MARINE BIOLOGICAL SURVEY
OF THE PROPOSED DOCK SITE
AT COLONIA, YAP

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INTRODUCTION

The University of Guam Marine Laboratory was asked by the U. S. Army Corps of Engineers to perform a survey of the biota of the proposed dock and harbor site at Colonia, Yap. The proposed site, on the north side of Colonia Peninsula, includes approximately 200,000 square feet of intertidal schistose rock and subtidal reef area, which extends from the present shoreline out to the edge of the existing channel to the north (Figure 1). The whole of the biota in this area will be removed or covered by the dredging and filling operation required for the construction of the dock. In order to assess the significance of this disruption of the environment, the Marine Laboratory survey team was requested to make a reconnaissance of the proposed dock site and to prepare a report which would include the following information:

1. A description of the qualitative conditions of the marine environment at the project site;
2. Discussion of the dominant coral, fish, algal, and invertebrate species found at the project site;
3. Discussion of the abundance and distribution of corals, fishes, algae, and invertebrates at the project site;
4. Discussion of the probable adverse effects of the projects on the marine resources found at the project site;
5. Recommendations for avoiding or mitigating adverse environmental impacts attributed to the project.

PERSONNEL

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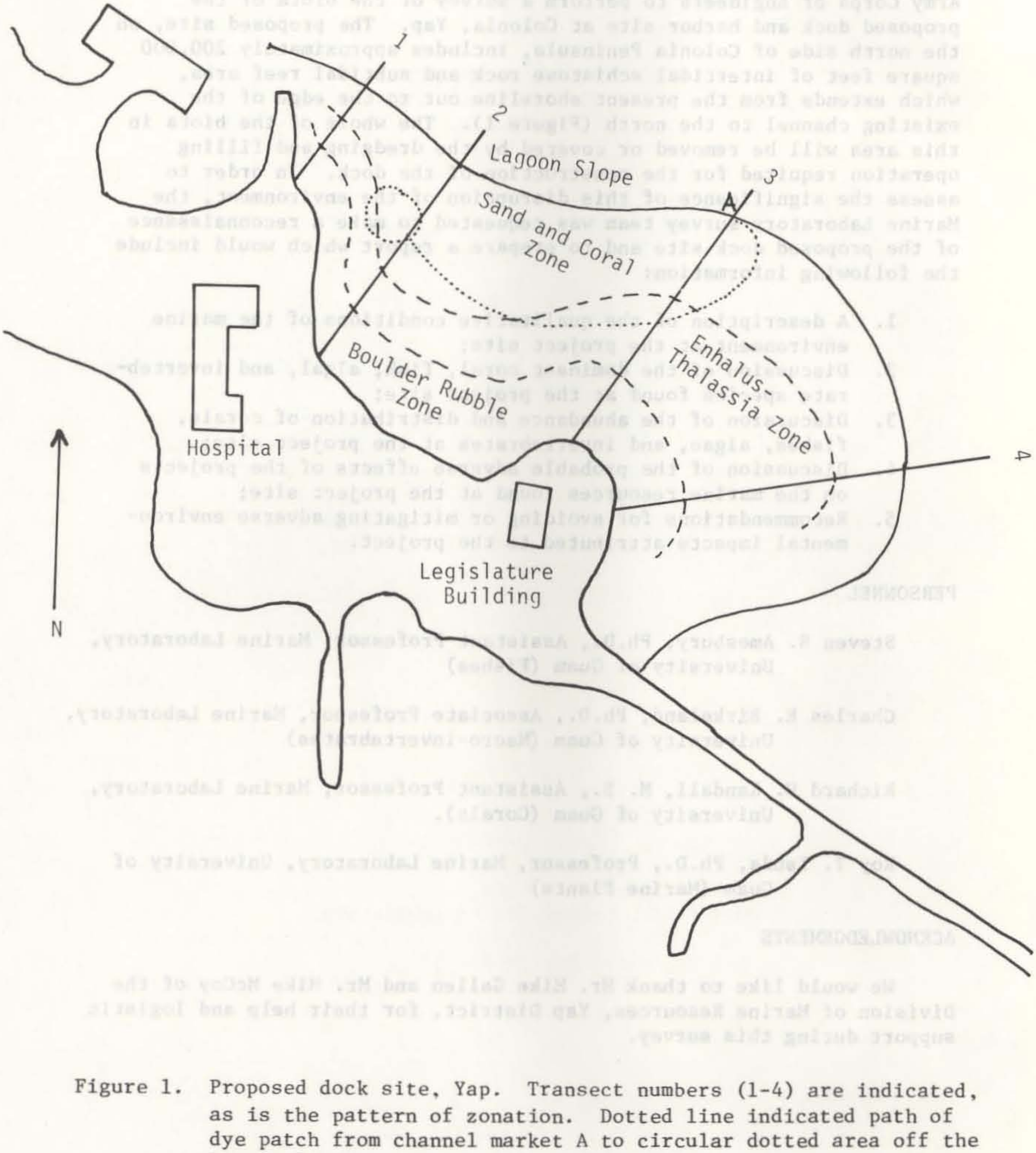

Figure 1. Proposed dock site, Yap. Transect numbers (1-4) are indicated, as is the pattern of zonation. Dotted line indicated path of dye patch from channel market A to circular dotted area off the hospital.

