discuss any questions you may have.

James A. Marsh, Jr.
JAMES A. MARSH, JR.
Director



UNIVERSITY OF GUAM MARINE LABORATORY

Technical Report No. 36

June 1977

LIMITED CURRENT AND UNDERWATER BIOLOGICAL SURVEY OF PROPOSED TRUK TUNA FISHERY COMPLEX, DUBLON ISLAND, TRUK

By

Steven S. Amesbury, James A. Marsh, Jr., Richard H. Randall
and Jeanine O. Stojkovich

Prepared for
ENVIRONMENTAL PROTECTION BOARD
TRUST TERRITORY OF THE PACIFIC ISLANDS

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INTRODUCTION

Background

A tuna fishery complex, consisting of a cannery-meal plant, warehouse, offices, living quarters, and power generating plant, has been proposed for Dublon Island, Truk District. A preliminary study by Living Marine Resources, Inc. (LMR) has indicated that the most promising site for these facilities is in the area of a dock used by the Japanese prior to the end of World War II for fuel discharge (Figure 1). In the LMR report, "Preliminary report on proposed site and facilities for Truk Tuna Fishery Complex," dated 14 October, 1976, this site is designated "Area 4" and is preferred for the following reasons:

1. good existing dock with excellent water depth;
2. weather protection for vessels at dock;
3. shallow adjacent area permitting relatively inexpensive site development for processing facility;
4. rock fill nearby;
5. required land already in public domain;
6. good water supply nearby;
7. road access to other areas on Dublon.

The proposed modifications of the dock involve enlarging it by adding approximately 7 ft. (2.1m) of fill along the entire north side and 100 ft. (30.5m) of fill along a 461-ft. (140.5m) section on the central portion of the south side of the dock. The fill is to be brought in from elsewhere on the island rather than dredged from the reef surrounding the dock.

Effluent from the cannery will presumably be discharged from the outermost end of the dock into the main channel between Dublon and Eten Islands. If the power generating facility is located at the same site, heated wastewater may also be discharged. Additional effluent can be expected in the form of domestic sewage from the living facilities to be constructed nearby.

Scope of Work

The University of Guam Marine Laboratory biologists were requested to survey the proposed cannery site and to provide the Trust Territory Environmental Protection Board with the following information:

- background information on the general physical, chemical, and biological characteristics of the marine waters;

- the projected effects of dredging and filling activities as well as the discharge of treated cannery wastes, domestic wastes, and industrial wastes into the lagoon waters;

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

- effects of power plant discharge, which normally includes waste heat, biocides, and inorganic materials if cooling towers and pond are used;

- the extent and magnitude of surface and subsurface currents at the proposed site, so that reliable predictions on plume movement, dispersion, and dilution can be developed;

- 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;

- identification and definition of further significant research that is urgently needed to insure that the environment and its resources will be adequately protected.

<u>Personnel</u>

Steven S. Amesbury, Ph.D., Assistant Professor, Marine Laboratory, University of Guam (Fishes, Plankton)

James A. Marsh, Jr., Ph.D., Director, Marine Laboratory, University of Guam (Water Chemistry and Circulation)

Richard H. Randall, M.S., Assistant Professor, Marine Laboratory, University of Guam (Corals)

Jeanine O. Stojkovich, Graduate Biology Student, Marine Laboratory, University of Guam (Marine Plants)

ACKNOWLEDGEMENTS

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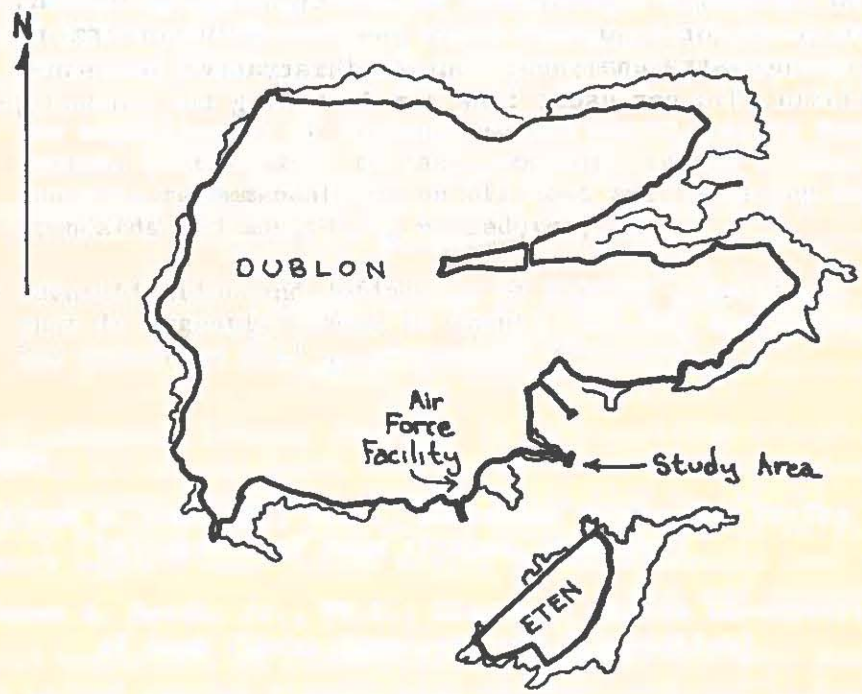

Figure 1. Location of study area on Dublon Island.

METHODS

Study Site and Transects

The Dublon cannery site was visited on 1 April - 4 April 1977. The old Japanese fuel dock extends out from the island some 1125 ft. (343m) in an east southeast direction, crossing the reef flat and ending on the lagoon slope at the edge of the channel in approximately 36 ft. (11m) of water. Six transects were established in the immediate vicinity of the dock, and a seventh was established on a reef area southwest of the dock (Fig. 2C). The depth profiles for the seven transects are shown in Fig. 3.

Chemical and Physical Characteristics of the Water

Samples for nutrient determinations were collected at 9 stations between 1130 and 1215 hours on 4 April 77. Sampling locations are shown in Fig. 2A. Both surface and near-bottom samples were taken at Station 1 near the end of the deep-water dock. The surface sample was collected in a plastic bucket and the water then siphoned into pre-cleaned plastic bottles. The bottom sample was collected in a van Dorn sampler. All other stations were sampled only at the surface by using the plastic bucket. Duplicate bottles were taken at each location. The samples were placed on ice and later put into a reefer at the Division of Marine Resources on Moen. Samples did not freeze completely and were transported back to Guam on ice but in a thawed condition. They were then frozen and held until later analysis. Laboratory analysis for phosphate-phosphorus (reactive phosphorus), nitrite-nitrogen, and nitrate-nitrogen followed the procedures in Strickland and Parsons (1968).

Salinity was measured in the field with a hand-held refractometer between 1025 and 1045 hours on 2 April 1977. Salinity sampling locations are shown in Fig. 2A.

Dissolved oxygen concentration was measured directly in the field with a YSI Model 54 oxygen meter, utilizing a polarographic electrode. Temperature was measured with a thermistor probe built into the oxygen electrode. Sampling was carried out at a series of stations at various times and dates during daylight hours (Fig. 2B).

Water Circulation

Periodically, during rising and falling tide on 3 April, pairs of drift drogues, with vanes 1 m and 5 m deep, were released from a point off the end of the dock. After appropriate time intervals (approximately 1 hr), the positions of the drogues were determined and plotted. Wind

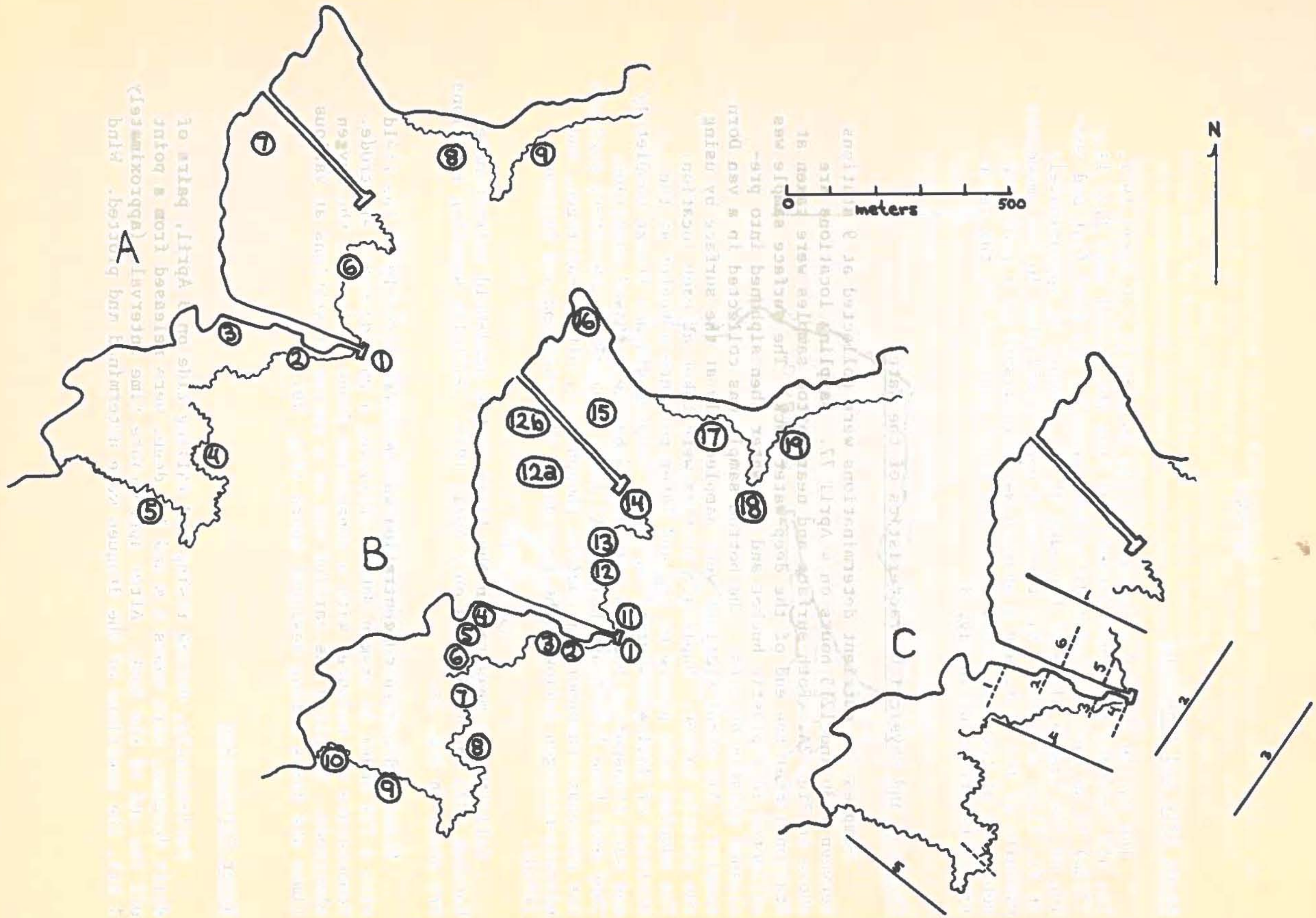

Figure 2. A. Nutrient and salinity sampling stations. B. Oxygen sampling stations.
C. Transect locations (dashed lines) and zooplankton tow paths (solid lines).