METHODS

The proposed dock site was visited from March 4 to 7, 1977. Four transects extending across the reef flat and down the slope to the channel floor, were established in the study area (Figure 2). The biota was quantified for each 10-meter interval along each of the four transects.

Marine plants were quantified by haphazardly tossing a 25 cm x 25 cm gridded quadrat with sixteen interior "points" (intersecting grid lines) five to ten times for each 10-meter transect interval. The percent cover or abundance was calculated by dividing the number of points at which each species was recorded by the total number of points (16 points x number of tosses) and multiplying by 100 to obtain a percent value.

Reef corals were quantified by a point-quarter technique (Cottam et al, 1953). At stations 5 meters apart (i.e., two per 10-meter interval along the transect), a point was selected somewhat randomly by dropping a collecting chisel. The orientation of the chisel was used to define perpendicular axes. Within each of the four quadrants delimited by these axes, the coral nearest the intersection point was located, and the species name, the diameter or basal area of the coral and the distance from the center of the coral to the point were recorded. By combining the data for all points falling within each of the various reef zones (see below), the percentage of substrate covered and the frequency of occurrence for each species encountered within a given zone was calculated. An importance value (IV) for each species was determined by summing the relative value of these two parameters. Overal density and percentage of substrate covered by living corals were also determined for each reef zone.

Large echinoderms and other macro-invertebrates which occurred within one meter of the transect line were enumerated for each 10-meter interval. A separate enumeration was made for the left side and the right side of the line in order that two censuses, each covering an area of 10 m^2, could be made for each 10-meter interval.

All fishes observed within one meter of either side of the transect line were recorded for each 10-meter interval.

Qualitative surveys of marine plants, corals, macro-invertebrates, and fishes in the study area and in an area on the opposite side of the channel (Figure 3) were also made so that more complete species lists could be compiled for the study site, and so that general comparisons could be made between the study site and the area across the channel.

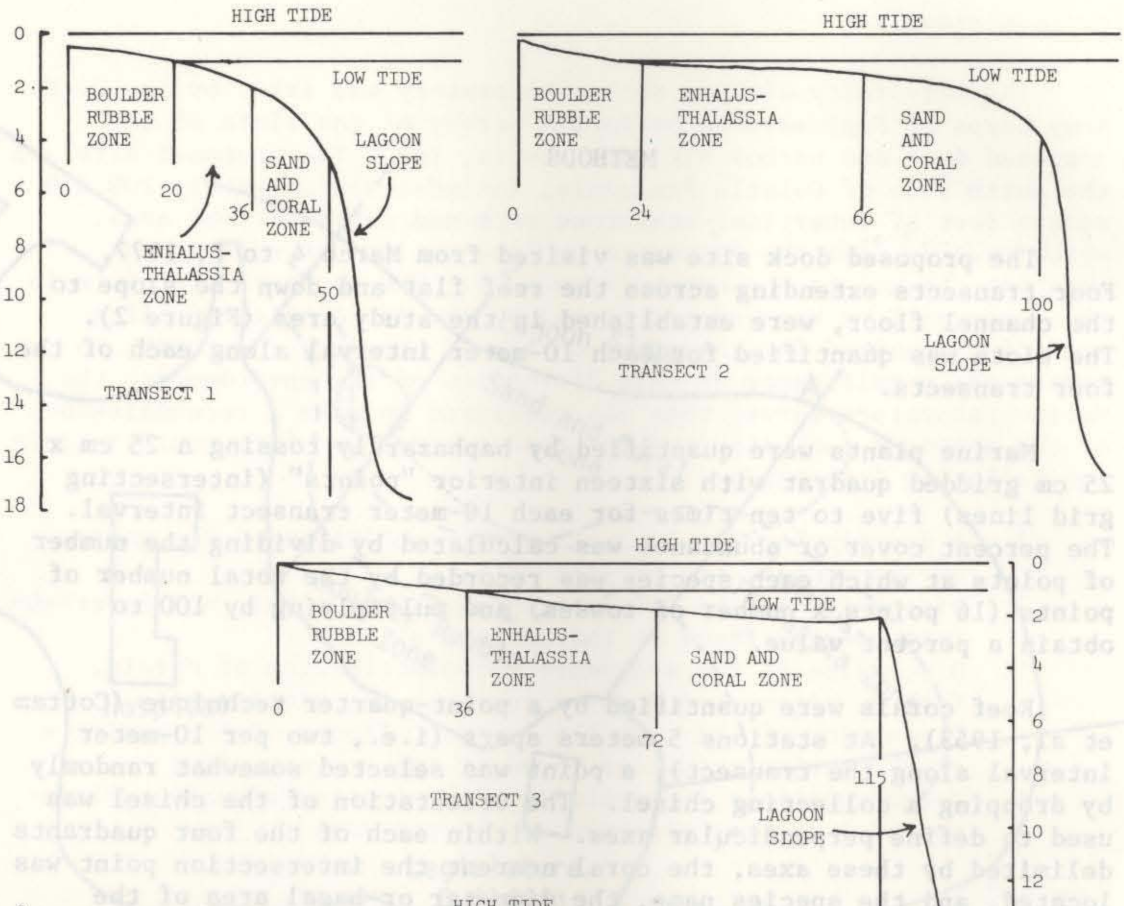

Figure 2. Depth profiles of the four transects showing boundaries of zones. Depth scale is in meters. Numbers at zone boundaries indicate distances along transect line. Vertical exaggeration X5.

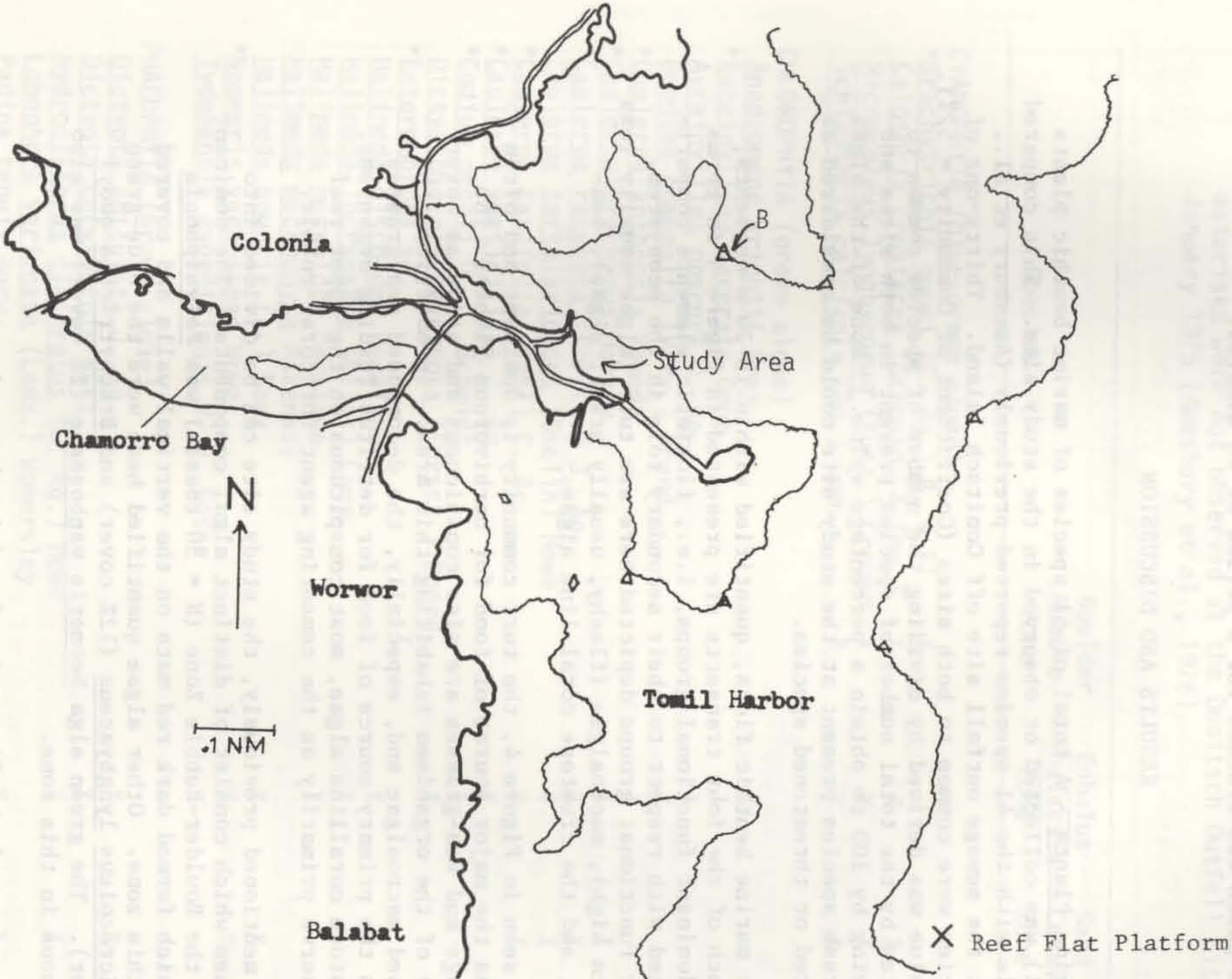

Figure 3. Map of Tomil Harbor showing study site, as well as channel Market B and reef flat platform where additional observations were made.