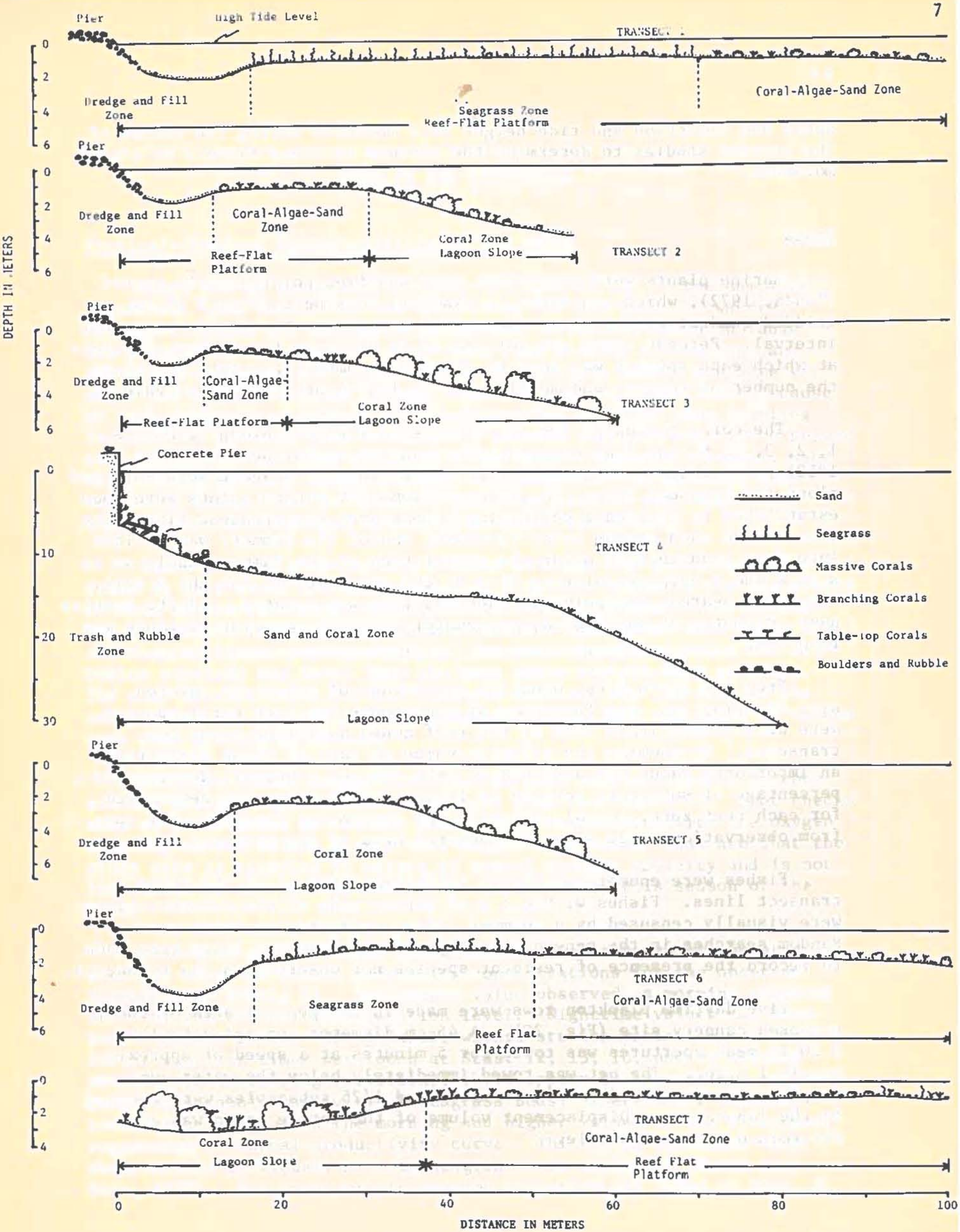

Figure 3. Vertical profiles of Transects 1-7. Vertical exaggeration is X2 except for Transect 4 which is X1.

speed and direction and tide height were measured during the course of the current studies to determine the effects of these factors on drogue movement.

Biota

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 two times at each 10-m transect interval. Percent cover was calculated by dividing the number of points at which each species was seen by the total number of points (16 times the number of tosses) and multiplying by 100 to obtain percent values.

The coral community was quantitatively analyzed along Transects 1, 2, 3, 5, 6, and 7 by using a point-quarter technique (Cottam et al., 1953). For this technique a series of stations 10 m apart were selected along the transect lines. A series of somewhat random points were then established by tossing a collecting hammer over the transect line. The area around each random point (proximal end of the hammer) was divided into four quadrants by using the orientation of the hammer handle as an x axis and a perpendicular to this at the point itself for the y axis. The coral nearest the point in each quadrant was located, and its species name, diameter or basal area, and center of coral-to-point distance was recorded.

From the above data, density, percentage of substrate covered, size distribution, and frequency of occurrence for each coral species were determined within each of the reef zones delimited along the transects. By summing the relative value of each of these parameters, an Importance Value was assigned to each species. Overall density and percentage of substrate covered by living corals were also determined for each reef zone. Coral diversity was determined for each reef zone from observations made along the general area of the transect line.

Fishes were enumerated within each 10-m interval of the seven transect lines. Fishes within 1 m of either side of the transect lines were visually censused by a swimmer using snorkeling or scuba gear. Random searches in the general vicinity of the transect lines were made to record the presence of resident species not observed on the transects.

Five daytime plankton tows were made in the general area of the proposed cannery site (Fig. 2C). A 45-cm diameter conical net with 0.20 mm mesh apertures was towed for 5 minutes at a speed of approximately 1 m/sec. The net was towed immediately below the water surface. Samples were preserved in 10% formalin and 1/25 subsamples were counted in the laboratory. Displacement volume of the entire catch was also determined for each sample.

RESULTS AND DISCUSSION

Physical-Chemical Characteristics of the Water

There was no detectable nitrite-nitrogen at any of the sampling locations; this result was not surprising for non-polluted waters. Nitrate-nitrogen and phosphate-phosphorus values are shown in Table 1. The phosphorus values do not vary much from station to station, and the differences are not significant. The nitrate values are more variable, but the differences between stations are not significant because of high variability between replicate bottles from the same sampling locations. However, some variability between stations might be expected because of the fact that a number of different habitats (channel, sand flat, fringing reef, mangrove area) were sampled. In general, the values in Table 1 are low and are characteristic of what might be expected for non-polluted waters in tropical ecosystems.

Table 2 shows a comparison between nitrogen and phosphorus values found in this study and those found in a earlier study by the University of Guam Marine Laboratory at Point Gabert, Moen (Tsuda et al., 1975). The phosphorus values at all Dublon stations were lower than those at all Moen stations; correspondingly, the mean phosphorus value for all Dublon stations was lower than the mean value for all Moen stations. The mean nitrate value for all stations combined was the same at the two places, but the variability (standard deviation) and range of values were much greater on Dublon.

Salinity values ranged from 34.4 to 35.5 ppt, and showed no consistent pattern with respect to station location (Table 3). Spot checks made at other times at various stations in conjunction with the oxygen sampling showed values within this range. The values indicate that the study site is occupied by waters of normal oceanic salinity and is not influenced by terrestrial runoff, at least during this season of the year.

Dissolved oxygen levels are generally high throughout the study area and match or exceed saturation concentrations for the observed temperatures (Table 4). The lowest value observed, a morning value at Sta. 16, was 80% of the saturation level. Nighttime values may have been somewhat lower. The greatest within-station variation for different sampling times was found at Stas. 12, 13, 10, and 15 (listed in order of decreasing variation); these appear to be stations influenced by metabolic activity of seagrass beds. There was a tendency toward lower values in the morning and higher values in the afternoon, suggesting a diurnal productivity curve. This is in agreement with observations previously made in seagrass beds in Saipan (Marsh and Ross, 1977). The least within-station variation was found at Stas. 8,

Table 1. Nutrient levels at various stations on 4 April 1977. Each value is the average of duplicate determinations. See Fig. 2A for station locations.

Station	NO_3-N μg-at/l	PO_4-P μg-at/l
1, Surface	0.14	0.20
1, Bottom	0.38	0.20
2	0.19	0.20
3	0.22	0.16
4	0.12	0.19
5	0.19	0.16
6	0.41	0.13
7	0.13	0.12
8	0.68	0.16
9	0.28	0.18

Table 2. A comparison of nitrogen and phosphorus concentrations at Point Gabert, Moen, and the deep-water dock, Dublon. Values given are means, 1 standard deviation, range, and number of samples.

	Moen	Dublon
NO_3-N	.27 ± .019; .25 - .29; 5	.27 ± .17; .12 - .68; 10
PO_4-P	.23 ± .012; .22 - .25; 5	.17 ± .029; .12 - .20; 10

Table 3. Salinity at various stations between 1025 and 1045 hours on 2 April 1977. See Fig. 2A for station locations.

Station	Salinity (°/oo)	Station	Salinity (°/oo)
1	34.4	10	34.4
2	34.4	11	35.0
3	34.4	12	34.4
4	34.4	12a	34.4
5	35.0	12b	34.4
6	35.0	14	34.4
7	35.0	15	34.4
8	35.5	16	34.4
9	35.0		34.4

Table 4. Dissolved oxygen concentrations (mg/l) and temperatures (°C) at various stations in the study area at various times and dates. Sampling times and dates are as follows: I - 1 April, 1305-1415 hours, high tide; II - 2 April, 0845-0930 hours, low tide; III - 2 April, 1420-1445 hours, high tide; IV - 2 April, 1710-1740 hours, falling tide; V - 4 April, 0948-1020 hours, low tide. See Fig. 2B for station locations.

	I		II		III		IV		V	
Station	O_2	T	O_2	T	O_2	T	O_2	T	O_2	T
1	6.6	29.0	6.2	28.5	6.1	29.0	6.3	28.5	6.0	29.0
2	7.1	29.0	6.1	28.5	6.3	29.0	6.3	28.5	6.2	29.+
3	7.0	29.0	6.5	28.5	7.0	29.5	6.5	29.-	6.8	29.5
4	7.4	29.5	6.3	28.5	7.2	30.0	6.65	29.-	6.35	30.0
5	7.5	30.0	7.2	28.5	7.2	29.5	6.65	29.-	6.65	29.5
6	7.7	29.5	6.7	28.5	7.0	29.5	6.4	29.-	6.1	29.+
7	-	-	6.5	28.5	6.8	29.5	6.3	29.-	6.2	29.5
8	-	-	6.1	28.5	6.3	29.0	6.4	29.-	6.0	29.+
9	-	-	6.25	28.5	6.8	29.0	6.4	28.5	6.45	29.5
10	8.1	29.+	6.4	28.5	7.3	30.0	6.7	29.0	6.0	29.0
11	6.5	29.0	6.3	28.5	6.5	29.+	6.4	29.0	5.9	29.0
12	8.8	29.5	6.0	28.5	7.4	30.0	7.4	30.0	6.35	29.+
13	8.5	29.5	6.0	28.5	6.6	31.0	6.45	29.5	5.9	29.+
14	6.4	29.0	6.2	28.5	6.6	30.0	6.4	30.0	5.9	29.+
15	7.5	29.5	5.6	29.-	6.6	31.0	6.85	30.5	5.55	29.5
16	6.5	30.0	5.0	29.-	6.1	32.0	6.1	31.+	-	-
17	6.4	30.0	5.9	28.5	6.3	31.0	6.4	30.+	5.5	30.+
18	6.3	29.0	6.45	29.-	6.3	29.+	6.3	29.0	5.95	30.-
19	6.8	29.+	6.3	29.-	6.7	30.-	6.4	29.0	6.1	30.-

3, 18, 1, 7, 9, and 11, stations which were most subject to water exchange with Takeshima Channel, lying between Dublon and Eten Islands. With respect to temperature, there was a tendency for morning values to be lower than afternoon values, a finding which was not surprising. In general, dissolved oxygen and temperature values were about what could be expected for uppolluted waters.

Water Circulation

Drift drogue patterns plotted for ten hourly runs between 0800 and 1800 hrs on 2 April 1977, showed a consistent water flow to the WSW during both rising and falling tide (Fig. 4). The 1-meter drogues traveled at an average speed of .095 m/sec, significantly faster than the average for the 5-meter drogues of .070 m/sec (Table 5). Greatest speeds were recorded with 1-meter drogue runs 4, 5, and 6, from 1100 to 1400 hrs. when the tide was rising and at its height (Fig. 4). This may reflect the increased amount of water entering the lagoon at rising and high tide and being forced at higher speeds through the restricted area between Dublon and Eten Island. The 5-meter drogues had slower and more variable velocities.

Wind direction was quite consistent throughout the day on 2 April, varying from 058° to 082°, thus blowing in essentially the same direction as the drogues were moving (Table 6). As the drogues present surface area above the surface of the water, some of their movements may be influenced by wind drag. The 1-meter drogue no. 8 lost its vane during the course of the run and its movements were largely the result of the force of the wind on the surface float; as shown in Fig. 4 this float moved in the same general direction as did the other drift drogues. However, periodic checks with fluorescein dye demonstrated that the water was actually moving in the directions shown by the drift drogues.

Reef Structure

Structurally, the reefs in the study area are of the fringing type that have developed within the protected waters of Truk Lagoon. The reef environment can be broadly divided into three physiographic units which can be further subdivided into a number of zones based upon the dominant marine communities present and the physical characteristics of the substratum. These various divisions are shown in vertical profile for the seven transect locations around the study site in Fig.3.