In order to assess the general pattern of water circulation at the study site, a patch of fluorescein dye was released at channel marker A at a depth of 2 meters on March 6, 1977, at 10:02 a.m. This dye patch was tracked for a period of 45 minutes.

RESULTS AND DISCUSSION

Marine Plants - A total of 51 species of marine benthic plants (Table 1) was collected or observed in the study site. This compared favorable with the 41 species reported previously (Amesbury et al., 1976) at the sewage outfall site off Conitsch Island. Thirty-one of the species were common to both sites (Coefficient of Community = 52%). [This value was derived by dividing the number of species common to both sites by the total number of species present in both sites and multiplying by 100 to obtain a percentage value.] None of the algal or seagrass species present at the study site could be considered as endangered or threatened species.

The marine benthic flora, quantified within 10-20 m segments, along each of the four transects are presented in Figure 4 in terms of the dominant functional groups, i.e., floristic elements compartmentalized with respect to their secondary role in the ecosystem. The four functional groups depicted here are turf (algae usually less than 2 cm high), macroalgae (fleshy, usually erect, algae), seagrasses, and the crustose coral-line algae.

As seen in Figure 4, the turf community is dominant and often serves as the major source of food for herbivorous fishes. The macroalage and sea-grasses are also conspicuous and serve as cover for many of the organisms inhabiting this area. In addition, the decomposed macroalgae and, especially, the decomposed sea-grasses serve as the primary source of food for detritus feeding organisms. The crustose coralline algae, most conspicuous on the upper reef slope, serve primarily as the cementing agent for coral rubble.

As mentioned previously, the study site can be divided into four zones which consist of distinct algal components. The dominant alga in the Boulder-Rubble Zone (N = 50 tosses) was Polysiphonia howei which formed dark red mats on the vertical walls and covered 37% of this zone. Other algae quantified here were the blue-green algae Microcoleus lyngbyaceus (12% cover) and Brachytrichia quoyi (3% cover). The green alga Neomeris vanbosseae (2% cover) was also conspicuous in this zone.

Forty-one of the 51 species found in the study site were present in the Enhalus-Thalassia Zone (N = 105 tosses). The two major seagrasses Thalassia hemprichii and Enhalus acoroides were the most conspicuous component covering 14% and 6%, respectively, of the

Table 1. Checklist of marine benthic plants collected or observed at the proposed Yap Dock Site, March 4-6, 1977. Species preceded by asterisks were not observed at the Donitsch Outfall Site in January 1976 (Amesbury et al., 1976).

Species	Boulder Rubble Zone	Enhalus Thalassia Zone	Sand Coral Zone	Lagoon Slope
CYANOPHYTA (blue-green algae)				
*Brachytrichia quoyi (C. Ag.) B. & Fl.	X			
Calothrix crustacea (Schousb. & Thu.)	X	X	X	X
Microcoleus lyngbyaceus (Kütz.) Crouan	X	X	X	X
Schizothrix calcicola (Ag.) Gom.	X	X	X	X
CHLOROPHYTA (green algae)				
Anadyomene wrightii Gray		X		X
*Avrainvillea lacerata Gepp		X		X
Avrainvillea obscura J. Ag.		X		
Boodlea composita (Harv.) Brand		X		
*Caulerpa antoensis Yamada		X		
*Caulerpa brachypus Harvey		X	X	
Caulerpa racemosa (Forssk.) J. Ag.		X	X	X
Caulerpa sertularioides (Gmelin) Howe		X	X	
*Caulerpa taxifolia (Vahl) C. Ag.		X	X	
*Caulerpa verticillata J. Ag.		X		
*Codium geppii O. C. Schmidt		X		
Dictyosphaeria cavernosa (Forssk.) Boerg.		X		
*Enteromorpha sp.	X			
Halimeda discoidea Decaisne		X		
Halimeda incrassata (Ellis) Lamx.		X		
Halimeda macroloba Decaisne		X		
Halimeda macrophysa Askenasy				X
Halimeda opuntia (L.) Lamx.		X	X	X
*Neomeris vanbosseae Howe		X	X	X
Tydemannia expeditionis W. v. Bosse				X
PHAEOPHYTA (brown algae)				
Dictyota apiculata J. Ag.		X	X	
Dictyota cervicornis Kützt.		X		
Hydroclathrus clathratus (C. Ag.) Howe		X	X	
Lobophora variegata (Lamx.) Womersley				X
Padina tenuis Bory		X	X	
Rosenvingea intricata (J. Ag.) Boerg.		X	X	

Table 1. Continued.

Species	Boulder Rubble Zone	Enhalus Thalassia Zone	Sand Coral Zone	Lagoon Slope
RHODOPHYTA (red algae)				
Acanthophora spicifera (Vahl) Boerg.		X	X	
Amphiroa foliacea Lamx.				X
Amphiroa fragilissima (L.) Lamx.		X	X	
*Antithamnion sp.		X		
*Centroceras clavulatum (C. Ag.) Mont.		X		
*Champia parvula (C. Ag.) Harvey		X		
*Chondria sp.		X		
*Galaxaura cf. marginata Lamx.				X
*Galaxaura cf. oblongata (E. & S.) Lamx.				X
*Gelidiopsis intricata (Ag.) Vickers			X	X
Gracilaria crassa Harvey		X		
Gracilaria salicornia (Mert.) Grev.		X		
*Heterosiphonia sp.		X		X
*Laurencia papillosa (Forssk.) Grev.		X		
*Polysiphonia howei Hollenberg	X			
Polysiphonia tepida Hollenberg		X		X
Spyridia filamentosa (Wulfen) Harv.		X		
ANTHOPHYTA (sea-grass)				
*Cymodocea rotundata Ehrenb. & Hempr.		X		
Enhalus acoroides (L.f.) Royle		X		
Halophila minor (Zoll.) den Hartog		X	X	
Thalassia hemprichii (Ehrenb.) Aschers.		X		
NUMBER OF SPECIES PER ZONE	6	41	17	17

TOTAL NUMBER OF GENERA = 36

TOTAL NUMBER OF SPECIES = 51

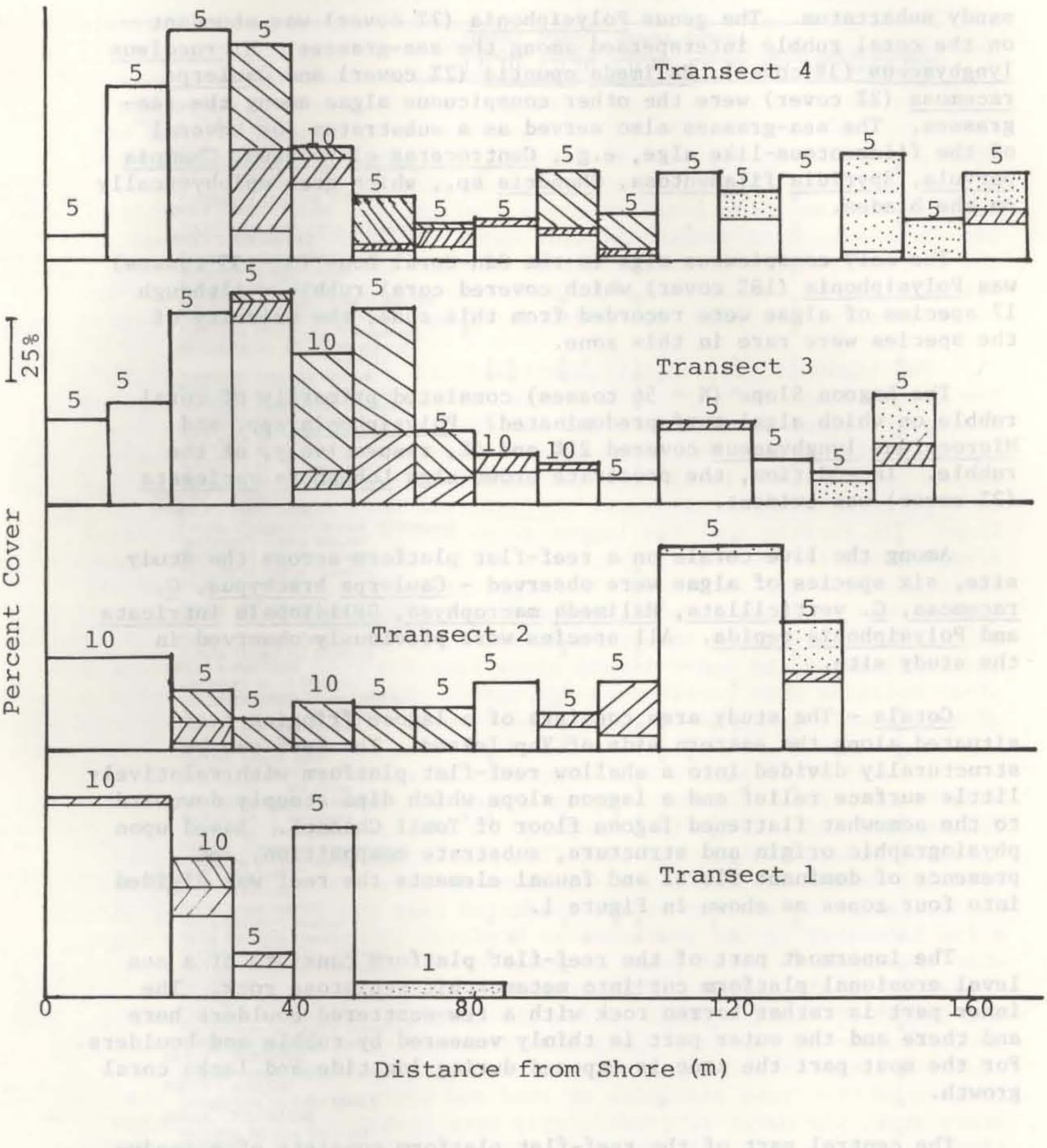

Figure 4. Percent cover of each functional group of marine plants, quantified within 10-20 m segments along the four transects. The number presented above each segment denotes the number of tosses on which the analyses are based. Unshaded = Turf; down-left hatching = macroalgae; down-right hatching = sea-grass; dotted = crustose coralline algae.