The most extensive of the physiographic units studied is the shallow reef-flat platform. At most places the reef flat extends outward from a mangrove shoreline except at locations where trees have been removed by coastal development. The inner part of the reef flat is somewhat elevated in respect to the outer part, with areas commonly exposing during low spring tides. A seagrass and sand zone dominates

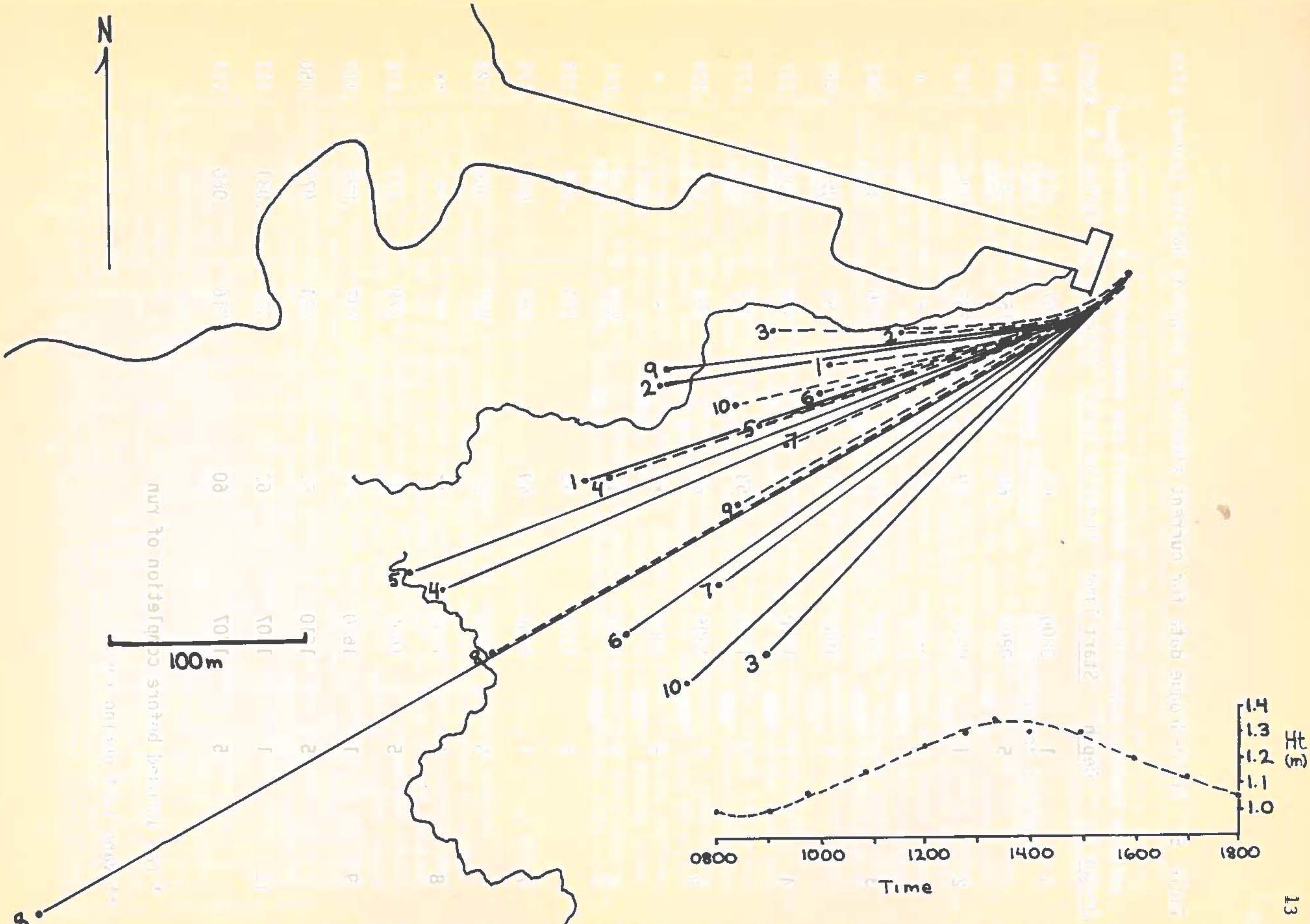

Figure 4. Paths of drift drogues. Solid lines are 1-meter drogues; dashed lines are 5-meter drogues. Inset: Relative tide height measured at the proposed site (in meters).

Table 5. Drift-drogue data for current studies at proposed Dublon cannery site.

Drogue No.	Depth	Start Time	Duration (min)	Distance (m)	Speed (m/sec	& knots)
1	1	0800	63	297	.079	.153
	5	0800	66	169	.043	.083
2	1	0910	49	253	.086	.167
	5	0910	*	*	*	*
3	1	1003	61	266	.073	.042
	5	1003	63	193	.051	.099
4	1	1110	53	388	.122	.237
	5	1110	53	289	.091	.177
5	1	1205	63	398	.105	.204
	5	1205	*	*	*	*
6	1	1318	42	313	.124	.241
	5	1318	45	174	.064	.124
7	1	1406	49	263	.090	.175
	5	1406	51	201	.066	.128
8	1	1500	**	**	**	**
	5	1500	57	378	.111	.216
9	1	1620	44	247	.094	.183
	5	1610	51	234	.077	.150
10	1	1707	63	307	.081	.157
	5	1707	60	216	.060	.117

* ran aground before completion of run

** vane lost during run

Table 6. Wind speed and direction measured during current studies.

Time	Wind Speed (knots)	Direction (of origin)
0800	13.5	071°
0945	13.5	072°
1050	11.5	069°
1200	12.5	074°
1320	14.0	072°
1400	13.5	058°
1500	18.0	068°
1610	10.0	063°
1700	20.0	082°
1800	13.0	069°

the shallow inner part of the platform and a coral-algal-sand zone is characteristic of the outer deeper part. Indentations and projecting points give the outer edge of the reef-flat platform a very irregular outline which is probably more reflective of the underlying ridge and valley topography of Dublon Island than of different rates of reef development.

At the outer margin of the reef-flat platform the lagoon slope dips gently to abruptly downward to the lagoon floor. Both the steepness of the lagoon slope and the depth at which it grades into the flatter lagoon floor vary considerably from place to place (Fig. 3). The upper lagoon slope is a region of optimum coral growth and cover, while the lower slope and lagoon floor is mostly a depositional environment that supports widely scattered to patchy coral cover. Sand mixed with considerable amounts of coral rubble dominates the substratum around the coralliferous upper slopes, with sand and finer sized sediments increasing downslope toward the lagoon floor.

A pier has been constructed across the fringing reef flat by dredging reef materials from both sides, forming trough-like depressions along its length (dredge-and-fill zone). At its seaward end the pier extends beyond the reef-flat platform into deeper water of the lagoon slope where a concrete pier head has been constructed. The vertical walls of pier head and boulder slopes along the outer part of the pier provide an artificial reef surface that is partly colonized by corals. Coral growth is particularly rich on the concrete pier head, while the trough-like depressed zones along both sides of the pier are for the most part depositional environments and corals are mostly absent.

Biota

Marine Plants--A total of 63 species of marine benthic plants (Table 7) were collected or observed at the study site. Although this represents considerable diversity, algal coverage in general was low, ranging from a high of 56% at Transect 6 to a low of 8% at Transect 3. It is estimated that fewer than 30 species accounted for 90% of the algal cover. Average cover for all seven transects was 27%. The paucity of benthic algal cover is directly related to the high percentage of sand, i.e., the lack of a hard substrate. Only those genera having large rhizoidal holdfasts or rhizomes (*Halimeda*, *Caulerpa*, *Udotea*, *Halophila*, *Thalassia* and *Enhalus* species) are able to prosper in sand, and these were by far the most conspicuous.

The marine benthic flora quantified along each of the seven transects are presented in Fig. 5. The histogram is based on twenty tosses of the quadrat per transect. Species were lumped according to four functional groups, i.e., turf (algae less than 2 cm high), macroalgae (fleshy, erect), seagrasses, and coralline algae. Since coverage was low two additional groups, i.e., sand/rubble and corals (no distinction was made between living and dead corals), are also depicted. A heavy black line partitions these two groups from the others.

Table 7 . Checklist of marine algae recorded from the vicinity of transects 1-7, proposed fish cannery site, Dublon Island, Truk E.C.I. 1-4 April 1977.

Species	Transect 1	2	3	4	5	6	7
CYANOPHYTA (blue-green algae)							
Anacystis sp.	X	X	X	X			X
Hormothamnion sp.	X						X
Microcoleus lyngbyaceus (Kütz.) Crouan	X	X	X	X	X	X	X
Schizothrix calcicola (Ag.) Gomont	X	X	X		X	X	X
Schizothrix mexicana Gomont	X	X	X	X	X	X	X
CHLOROPHYTA (green algae)							
Avrainvillea obscura J. Ag.			X			X	X
Boodlea composita (Harv.) Brand	X					X	
Caulerpa brachypus Harvey				X		X	X
Caulerpa cupressoides (West) C. Ag.	X	X			X	X	X
Caulerpa filicoides Yamada	X	X	X	X	X	X	X
Caulerpa racemosa (Forsk.) J. Ag.	X	X	X	X	X	X	X
Caulerpa serrulata (Forsk.) J. Ag.	X				X		X
Caulerpa sertularioides (Gmel.) Howe	X					X	X
Caulerpa webbiana Montagne				X		X	X
Cladophoropsis sp.		X	X		X	X	
Dictyosphaeria cavernosa (Forsk.) Boerg.				X		X	X
Enteromorpha sp.	X						
Halimeda cylindracea Decaisne	X	X	X		X	X	
Halimeda discoidea Decaisne		X			X	X	X
Halimeda gigas Taylor				X			
Halimeda incrassata (Ellis) Lamx.			X		X		X
Halimeda macroloba Decaisne	X	X	X	X	X	X	X
Halimeda macrophysa Askenasy				X		X	
Halimeda micronesica Yamada	X						X
Halimeda opuntia (L.) Lamx.		X	X	X	X	X	X
Neomeris vanbosseae Howe		X		X		X	

Table 7. (Continued)

Species	Transect 1	2	3	4	5	6	7
<u>Rhipilia</u> <u>orientalis</u> Yamada					X		
<u>Tydemannia</u> <u>expeditionis</u> W. v. Bosse			X	X		X	X
<u>Udotea</u> <u>argentea</u> Zanard		X	X			X	X
<u>Udotea</u> <u>geppii</u> Yamada			X				
PHAEOPHYTA (brown algae)							
<u>Dictyota</u> <u>bartayresii</u> Lamx.		X	X	X	X	X	X
<u>Dictyota</u> <u>patens</u> J. Ag.			X	X		X	
<u>Ectocarpus</u> <u>breviarticulatus</u> J.Ag.	X		X				
<u>Feldmannia</u> <u>indica</u> (Sonder) Womersley			X				
<u>Hydroclathrus</u> <u>clathratus</u> (Bory) Howe	X						
<u>Lobophora</u> <u>variegata</u> (Lamx.) Womersley			X	X		X	X
<u>Padina</u> <u>jonesii</u> Tsuda		X	X	X			
<u>Padina</u> <u>tenuis</u> Bory	X	X	X			X	
<u>Rosenvingea</u> <u>intricata</u> (J. Ag.) Boerg.			X	X			
<u>Sphacelaria</u> <u>tribuloides</u> Meneghini	X						
<u>Turbinaria</u> <u>ornata</u> (Turn.) J. Ag.					X	X	X
RHODOPHYTA (red algae)							
<u>Actinotrichia</u> <u>fragilis</u> Boerg.				X	X	X	X
<u>Amphiroa</u> <u>foliacea</u> Lamx.		X		X		X	X
<u>Amphiroa</u> <u>fragilissima</u> Lamx.			X	X		X	X
<u>Asparagopsis</u> <u>taxiformis</u> (Delile) Collins					X	X	
<u>Centroceras</u> <u>clavulatum</u> (C. Ag.) Mont.	X	X					X
<u>Ceramium</u> <u>gracillimum</u> Griff.	X				X		
<u>Ceramium</u> <u>sympodiale</u> Dawson	X	X				X	
<u>Corallina</u> <u>pinnatifolia</u> Dawson			X				X
<u>Galaxaura</u> <u>fascicularis</u> Kjellman			X	X		X	
<u>Gelidiopsis</u> <u>intricata</u> (Ag.) Vickers		X				X	
<u>Gelidium</u> <u>divaricatum</u> Martens		X				X	
<u>Herposiphonia</u> <u>tenella</u> (C. Ag.) Nageli	X						

Table 7. (Continued)

Species	Transect 1	2	3	4	5	6	7
Herposiphonia sp.	X						
Hypnea pannosa J. Ag.			X	X		X	X
Jania capillacea Harvey							X
Polysiphonia howei Hollenberg		X	X			X	
Porolithon sp.				X			X
Pterocladia parva Dawson		X					
Tolypiocladia glomerulata (Ag.) Schmidt						X	
ANTHOPHYTA (seagrasses)							
Enhalus acoroides (L.f.) Royle	X	X				X	
Halophila ovalis (R. Br.) Hook	X						
Thalassia hemprichii (Ehrenb.) Aschers	X	X				X	X
NUMBER OF SPECIES PER TRANSECT OR IN IMMEDIATE VICINITY	27	26	28	25	19	39	33

TOTAL NUMBER OF GENERA 43

TOTAL NUMBER OF SPECIES 63

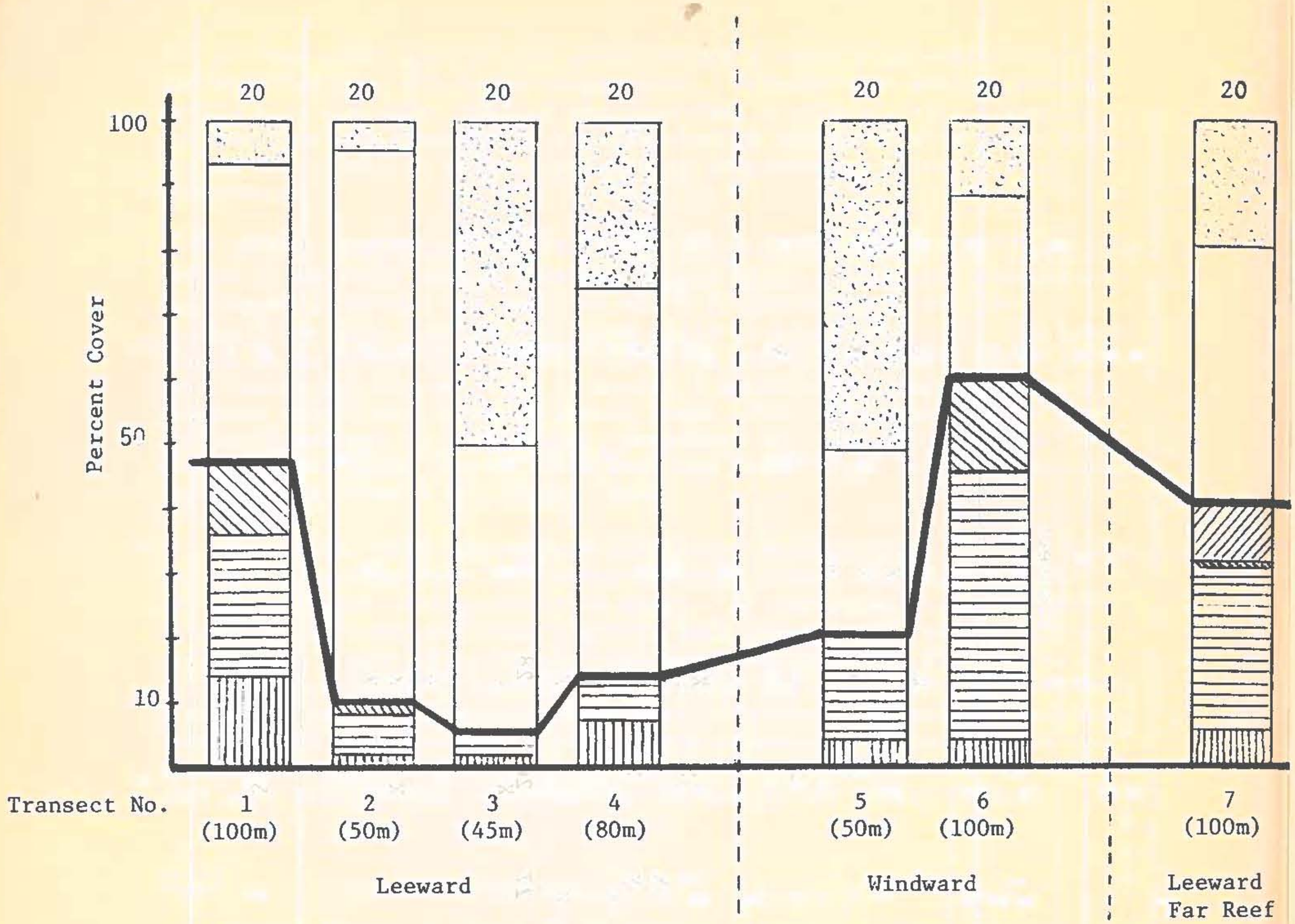

Figure 5. Percent cover of each functional group of marine plants, quantified along the seven transects. The number above each bar denotes the number of tosses on which the analyses are based. The heavy black line separates marine plants from sand and coral. Vertical hatching= turf; horizontal hatching=macroalgae; down-right hatching=seagrass; down-left=coralline algae; unshaded=sand/rubble; dotted=coral.

Enhalus acoroides, Halophila ovalis and Thalassia hemprichii accounted for approximately 20% of the cover at Transects 1 and 6, which intersected portions of large inshore patches of seagrass. Macroalgae predominated over turf forms by approximately 4:1 along the transects. This again reflects the lack of hard substratum. Halimeda cylindracea, Halimeda macroloba, Halimeda opuntia, Udotea argentea, Dictyota patens and Padina jonesii accounted for 90% of the algae observed at Transects 2, 3 and 4. A 13% coralline algal cover was observed at Transect 7.

Distinctive algal zones were recognized at the study site on the basis of qualitative observations. Because of insufficient sample size 10-m incremental quantification was not possible.

The dredge and fill zone typically extended 10-15 m out from the causeway. The predominant genera included Anacystis, Microcoleus, Schizothrix, Enteromorpha, Ectocarpus, Feldmannia, Padina, Gelidium and Polysiphonia. Other genera were observed but were comparatively rare.

The reef flat was divided into two zones, seagrass and coral-sand, respectively. Algal cover was the most variable in these two zones, based on the relative percentage of sand and coral. Expanses of sand were interspersed with large and small patches of corals and algae. Considerable differences were also noted between the leeward and windward sides of the causeway, the latter being much richer in algal cover and diversity.

At Transect 1 the seagrass zone extended out approximately 60 m from the causeway, beyond which sand and coral patches predominated. Algal cover was approximately 35%, with 24 species being observed.

Transects 2, 3 and 4, travered areas of very low algal abundance. Most of the substrate consisted of sand and rubble.

The richest algal areas occurred at Transects 5 and 6 on the windward side of the causeway. Forty-three of the 63 species found at the study site were observed in the vicinity of the two transects. The most conspicuous genera were Halimeda, Caulerpa, Neomeris, Dictyota, Turbinaria, Amphiroa and Asparagopsis; many smaller forms were also evident.

Transect 7 had an algal cover of approximately 40% but exhibited much less patchiness than the others. With the exception of the 20-m point, plants were observed along the entire length of the transect.

The marine plants observed at the study site were quite diverse in those areas with suitably hard substrata; but most of the area, especially on the leeward side of the causeway (Transects 1-4), was composed of sand. The rich "patches," however, seemed to provide ample food and shelter for herbivorous fishes and invertebrates.

Corals--The fringing reef at the study site supports a moderately diverse coral community consisting of 35 genera and 102 species (Table 8). Similar fringing reefs investigated in Palau and Yap Lagoons have coral communities consisting of 48 genera and 163 species (Birkeland et al., 1976) and 31 genera and 81 species (Amesbury et al., 1976) respectively. All three of these study sites represent regions of previous disturbance and the total species diversity at all three locations would probably be higher in nearby more pristine habitats.

Coral density and percentage of substratum covered by corals vary considerably from transect to transect (Table 9). These differences are for the most part truly reflective of the variation in coral community structure and development from place to place within the study area. The low coral density and substratum coverage reported at Transect 1, however, are not a good measure of the coral development there because only the inner part of the reef flat (coral-algae-sand zone) was quantitatively investigated. Qualitative investigations of the outer part of this zone showed it to be more similar to the values found on Transects 2 and 3. Coral density and substratum coverage on the reef flat (coral-algae-sand zone) at Transect 6 was found to be quite low because of the presence of a dense mat of benthic algae which covered most of the surface. At places the algal mat was overgrowing and killing small _Pocillopora damicornis_ colonies. In general the greatest coral coverage was found along the upper lagoon slopes and outer part of the reef flat (coral-algae-sand zone). At some places coral growth extended further down the lagoon slopes, while at other places tongues of sand and rubble with little coral growth penetrated upward into the outer reef flat (coral-algae-sand zone). Coral coverage was particularly high (29.33%) on the lagoon slope at Transect 3, where a large assemblage of _Porites_ colonies extended well down the slope. Coral coverage, density, and species diversity attenuated both down the lagoon slope toward the lagoon floor and in a shoreward direction from the upper lagoon slope and outer reef-flat platform.

The coral community showed less variation in total species composition between the transects (Table 8) than in coral density and coverage (Table 9). The species diversity lists are of a qualitative nature and are much less sensitive to variation in the development and structure of the coral community. Greater species diversity was found on the concrete pier face at the shoreward end of Transect 4 than at any other location. Effects of sediments are minimal on these vertical pier surfaces and competition from fleshy benthic algae appeared to be less intense, which might account for the higher species diversity found there. Coral diversity was for the most part greater on the south side of the pier than on the north side. This may be due to less favorable conditions for coral growth on the north side, where the water was found to be considerably more turbid.

Reef growth was better developed and coral density and substratum coverage was higher overall on Transect 7 than on the north and south sides of the pier at Transects 1-6. Although species diversity was not

Table 8. List of corals observed within the study area.

CORALS	TRANSECT 1	2	3	4	5	6	7
CLASS ANTHOZOA							
ORDER SCLERACTINIA							
FAMILY ASTROCOENIIDAE							
Stylocoeniella armata (Ehrenberg)	x			x			x
FAMILY THAMNASTERIIDAE							
Psammocora contigua (Esper)	x	x	x		x		x
Psammocora (Stephanaria) togianensis (Umbgrove)		x	x			x	x
Psammocora nierstrasi van der Horst			x				
FAMILY POCILLOPORIDAE							
Seriatopora hystrix Dana				x			
Pocillopora damicornis (Linnaeus)	x	x	x	x	x	x	x
Pocillopora danae Verrill	x	x	x	x	x	x	x
Pocillopora meandrina Dana				x		x	x
Pocillopora setchelli Hoffmeister		x		x			
Pocillopora verrucosa (Ellis & Solander)	x	x	x	x	x	x	x
Pocillopora sp. 1				x			
Pocillopora sp. 2			x		x	x	x
FAMILY ACROPORIDAE							
Acropora abrotanoides (Lamark)						x	
Acropora acuminata Verrill				x		x	
Acropora arbuscula (Dana)				x			
Acropora aspera (Dana)	x				x		x
Acropora clathrata (Brook)				x			
Acropora convexa (Dana)				x			x
Acropora cymbicyathus (Brook)				x			x
Acropora diversa (Brook)	x						
Acropora echinata (Dana)	x	x			x		x
Acropora florida (Dana)			x				x
Acropora formosa (Dana)	x	x		x	x		x
Acropora humilis (Dana)				x		x	x
Acropora hyacinthus (Dana)				x	x	x	x
Acropora kenti (Brook)		x	x				
Acropora murrayensis Vaughan	x	x	x		x	x	x
Acropora nasuta (Dana)	x	x		x	x	x	x
Acropora polymorpha (Brook)	x	x	x	x	x	x	x
Acropora virgata (Dana)					x		
Acropora sp. 1		x		x			
Acropora sp. 2	x						
Astreopora gracilis Bernard					x		
Astreopora myriophthalma (Lamark)				x			

Table 8. (continued)