sandy substratum. The genus Polysiphonia (7% cover) was abundant on the coral rubble interspersed among the sea-grasses. Microcoleus lyngbyaceus (3% cover), Halimeda opuntia (2% cover) and Caulerpa racemosa (2% cover) were the other conspicuous algae among the sea-grasses. The sea-grasses also served as a substratum for several of the filamentous-like alge, e.g., Centroceras clavulatum, Champia parvula, Spyridia filamentosa, Chondria sp., which grew epiphytically on the blades.

The only conspicuous alga in the San-Coral Zone (N = 55 tosses) was Polysiphonia (18% cover) which covered coral rubble. Although 17 species of algae were recorded from this zone, the majority of the species were rare in this zone.

The Lagoon Slope (N = 56 tosses) consisted primarily of coral rubble on which algal turf predominated. Polysiphonia spp. and Microcoleus lyngbyaceus covered 21% and 4%, respectively, of the rubble. In addition, the prostrate brown alga Lobophora variegata (2% cover) was evident.

Among the live corals on a reef-flat platform across the study site, six species of algae were observed - Caulerpa brachypus, C. racemosa, C. verticillata, Halimeda macrophysa, Gelidiopsis intricata and Polysiphonia tepida. All species were previously observed in the study site.

Corals - The study area consists of a lagoon fringing reef situated along the eastern side of Yap Island. The reef can be structurally divided into a shallow reef-flat platform with relatively little surface relief and a lagoon slope which dips steeply downward to the somewhat flattened lagoon floor of Tomil Channel. Based upon physiographic origin and structure, substrate composition, and presence of dominant floral and faunal elements the reef was divided into four zones as shown in Figure 1.

The innermost part of the reef-flat platform consists of a sea level erosional platform cut into metamorphic schistose rock. The inner part is rather barren rock with a few scattered boulders here and there and the outer part is thinly veneered by rubble and boulders. For the most part the zone is exposed during low tide and lacks coral growth.

The central part of the reef-flat platform consists of a sandy-floored region dominated principally by sea grasses, called the Enhalus-Thalassia zone. Corals are widely scattered and of small size in this zone with the total number of species observed on any transect ranging from 3 to 4 (Table 2). The principal species encountered was Porites australiensis.

Table 2. List of corals observed along the transects of the study area. Symbols indicate their relative abundance within the various reef zones: D = dominant, A = abundant, C = common, O = occasional, R = rare. [I = Enhalus-Thalassia Zone, II = Sand and Coral Zone, III = Lagoon Slope.]