CORALS	TRANSECT 1	2	3	4	5	6	7
Montipora ehrenbergii Verrill		x					
Montipora elschneri Vaughan							x
Montipora hoffmeisteri Wells			x				
Montipora prolifera Bernard	x	x	x	x		x	
Montipora socialis Bernard	x						x
Montipora tuberculosa (Lamarck)	x	x					
Montipora venosa (Ehrenberg)		x					
Montipora sp. 1 (tuberculate)	x		x				
Montipora sp. 2 (papillate)		x	x		x		
FAMILY AGARICIIDAE							
Pavona (*Polyastra*) *obtusata* (Quelch)	x	x	x		x	x	x
Pavona (*Polyastra*) *venosa* Ehrenberg			x	x	x		
Pavona (*Polyastra*) sp. 1				x			x
Pavona sp. 2 (encrusting)			x				
Pachyseris rugosa (Lamarck)		x	x				x
Pachyseris speciosa (Dana)			x	x			
FAMILY FUNGIIDAE							
Fungia echinata (Pallas)				x			
Fungia fungites (Linnaeus)	x	x	x	x			x
Fungia repanda Dana	x	x	x		x	x	x
Herpentoglossa simplex (Gardiner)			x				
Herpolitha limax (Esper)		x	x				
Polyphyllia talpina (Lamarck)			x				
FAMILY PORITIDAE							
Porites andrewsi Vaughan	x	x	x	x	x	x	x
Porites australiensis Vaughan				x	x		x
Porites compressa Dana	x		x	x			x
Porites lichen Dana					x		
Porites lutea Milne-Edwards & Haime	x	x	x	x	x	x	x
Porites murrayensis Vaughan	x	x			x		x
Porites sp. 1		x					
Porites sp. 2		x					
Porites sp. 3		x					
Porites (*Synaraea*) *convexa* Verrill	x	x	x	x	x	x	x
Porites (*Synaraea*) *horizontalata* Hoffmeister				x			
Porites (*Synaraea*) *iwayamaensis* Eguchi		x	x	x			
Porites (*Synaraea*) sp. 1		x					
Goniopora lobata Milne-Edwards & Haime			x	x	x		x
Goniopora tenuidens (Quelch)		x					x
Goniopora sp. 1		x					

Table 8. (continued)

CORALS	TRANSECT 1	2	3	4	5	6	7
Alveopora sp. 1		x					
FAMILY FAVIIDAE							
Bikiniastrea laddi Wells				x	x		
Favia matthai Vaughan			x	x			x
Favia pallida (Dana)	x	x	x	x	x	x	x
Favia stelligera (Dana)				x			
Favites flexuosa (Dana)		x		x			x
Favites palauensis (Yabe & Sugiyama)		x	x			x	x
Favites pentagona (Esper)		x					x
Favites virens (Dana)				x			
Favites sp. 1		x	x				x
Plesiastrea versipora (Lamarck)				x			
Plesiastrea sp. 1	x						
Goniastrea parvistella (Dana)			x		x		
Goniastrea retiformis (Lamarck)				x			
Oulophyllia crispa (Lamarck)		x					x
Leptastrea bottae (Milne-Edwards & Haime)	x	x					
Cyphastrea microphthalma (Lamarck)				x			
Diploastrea heliopora (Lamarck)		x	x				x
FAMILY OCULINIDAE							
Acrhelia horrescens (Dana)			x	x			
FAMILY MUSSIDAE							
Lobophyllia corymbosa (Forskaal)	x				x		x
Lobophyllia costata (Dana)	x			x	x		x
Lobophyllia sp. 1				x			
Symphyllia valenciennesii Milne-Edwards and Haime					x		
FAMILY MERULINIDAE							
Clavarina scrabicula Dana	x	x	x	x	x	x	x
FAMILY PECTINIIDAE							
Pectinia lactuca (Pallas)		x		x			
FAMILY CARYOPHYLLIIDAE							
Plerogyra sinuosa (Dana)			x				
Physogyra lichtensteini (Milne-Edwards and Haime		x					x

Table 8. (continued)

CORALS		TRANSECT 1	2	3	4	5	6	7
FAMILY DENDROPHYLLIIDAE								
Tubastraea aurea (Quoy & Gaimard)					x			
ORDER COENOTHECALIA								
FAMILY-HELIOPORIDAE								
Heliopora coerulea (Pallas)		x	x		x			x
CLASS HYDROZOA								
ORDER MILLEPORINA								
FAMILY MILLEPORIDAE								
Millepora exaesa Forskaal		x	x	x	x	x	x	x
Millepora dichotoma Forskaal		x		x	x	x		x
TOTAL GENERA	35	15	21	20	24	16	11	19
TOTAL SPECIES	102	34	48	42	52	34	23	49

Table 9. Size distribution, frequency, density, and percent of substratum covered by stony corals in the fringing reef zones at the Dublon Island study site. Relative values of frequency, density, and percent of substratum covered are also given and an importance value is calculated from the sum of these three relative values. The procedures for calculating the statistics in the columns from the data obtained by the point-quarter sampling technique are explained in the Methods section. The standard symbols are used for the number of data (n), arithmetic mean ($\bar{Y}$), standard deviation (s), and range (w).

TRANSECT No. 1	Size Distribution of Colonies (Dia. in cm) n	$\bar{Y}$	s	w	Frequency	Relative Frequency	Density Per m^2	Relative Density	Percent of Cover	Relative Percent of Cover	Importance Value
Reef Flat (Dredge and Fill and Seagrass Zones, 0-70 meters) (no corals encountered)											
Reef Flat (Coral-Algae-Sand Zone, 70-100 meters)											
Pocillopora damicornis	6	10.67	3.39	7-16	.75	33.33	.55	37.50	.53	67.95	138.78
Porites lutea	8	5.63	2.45	2-8	1.00	44.44	.74	50.00	.22	28.21	122.65
Porites andrewsi	2	3.5	3.54	1-6	.50	22.23	.18	12.50	.02	3.84	38.57
Overall Density 1.47 Corals Per m^2											
Overall Percent of Substratum Coverage 0.78%											
Lagoon Slope (not investigated)											

TRANSECT No. 2	Size Distribution of Colonies (Dia. in cm) n	$\bar{Y}$	s	w	Frequency	Relative Frequency	Density Per m^2	Relative Density	Percent of Cover	Relative Percent of Cover	Importance Value
Reef Flat (Dredge and Fill Zone, 0-10 meters) (no corals encountered)											
Reef Flat (Coral-Algae-Sand Zone, 10-30 meters)											
Porites lutea	9	9.56	16.46	1.52	1.00	60.24	2.03	75.00	5.30	87.03	222.27
Acropora formosa	1	21.00	-	-	.33	19.88	.22	8.33	.76	12.48	40.69
Pocillopora damicornis	2	3.00	0.00	3-3	.33	19.88	.45	16.67	.03	.49	37.04
Overall Density 6.09 Corals Per m^2											
Overall Percent of Substratum Coverage 2.70%											
Lagoon Slope (Coral Zone, 30-50 meters)											
Porites lutea	2	40.50	12.02	32-49	1.00	50.00	.41	40.00	5.52	70.32	160.32
Millepora exaesa	2	21.50	4.95	18-25	.50	25.00	.41	40.00	1.54	19.62	84.62
Goniopora sp. 1	1	22.00	-	-	.50	25.00	.21	20.00	.79	10.06	55.06
Overall Density 1.03 Corals Per m^2											
Overall Percent of Substratum Coverage 7.85%											
TRANSECT No. 3											
Reef Flat (Dredge and Fill Zone, 0-10 meters) (no corals encountered)											
Reef Flat (Coral-Algae-Sand Zone, 10-20 meters)											
Pocillopora damicornis	4	8.50	6.25	2-17	.50	25.00	1.26	50.00	1.01	38.70	113.70
Porites lutea	1	23.00	-	-	.50	25.00	.31	12.50	1.29	49.42	86.92
Porites (S.) convexa	2	4.00	1.41	3-5	.50	25.00	.63	25.00	.09	3.45	53.45
Porites compressa	1	9.00	-	-	.50	25.00	.31	12.50	.22	8.43	45.93
Overall Density 2.51 Corals Per m^2											
Overall Percent of Substratum Coverage 2.61%											

	Size Distribution of Colonies (Dia. in cm) n	$\bar{Y}$	s	w	Frequency	Relative Frequency	Density Per m^2	Relative Density	Percent of Cover	Relative Percent of Cover	Importance Value
Lagoon Slope (Coral Zone, 20-45 meters)											
Pavona (P.) obtusata	2	21.00	18.38	8-34	1.00	28.55	1.61	25.00	7.61	25.95	79.50
Porites andrewsi	1	40.00	-	-	.50	14.29	.81	12.50	10.23	34.88	61.67
Goniopora sp. 1	2	13.00	11.31	5-21	.50	14.29	1.61	25.00	2.94	10.02	49.31
Porites lutea	1	27.00	-	-	.50	14.29	.81	12.50	4.63	15.79	42.58
Porites (S.) convexa	1	19.00	-	-	.50	14.29	.81	12.50	2.30	7.84	34.63
Millepora exaesa	1	16.00	-	-	.50	14.29	.81	12.50	1.62	5.52	32.31
Overall Density 6.46 Corals Per m^2											
Overall Percent of Substratum Coverage 29.33%											
TRANSECT No. 4											
No Quantitative Coral Data Collected											
TRANSECT No. 5											
Reef Flat (not present on this transect)											
Lagoon Slope (Dredge and Fill Zone, 0-10 meters) (no corals encountered)											
Lagoon Slope (Coral Zone, 10-60 meters)											
Millepora exaesa	8	14.38	7.03	4-22	.83	29.22	.90	36.35	1.74	37.02	102.59
Porites lutea	4	20.00	15.06	8-42	.50	17.60	.45	18.18	2.00	42.55	78.33
Pocillopora verrucosa	5	5.60	2.07	4-9	.67	23.59	.56	22.73	.15	3.19	49.51
Acropora formosa	2	9.00	1.41	8-10	.33	11.62	.23	9.09	.15	3.19	23.90
Acropora virgata	1	22.00	-	-	.17	5.99	.11	4.55	.42	8.94	19.48
Porites murrayensis	1	17.00	-	-	.17	5.99	.11	4.55	.23	4.89	15.43
Favia amicorum	1	3.00	-	-	.17	5.99	.11	4.55	.01	.22	10.76
Overall Density 2.47 Corals Per m^2											
Overall Percent of Substratum Coverage 4.70%											

TRANSECT No. 6	Size Distribution of Colonies (Dia. in cm) n	$\bar{Y}$	s	w	Frequency	Relative Frequency	Density Per m^2	Relative Density	Percent of Cover	Relative Percent of Cover	Importance Value
Reef Flat (Dredge and Fill Zone, 0-10 meters) (no corals encountered)											
Reef Flat (Seagrass Zone, 10-50 meters)											
<u>Pocillopora damicornis</u>	10	7.90	4.09	2-13	1.00	100.00	.43	100.00	.26	100.00	300.00
Overall Density 0.43 Corals Per m^2											
Overall Percent of Substratum Coverage 0.26%											
Reef Flat (Coral-Algae-Sand Zone, 50-100 meters)											
<u>Porites andrewsi</u>	8	13.38	13.19	2-43	.80	36.36	2.08	40.00	2.87	51.34	127.70
<u>Pocillopora damicornis</u>	4	7.00	6.38	1-16	.40	18.18	1.04	20.00	.65	11.63	49.81
<u>Porites lutea</u>	2	12.00	11.31	4-20	.40	18.18	.52	10.00	.84	15.03	43.21
<u>Acropora polymorpha</u>	3	9.33	2.31	8-12	.20	9.09	.78	15.00	.55	9.84	33.93
<u>Millepora exaesa</u>	2	10.50	.71	10-11	.20	9.09	.52	10.00	.43	7.69	26.78
<u>Pocillopora danae</u>	1	11.00	-	-	.20	9.09	.26	5.00	.25	4.47	18.56
Overall Density 5.20 Corals Per m^2											
Overall Percent of Substratum Coverage 5.59%											
Lagoon Slope (not investigated)											
TRANSECT No. 7											
Reef Flat (Coral-Algae-Sand Zone, 0-65 meters)											
<u>Acropora formosa</u>	7	29.71	16.09	7-50	.33	15.14	2.70	29.16	33.47	80.37	124.67
<u>Psammocora contigua</u>	6	5.33	3.01	3-11	.55	22.93	2.32	25.00	.66	2.26	50.19
<u>Porites andrewsi</u>	5	7.20	6.42	2-16	.33	15.13	1.94	20.82	1.24	4.25	40.20
<u>Porites compressa</u>	1	26.00	-	-	.17	7.80	.39	4.17	2.07	7.09	19.06
<u>Pocillopora damicornis</u>	1	17.00	-	-	.17	7.80	.39	4.17	.89	3.05	15.02
<u>Fungia fungites</u>	1	11.00	-	-	.17	7.80	.39	4.17	.37	1.27	13.24
<u>Acropora polymorpha</u>	1	10.00	-	-	.17	7.80	.39	4.17	.31	1.06	13.03
<u>Fungia repanda</u>	1	6.00	-	-	.17	7.80	.39	4.17	.11	.38	12.35
<u>Millepora exaesa</u>	1	5.00	-	-	.17	7.80	.39	4.17	.08	.27	12.27
Overall Density 9.30 Corals Per m^2											
Overall Percent of Substratum Coverage 29.20%											

Overall Density 9.30 Corals Per m²
Overall Percent of Substratum Coverage 29.20%

	Size Distribution of Colonies (Dia. in cm)				Frequency	Relative Frequency	Density Per m²	Relative Density	Percent of Cover	Relative Percent of Cover	Importance Value
	n	$\bar{Y}$	s	w							
Lagoon Slope (Coral Zone, 65-100 meters)											
Porites (S.) convexa	6	28.00	18.48	5-55	.50	22.23	1.14	37.50	9.60	55.54	115.27
Porites lutea	3	28.00	11.14	16-38	.25	11.11	.57	18.75	3.87	21.82	51.68
Acropora formosa	1	40.00	-	-	.25	11.11	.19	6.25	2.39	13.95	31.31
Pocillopora damicornis	2	12.50	2.12	11-14	.25	11.11	.39	12.50	.49	2.93	26.54
Montipora elschneri	1	22.00	-	-	.25	11.11	.19	6.25	.72	4.26	21.62
Acropora polymorpha	1	9.00	-	-	.25	11.11	.19	6.25	.11	.66	18.02
Millepora exaesa	1	9.00	-	-	.25	11.11	.19	6.25	.11	.66	18.02
Pocillopora verrucosa	1	4.00	-	-	.25	11.11	.19	6.25	.03	.18	17.54

Overall Density 3.05 Corals Per m
Overall Percent of Substratum Coverage 17.32%

higher there (Table 8), less time was spent making qualitative observations at Transect 7 than on the other transects and this may account for the lower number of species observed. Coral density for the reef flat (coral-algae-sand zone) was high at Transect 7 because of abundant patches of arborescent Acropora formosa and small ramose clusters of Porites andrewsi and Psammocora contigue growing there. Because of larger coral colony size on the lagoon slope at Transect 7 coral density was less but coral coverage was higher (Table 9).

Fishes--Approximately 65 species of fish were observed in the vicinity of the proposed cannery site (Table 10). The abundance and diversity of fishes was strongly influenced by the pattern of reef zonation. The dredged and filled areas along the margin of the dock were quite depauperate in fishes as were seagrass areas encountered on Transects 1 and 6. The reef flat coral-algae-sand-zone was occupied by a considerably richer fish fauna, and the lagoon slope fauna was even more diverse and abundant (Figures 6 and 7). Of the areas surveyed, the richest in terms of fish abundance and diversity was the reef lying off the Air Force installation: 46 of the total 65 species observed were found here, and 21 species were seen only on this reef. The damselfishes (Pomacentridae) and the wrasses (Labridae) were the best represented fish families (Table 10) and together accounted for more than 40% of the species seen. Typical food fishes such as the surgeonfishes (Acanthuridae), squirrelfishes (Holocentridae), rudderfishes (Kyphosidae), snappers (Lutjanidae), goatfishes (Mullidae), parrotfishes (Scaridae), groupers (Serranidae), and rabbitfishes (Siganidae), were not especially abundant; and some groups, for instance the jacks (Carangidae) and mullets (Mugilidae), were not seen at all. This does not imply that the edible fish resources of this area are negligible, however, as these groups are generally roamers and may occur periodically in large numbers. The richness of the assemblage of resident species indicates that the reef areas surveyed are "healthy," thriving communities and are presently under no undue stress.

Zooplankton--Zooplankton abundance and diversity was rather low in the area of the proposed cannery site (Table 11). The total density of planktonic organisms of a size appropriate to the mesh of the net varied from 24 to 90 per m^3. Plankton surveys elsewhere in Micronesia using the same net showed considerably greater density in lagoon environments: 318 organisms per m^3 in daytime samples in Apra Harbor, Guam (UGML, 1977), 413-710 organisms per m^3 in daytime samples in Tanapag Harbor, Saipan (Amesbury and Doty, 1977), and 617 organisms per m^3 in daytime samples off Ebeye, Kwajalein Atoll (Amesbury et al., 1975a). The plankton densities observed off Dublon are more similar to those in oceanic water off Majuro Atoll (54 organisms per m^3 ; Amesbury et al., 1975b).

The collections were dominated by copepods, larvaceans, and fish eggs, except for tow 5 in which fragments of benthic algae were the most numerous component. This tow was made in the area just downstream from the reef extending out from the Air Force facility, and this reef was no doubt the source of these algal fragments. The great majority of the

Table 10. Fishes observed at the proposed Dublon cannery site. A = observed in vicinity of cannery dock; B = observed on reef in vicinity of Air Force Dock; underlined numerals refer to transect numbers; following these are the 10-meter intervals within which fishes were observed, and, in parentheses, the number of individuals seen.

Acanthuridae

Acanthurus lineatus (Linnaeus) A; B
A. nigrofuscus Forskal A; 3:40-45(1)
A. triostegus (Linnaeus) B
Ctenochaetus striatus (Quoy & Gaimard) A; 2:30-40(2); 7:0-10(3); 20-30(2)
Naso unicornis (Forskal) B
Zebrasoma veliferum (Bloch) B
juv. acanthurids 2:0-10(1); 4:10-20(1); 5:20-30(1); 7:60-70(1), 80-90(1)

Apogonidae

Paramia quinquelineata (Cuvier & Valenciennes) 4:0-10(31)
juv. apogonids 4:70-78(25)

Atherinidae

unidentified atherinids A; 1:30-40(10); 7:60-70(40), 80-90(2), 90-100(5)

Balistidae

Rhinecanthus aculeatus (Linnaeus) 6:90-100(1)
R. verrucosus (Linnaeus) 2:10-20(1)

Blenniidae

Meiacanthus atrodorsalis (Gunther) A; B; 4:0-10(1), 60-70(1), 70-78(2)

Canthigasteridae

Canthigaster bennetti (Bleeker) 7:80-90(1)
C. solandri (Richardson) A

Chaetodontidae

Chaetodon auriga Forskal A; B; 1:80-90(2), 2:20-30(1); 5:10-20(1); 6:80-90(1); 7:80-90(1).
C. citrinellus Cuvier B
C. ephippium Cuvier B
C. kleini Bloch A; B
C. semeion Bleeker B
C. trifascialis Quoy and Gaimard B
C. trifasciatus Mungo Park 7:20-30(1)
C. ulietensis Cuvier 2:30-40(2)
C. vagabundus Linnaeus 7:20-30(1)

Table 10. (continued)

Eleotridae

Ptereleotris microlepis Bleeker 4:10-20(2); 5:10-20(2)

Gobiidae

Amblygobius albimaculatus (Ruppell) 2:0-10(1), 10-20(1); 3:20-30(2), 40-50(4); 4:10-20(2), 30-40(1); 5:10-20(2)
unidentified gobiids 1:0-10(2), 10-20(4), 20-30(3), 30-40(1), 80-90(4), 90-100(4); 2:0-10(1), 10-30(11), 20-30(2), 30-40(2), 40-50(1); 3:10-20(2), 30-40(1), 40-45(3); 4:10-20(1), 20-30(2), 30-40(3), 40-50(14); 6:10-20(2), 30-40(2); 7:80-90(1), 90-100(1)

Holocentridae

Flammeo sp. A
Myripristis sp. A; 4:0-10(1); 7:0-10(2)

Kyphosidae

Kyphosus cinarescens (Forskal) A

Labridae

Cheilinus fasciatus (Bloch) A
Cheilinus sp. 3:20-30(1); 4:70-79(1); 7:40-50(2)
Gomphosus varius Lacepede A; B
Halichoeres marginatus Ruppell 4:0-10(1); 7:50-60(1)
Hemigymnus melapterus (Bloch) B
Labrichthys unilineata Bleeker 2:30-40(1)
Labroides dimidiatus (Cuvier & Valenciennes) A
Macropharyngodon meleagris Seale 7:30-40(1)
Pseudocheilinus hexataenia (Bleeker) 2:20-30-(4), 30-40(1); 3:10-20(2), 20-30(6), 30-40(1); 4:0-10(2), 10-20(1), 20-30(3), 40-50(4), 50-60(1), 60-70(2); 5:0-10(2), 10-20(2), 20-30(10), 30-40(1), 40-50(5), 50-60(2); 6:80-90(6), 90-100(1); 7:0-10(3), 10-20(2), 20-30(1), 30-40(3), 40-50(7), 50-60(1), 60-70(2), 70-80(1), 80-90(1)
Stethojulis bandanensis Bleeker 1:80-90(1), 90-100(1); 6:60-70(1), 80-90(1), 90-100(1); 7:20-30(2), 30-40(5), 40-50(2), 50-60(1), 60-70(2), 70-80(1), 80-90(6)
Thalassoma hardwicki (Bennett) A; B; 7:4050(1)
T. lutescens (Lay & Bennett) A
T. quinquevittata (Lay & Bennett) A; 7:80-90(1)
juv. Thalassoma 5:20-30(1)
unidentified and juvenile labrids 1:30-40(1), 70-80(1), 90-100(3); 4:10-20(1), 20-30(1), 30-40(2), 40-50(1), 60-70(4); 5:10-20(2); 6:20-30(3), 60-70(2), 70-80(9), 90-100(12); 7:60-70(2).

Table 10. (continued)

Lutjanidae

Caesio caerulaureus Lacepede A; 4:0-10(25)
Lutjanus vaigiensis (Quoy & Gaimard) A
Monotaxis grandoculis (Forskal) 6:0-10(1)
Scolopsis cancellatus (Cuvier & Valenciennes) B

Mullidae

Parupereus trifasciatus (Lacepede) B; 5:10-20(4), 20-30(2), 30-40(1);
6:60-70(4), 80-90(2)

Pomacentridae

Abudefduf coelestrus (Cuvier) A; B
Amblyglyphidodon curacao (Bloch) A;2:20-30(45), 40-50(1); 3:20-30(1), 30-40(17),
40-45(6); 4:10-20(8); 7:0-10(16), 10-20(27),
30-40(15), 50-60(1), 60-70(3)
Chromis atripectoralis Welander & Schultz 7:10-20(1)
C. margaritifer Fowler 7:0-10(4), 20-30(1)
Dascyllus aruanus (Linnaeus) B; 4:0-10(4), 40-50(2), 60-70(2); 6:70-80(2)
Eupomacentrus lividus (Bloch & Schneider) 3:20-30(1); 4:60-70(1); 7:50-60(2),
70-80(1)
Glyphidodontops biocellatus (Quoy & Gaimard) 7:80-90(1)
G. leucopomus (Lesson) B
Plectroglyphidodon leucozona (Bleeker) 5:10-20(1); 6:80-90(3), 90-100(1);
7:30-40(1), 60-70(1), 70-80(2),
80-90(1)
Pomacentrus melanopterus Bleeker A
P. moluccensis Bleeker 3:10-20(1), 20-30(1), 30-40(1), 40-45(1); 4:0-10(2),
10-20(2), 60-70(1); 5:40-50(1); 7:30-40(1)
P. pavo (Bloch) A; 2:40-50(42), 50-55(13); 3:40-45(10); 4:0-10(1), 20-30(2);
5:40-50(1); 6:80-90(2); 7:20-30(29)
P. tripunctatus Cuvier 3:30-40(2), 40-45(1); 4:0-10(1), 50-60(1); 5:20-30(1),
40-50(1), 50-60(2); 6:90-100(1); 7:0-10(4), 10-30(1),
20-30(4), 40-50(4), 50-60(2)
P. vaiuli Jordan & Seale 2:30-40(1); 3:20-30(5), 30-40(4), 40-45(12);
4:10-20(9), 20-30(20), 30-40(6), 40-50(20), 50-50(8),
60-70(2), 70-78(8); 5:30-40(2), 40-50(1), 50-60(4);
7:0-10(1), 10-20(11), 20-30(1), 30-40(1)
juvenile pomacentrid 4:20-30(2)