	Transect No.1			Transect No.2			Transect No.3			Transect No.4			North Side of Channel	
	I	II	III	I	II	III	I	II	III	I	II	III	Reef Flat	Lagoon Slope
CLASS - ANTHOZOA														
ORDER - SCLERACTINIA														
SUBORDER - ASTROCOENIINA														
FAMILY - ASTROCOENIIDAE														
Stylocoeniella armata (Ehrenberg)		R												O
FAMILY - THAMNASTERIIDAE														
Psammocora contigua (Esper)													R	
FAMILY - POCILLOPORIDAE														
Pocillopora damicornis (Linnaeus)										R			O	O
FAMILY - ACROPORIDAE														
Acropora exigua (Dana)		R		R										
Acropora formosa (Dana)								R					R	
Acropora teres Verrill							R							
Astreopora myriophthalma (Lamarck)					R			O					O	
Montipora berryi Hoffmeister		O			O			O	O		O		O	O
Montipora divaricata Brueggemann	R												R	
Montipora sp. cf. M. ehrenbergii Verrill		C	O		C	O		C	O		C	O	C	O
Montipora lobulata Bernard		R	O		O			O	O		O		O	O
Montipora millepora Crossland												R		
Montipora tuberculosa (Lamarck)								O						R
Montipora turgescens Bernard		R			O			O	R		R		R	
Montipora verrucosa (Lamarck)														R
Montipora sp. 1 (Papillate)		R	R		O	O		O	O		O	O	R	O
Montipora sp. 2 (Papillate)					R			O	R				R	
Montipora sp. 3 (Foveolate)		O			O			O			O		O	
SUBORDER - FUNGIINA														
FAMILY - AGARICIIDAE														
Pavona (Polyastra) venosa (Ehrenberg)														R
Leptoseris scabra Vaughan						O			O			O		O
Pachyseris speciosa (Dana)												R		O
Pachyseris rugosa (Lamarck)								R						
FAMILY - FUNGIIDAE														
Fungia (Heliofungia) actiniformis Quoy and Gaimard					R			O	O				R	
Fungia (Fungia) fungites (Linnaeus)								R						R
Fungia (tenactis) echinata					R			R					R	
FAMILY - PORITIDAE														
Goniopora sp. 1 (Ramose)												O		
Goniopora lobata Milne-Edwards and Haime														
Porites andrewsi Vaughan					R			O	R		O	R	A	R
Porites australiensis	D	D	D	D	D	D	D	D	D	D	D	D	O	D
Porites lobata Dana		R							O	R				A
Porites lutea Milne-Edwards and Haime								R					R	O
Porites murrayensis Vaughan								R			R		R	R
Porites sp. 1 (massive)	R	O			R		O	O	O		O			O
Porites sp. 2 (massive)											R			
Porites (Synaraea) iwayamaensis													O	C
Alveopora allingi Hoffmeister						O						O		O
SUBORDER - FAVIINA														
FAMILY - FAVIIDAE														
Favia danae Verrill											R		R	
Favia matthaii Vaughan		R			R		R	O			R		O	
Favia speciosa (Dana)			O			O		R	O			O		O
Favites acuticollis (Ortman)		R											R	
Favites melicerum (Ehrenberg)					R									R
Favites sp. 1								R				R		R
Platygyra lamellina (Ehrenberg)								R						O
Platygyra daedalea (Ellis and Solander)														O
Diploastrea heliopora (Lamarck)											R			R
Leptastrea purpurea (Dana)	R			R									O	
FAMILY - OCULINIDAE														
Galaxea fascicularis (Linnaeus)														O
FAMILY - MUSSIDAE														
Lobophyllia costata (Dana)									R					O
FAMILY - PECTINIIDAE														
Pectinia lactuca (Pallas)														O
CLASS - HYDROZOA														
ORDER - MILLEPORINA														
FAMILY - MILLEPORIDAE														
Millepora exaesa Forskaal													O	
TOTAL SPECIES PER REEF ZONE	4	13	5	3	14	5	4	23	15	3	14	11	24	29
TOTAL GENERA PER REEF ZONE	3	6	3	3	6	4	3	9	7	2	4	8	11	17
TOTAL SPECIES PER TRANSECT		16			19			28			23		44	
TOTAL GENERA PER TRANSECT		7			8			11			10		22	
TOTAL SPECIES FOR STUDY AREA (TRANSECTS 1-4) - 41														
TOTAL GENERA FOR STUDY AREA (TRANSECTS 1-4) - 17														

The outermost part of the reef-flat platform called the Sand and Coral zone consists of a region dominated by sand-sized sediments and scattered to locally abundant, massive, hemispherical shaped Porites colonies. Some of these colonies attain a diameter of a meter or more and up to 80 cm in height. Although coral density, coverage, and species diversity is greater in this zone than for any other, there is no apparent structural reef development taking place, except for possibly a minor amount at Transect 3 where the outer edge of the reef-flat platform forms a slightly raised topographic lip (Fig. 2). Even though the wide range of coverage measured on the transects (1.10-6.75 %, Table 3) reveals the patchy and uneven distribution of corals along the zone there is a general increase in coral density, coverage, and diversity from the inner to outer part.

The lagoon slope was not quantitatively analyzed because of the few corals observed there. In general corals are more abundant along the upper slopes where more light and less sedimentation occurs than along the lower part, although locally where the slope flattens out to the lagoon floor local aggregations of deeper water species such as Leptoseris scabra, Alveopora allingi, and Goniopora sp. 1 are found. It appears that the lagoon slope has been altered by previous dredging and the surface consists of rather unstable rubble and sand. Coral planulae may settle on the larger pieces of more stable rubble, but as they increase in size, these colonies would tend to slump quite easily downslope to more unfavorable growing conditions. Observations on the upper lagoon slope revealed that except for small sized colonies most corals were aggregated where uncommon exposures of more stable large blocks and boulders were exposed.

A total of 17 genera and 41 species of reef-building corals were found within the study region enclosed by the area between Transects 1 and 4 (Fig. 1). Compared to the rich fauna (over 100 species) observed along the reef-flat platforms near the outer part of Tomil Harbor Channel the coral fauna at this study site is rather depauperate. An earlier study, conducted near the present study site a few kilometer to the southeast at Donitsch Island, revealed a somewhat intermediate coral fauna composed of 31 genera and 81 species (Amesbury et al., 1976). This attenuation of coral species along the length of Tomil Channel is for the most part caused by a general deterioration of the more optimum conditions for coral growth found near the mouth of the channel toward its head near the study area. Because of the close proximity of land and surface drainage at the study area, the water is considerably more turbid and the accumulation of silt on the reef surface greater than at reef areas located farther seaward. Previous disturbance at the study site by dredging, land filling, and construction has also influenced the coral community to an undetermined degree. It is suspected that the present lagoon slope is particular and parts of the reef-flat platform are depauperate (16-23 species, Table 2) because of previous dredging.