Scaridae

Scarus ghobban Forskal B
S. sordidus Forskal B
S. troscheli Bleeker B
unidentified and juv. scarids A; B; 5:10-20(2); 7:60-70(6), 70-80(2), 80-90(5)

Serranidae

Calloplesiops altivelis (Steindachner) 4:40-50(1)
unidentified serranid B

Table 10. (continued)

Siganidae

Siganus puellus (Schlegel) B
juv. siganids 6:20-30(1)

Syngnathidae

unidentified syngnathid 4:0-10(1)

unidentified juvenile fishes 2:40-50(150); 3:40-45(300); 4:40-50(2), 60-70(1)

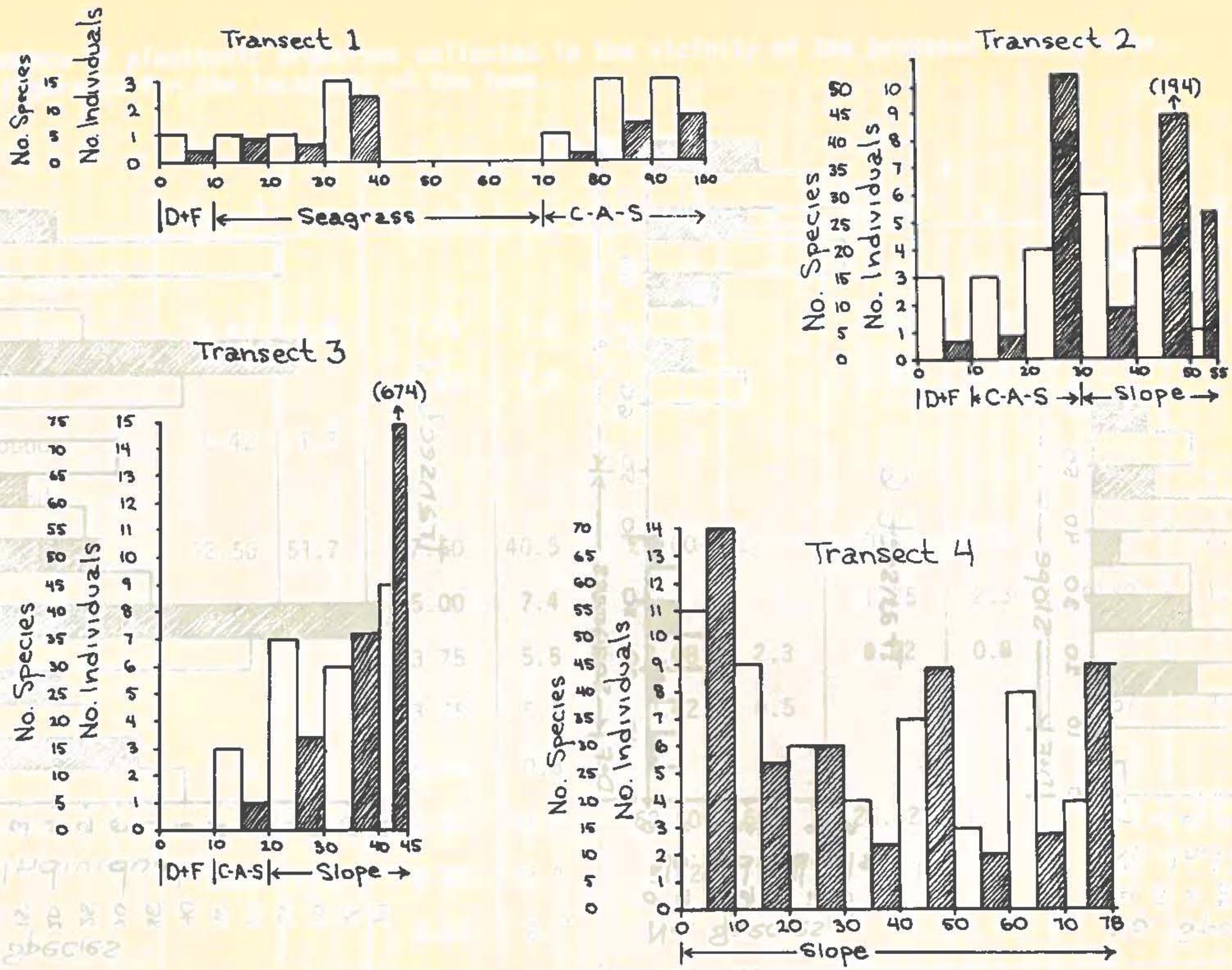

Figure 6. Fish diversity and abundance along transects 1 through 4. Fish are censused within 10-meter intervals along the transect lines (with occasional shorter intervals at the end of the line). The clear bar on the left within each transect interval indicates the number of species seen; the hatched bar to the right indicates the number of individual fish per 20 m^2. The general pattern of reef zonation is shown beneath each histogram. D+F = dredged and filled zone; C-A-S = coral, algae, sand zone.

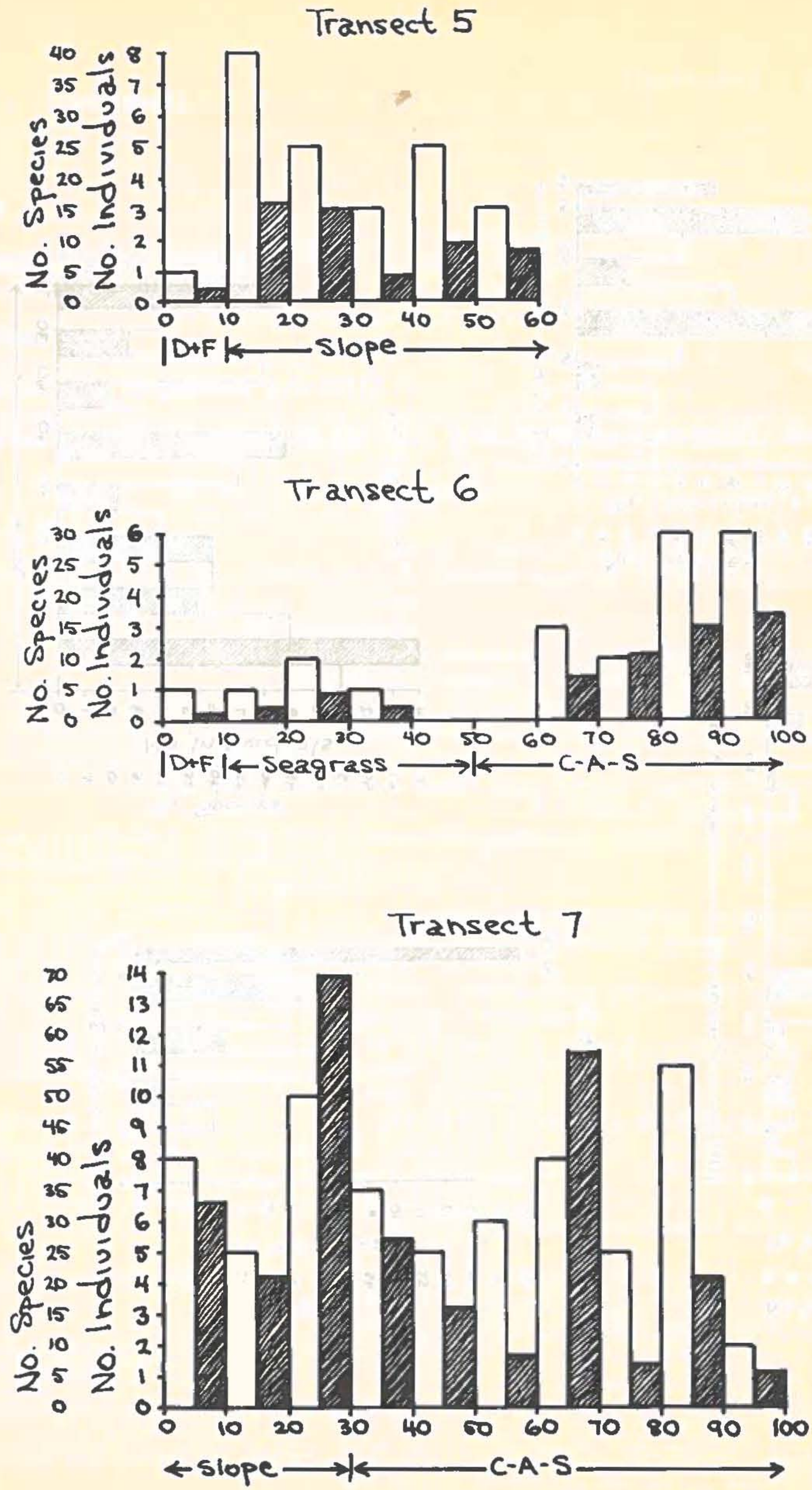

Figure 7. Fish diversity and abundance along transects 5 through 7. See caption to Figure 6 for explanation of symbols.

Table 11. Abundance of planktonic organisms collected in the vicinity of the proposed cannery site. See Figure 2C for the locations of the tows.

	TOW NUMBER 1		2		3		4		5	
	No./m^3	%	No./m^3	%	No./m^3	%	No./m^3	%	No./m^3	%
benthic algae fragments									17.08	48.2
foraminifera	0.83	3.5	1.25	1.8			0.42	0.8	0.42	1.2
medusae			0.83	1.2			0.42	0.8		
gymnosome pteropods	0.42	1.7								
thecosome pteropods									0.42	1.2
copepods	12.50	51.7	27.50	40.5	20.00	22.1	20.42	38.3	4.58	12.9
"shrimp" zoeae*			5.00	7.4			1.25	2.3	0.42	1.2
carb zoeae			3.75	5.5	2.08	2.3	0.42	0.8		
chaetognaths			3.75	5.5	0.42	0.5			1.67	4.7
salps	0.42	1.7	0.42	0.6						
larvaceans	6.67	27.6	16.67	24.5	62.50	69.1	25.42	47.7	8.33	23.5
fish eggs	3.33	13.8	8.33	12.3	5.42	6.0	5.00	9.4	2.50	7.1
fish larvae			0.42	0.6						
Total number/m^3	24.17		67.92		90.42		53.33		35.42	
Total volume/100 m^3	2.25 ml		2.00 ml		3.33 ml		1.67 ml		0.67 ml	

*This category includes all non-crablike zoeae fish eggs appeared to be those of parrotfishes (Scaridae), which indicates that parrotfishes were spawning in this area at the time of the survey. Crustacean larvae were quite sparse in the collections, but these are often most abundant in near-surface waters at night, and our daytime collections may have underestimated their true abundance in the area. The overall abundance and composition of the plankton most resembles oceanic plankton communities (as exemplified by the collections made off Majuro; Amesbury et al, 1975b) rather than a typical lagoon assemblage, suggesting that the water moving through this area has rather recently entered the lagoon over the barrier reef, and has not yet been thoroughly mixed with lagoon waters and their characteristic zooplankton communities.

CONCLUSIONS

Impact of Construction of Fishery Complex

The enlargement of the dock by the placing of fill material on the reef flat adjacent to it will result in approximately 4000 m^2 of reef area being covered. The area to be filled is that part of the reef that is presently rather depauperate in fishes and corals, although algae and seagrasses are thriving here. The construction and fill activities will no doubt cause silt to be suspended in the water and to be carried by prevailing water movements. The circulation studies described in this report indicate that suspended material will be carried toward the west-southwest onto the extensive reef extending out from the Air Force facility. This rather rich reef will be subject to increased sediment load during the construction period. If this period is protracted, damage to the less silt-tolerant reef species can be expected.

Impact of Operation of Fishery Complex

A variety of potential pollutants will be discharged in the area of the cannery once it is in operation: cannery wastes, domestic sewage, heated water from the power generator, petroleum products discharged from fishing vessels at the dock, etc. Heavier materials will move downward into the deep channel off the end of the dock. The water circulation appears to be strong enough to carry floating material away from the dock area, but much of this material can be expected to impinge on the reef extending out from the Air Force facility. The effects of these discharges on this reef will depend on the magnitudes of the various components: petroleum products, chlorine, and hot water may damage or drive away some reef organisms; cannery wastes and sewage may lead to nutrient enrichment and the enhancement of plant growth. Cannery wastes may provide a new source of food for fishes, including sharks, and it is quite likely that the abundance of certain species will increase.

Suitability of the Proposed Site

Because of the richness of reef areas in the Truk lagoon, it would be difficult to find any area that a facility of the type proposed would not adversely impact. As the currents were flowing in a westerly direction during the course of our studies, the implication is that a site on the southwestern corner of Dublon (area #1, the Nanko location, in the LMR report) would allow the various pollutants to be carried away from Dublon. However, in the absence of any current measurements in this area, it is difficult to predict just where these effluents might end up; it is conceivable that they might impinge on the reefs surrounding northern Fefan Island.

RECOMMENDATIONS

The proposed site is a reasonable choice. Although some reef damage can be expected, water circulation is strong enough to prevent any long-term build-up of discharged pollutants. Various effluents should be discharged off the end of the dock into Takeshima Channel rather than into areas with more restricted water circulation. The Nanko location is possibly a better choice from the environmental standpoint, but current patterns in this area would have to be determined before any definite recommendations could be made.

LITERATURE CITED

Amesbury, S. S. and J. E. Doty. 1977. The zooplankton of Tanapag Harbor. Chapter 10 in J. E. Doty and J. A. Marsh, Jr. (eds.), 1977, Marine survey of Tanapag Harbor, Saipan: the power barge "Impedence." Univ. Guam Mar. Lab. 33. pp. 114-117.

Amesbury, S. S., R. T. Tsuda, R. H. Randall, C. E. Birkeland, and F. A. Cushing. 1976. Limited current and underwater biological survey of the Donitsch Island sewer outfall site, Yap, Western Caroline Islands. Univ. Guam Mar. Lab. Tech. Rept. 24. 48 p.

Amesbury, S. S., R. T. Tsuda, W. J. Zolan, and T. L. Tansy. 1975a. Limited current and underwater biological surveys of proposed sewer outfall sites in the Marshall Island District: Ebeye, Kwajalein Atoll. Univ. Guam Mar. Lab. Tech. Rept. 22. 30 p.

Amesbury, S. S., R. T. Tsuda, W. J. Zolan, and T. L. Tansy. 1975b. Limited current and underwater biological surveys of proposed sewer outfall sites in the Marshall Island District: Darrit-Uliga-Dalap Area, Majuro Atoll. Univ. Guam Mar. Lab. Tech. Rept. 23. 30 p.

Birkeland, C., R. T. Tsuda, R. H. Randall, S. S. Amesbury, and F. A. Cushing. 1976. Limited current and underwater biological surveys of a proposed sewer outfall site on Malakal Island, Palau. Univ. Guam Mar. Lab. Tech. Rept. 25. 58 p.

Cottam, G., J. T. Curtis, and B. W. Hale. 1953. Some sampling characteristics of a population of randomly dispersed individuals: Ecology 34:741-757.

Marsh, J. A., Jr., and R. M. Ross. 1977. Oxygen and nutrients. Chapter 5 in J. E. Doty and J. A. Marsh, Jr. (eds.), 1977, Marine survey of Tanapag Harbor, Saipan: the power barge "Impedence." Univ. Guam Mar. Lab. Tech. Rept. 33. pp 61-67.

Strickland, J. D. H., and T. R. Parsons. 1968. A practical handbook of seawater analysis. FRBC Bulletin 167. Fisheries Research Board of Canada, Ottawa.

Tsuda, R. T. 1972. Morphological, zonational, and seasonal studies of two species of Sargassum on the reefs of Guam. Proc. Seventh International Seaweed Symp. Univ. Tokyo Press. pp. 40-44.

Tsuda, R. T., S. S. Amesbury, S. C. Moras, and P. P. Beeman. 1975. Limited current and underwater biological survey at the Point Gabert wastewater outfall on Moen, Truk. Univ. Guam Mar. Lab. Tech. Rept. 20. 39 p.

University of Guam Marine Laboratory. 1977. Marine Environmental baseline report, Commercial Port, Apra Harbor, Guam. Univ. Guam Mar. Lab. Tech. Rept. 34. 96 p.

PLATE I

Fig. a. Seagrass community on the reef-flat platfrom near Transect 1.

Fig. b. Iron wreckage and angular basaltic fill material on the outer submerged part of the pier at Dublon Is.

Fig. c. Sand and coral rubble with scattered mounds of massive *Porites* species dominate the upper lagoon slope at Transect 3.

Fig. d. A community of massive *Porites lutea* colonies forms a long ridge on the upper lagoon slope between Transects 3 and 6.

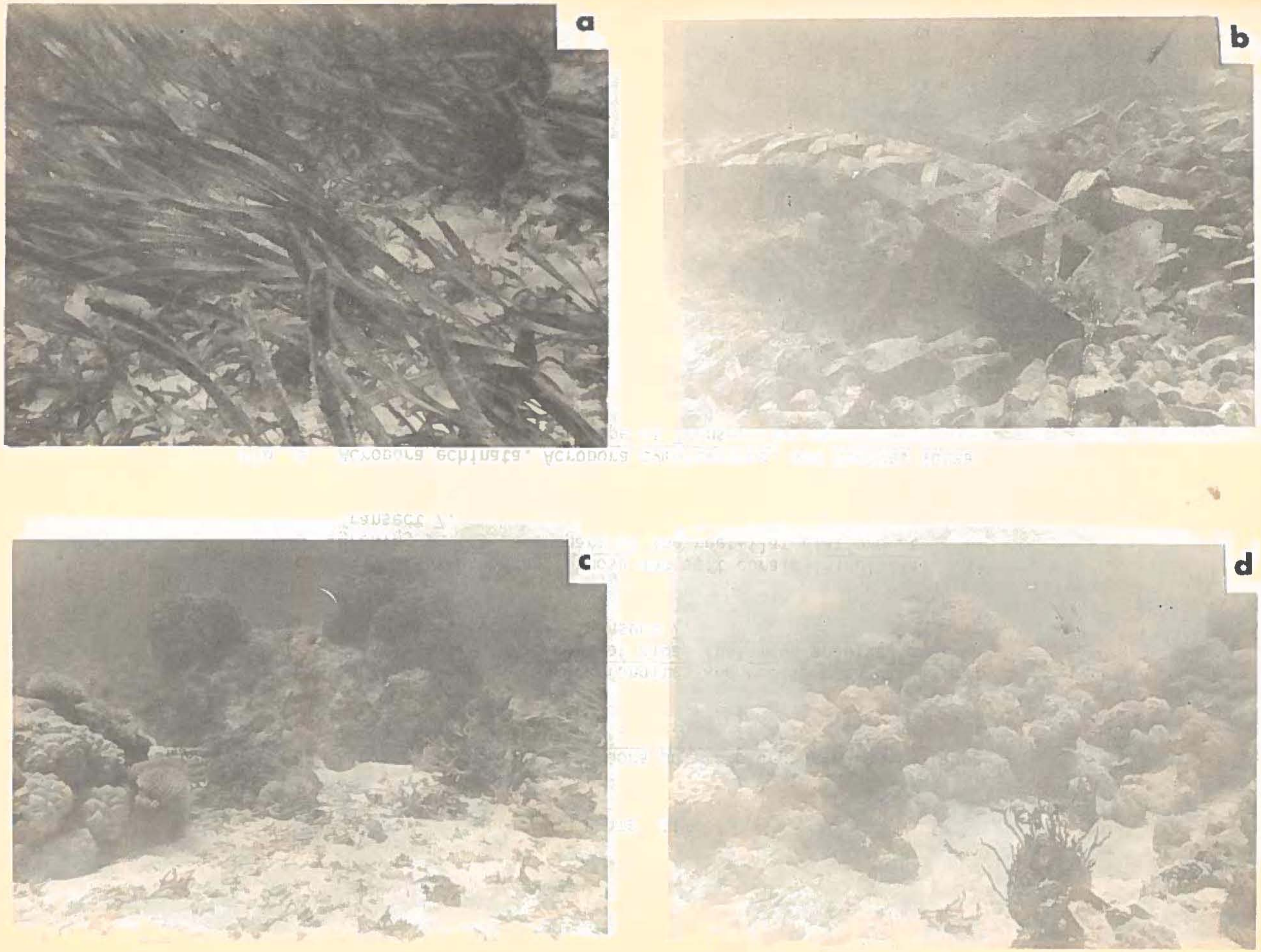
a
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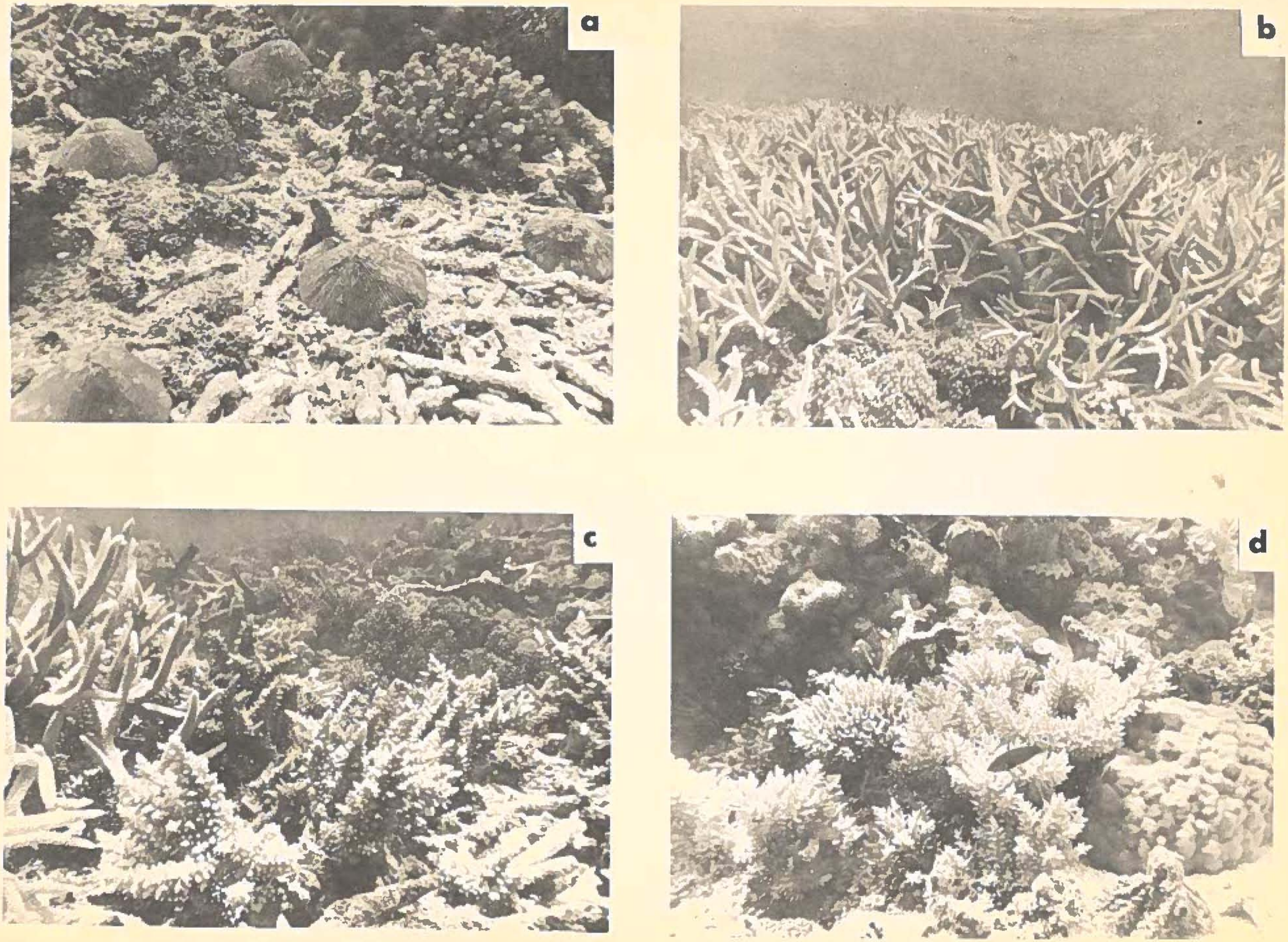
PLATE II

Fig. c. *Acropora formosa* and *Acropora polymorpha* growing on the upper lagoon slope at Transect 7.

Fig. a. Scattered corals (*Fungia fungites* and *Pocillopora verruosa*), coral rubble, and clumps of algae (*Halimeda opuntia*) on the reef-flat platform at Transect 7.

Fig. b. Thicket of *Acropora formosa* and soft corals (*Sinularia*) growing on the outer part of the reef-flat platform at Transect 7.

Fig. d. *Acropora echinata*, *Acropora cymbicyathus*, and *Porites lutea* growing on the lagoon slope at Transect 7.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b
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