Table 3. Size distribution, frequency, density, and percentage of substratum covered by stony corals in various zones along Transects 1-4. Relative values of frequency, density, and percentage 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-centered 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. Transect Zone Corals	n	Size Distribution of colonies (Dia. in cm) $\bar{Y}$	s	w	F	RF	Density per 100m²	RD	% cover	Rel. % cover	IV
Transect No. 1											
Boulder-Rubble Zone											
No corals encountered											
Enhalus-Thalassia Zone											
Porites australiensis	10	7.8	7.7	1-22	1.0	52.6	122	76.9	1.06	95.5	225.0
Montipora sp. cf. *M. ehrenbergii*	1	-	-	-	.3	15.8	12	7.7	.02	1.8	25.3
Montipora divaricata	1	-	-	-	.3	15.8	12	7.7	-	1.8	25.3
Porites sp. 1 (massive)	1	-	-	-	.3	15.8	12	7.7	.01	.9	24.4
Overall Density 1.58 corals per m²											
Overall Percent of coverage 1.11%											
Sand and Coral Zone											
Porites australiensis	10	13.9	14.3	2-46	1.0	62.5	190	83.3	5.57	92.5	238.3
Porites sp. 1 (massive)	1	-	-	-	.3	18.8	19	8.3	.29	4.8	31.9
Porites lobata	1	-	-	-	.3	18.8	19	8.3	.16	2.7	29.8
Overall Density 2.28 corals per m²											
Overall Percent of coverage 6.02%											
Transect No. 2											
Boulder-Rubble Zone											
No corals encountered											
Enhalus-Thalassia Zone											
Porites australiensis	5	6.4	3.0	3-10	.3	42.9	27	83.3	.11	91.7	217.9
Leptastrea purpurea	1	-	-	-	.4	57.1	6	16.7	.01	8.3	82.1
Overall Density .33 corals per m2											
Overall Percent of coverage .12%											
Sand and Coral Zone											
Porites australiensis	20	8.7	11.6	3-55	1.0	83.3	64	90.9	1.02	86.4	260.6
Montipora sp. cf. *M ehrenbergii*	1	-	-	-	.1	8.3	3	4.6	.15	12.7	25.6
Porites sp.1 (massive)	1	-	-	-	.1	8.3	3	4.6	.01	.9	13.8
Overall Density .70 corals per m²											
Overall Percent of coverage 1.18%											
Transect No. 3											
Boulder-Rubble Zone											
No corals encountered											
Enhalus-Thalassia Zone											
Porites australiensis	5	6.0	3.1	3-10	.5	100.0	31	100.0	.10	100.0	300.0
Overall Density .31 corals per m²											
Overall Percent of coverage .10%											
Sand and Coral Zone											
Porites australiensis	28	10.1	7.1	2-33	1.0	62.5	165	80.0	2.06	72.2	214.7
Montipora sp. cf. *M. enrenbergii*	1	-	-	-	.1	6.3	6	2.9	.54	18.9	28.1
Favia matthai	2	7.5	0.7	7-8	.2	12.5	12	5.7	.05	1.8	20.0
Porites sp. 1 (massive)	1	-	-	-	.1	6.3	6	2.9	.17	6.0	15.2
Porites andrewsi	2	5.0	0.0	5-5	.1	6.3	12	5.7	.02	.7	12.7
Overall Density 2.07 corals per m2											
Overall Percent of coverage 2.85%											
Transect No. 4											
Boulder-Rubble Zone											
No corals encountered											
Enhalus-Thalassia Zone											
Porites australiensis	33	8.4	5.2	1-22	.8	72.7	65	91.6	.47	87.0	251.3
Montipora lobulata	1	-	-	-	.1	9.1	2	2.8	.05	9.3	21.2
Porites andrewsi	1	-	-	-	.1	9.1	2	2.8	<.01	<.1	11.9
Porites lobata	1	-	-	-	.1	9.1	2	2.8	.02	3.7	15.6
Overall Density .71 corals per m2											
Overall Percent of coverage .54%											
Sand and Coral Zone											
Porites australiensis	19	13.3	10.7	2-34	1.0	55.6	196	82.4	4.38	65.4	203.4
Montipora berryi	1						10	4.4	.26	3.9	19.4
Porites andrewsi	1						10	4.4	.03	.4	15.9
Porites matthai	1						10	4.4	1.89	28.2	43.7
Porites murrayensis	1						10	4.4	.14	2.1	17.6
Overall Density 2.37 corals per m²											
Overall Percent of coverage 6.75%											

To get some kind of idea what the study site was possibly like before being disturbed a qualitative snorkeling observation was conducted on the opposite lagoon slope and reef-flat platform directly across the channel (Fig. 3) which revealed a coral fauna composed of 44 species. If scuba observations were made on deeper parts of the lagoon slope the difference in species composition would probably be even greater.

Macro-invertebrates - The prevalent macro-invertebrates on the reef flat were large deposit-feeding holothurians. Although several species of holothurians could be found in each zone (Table 4), each zone was characterized by different species which were particularly common and representative of that zone. The Enhalus-Thalassia Zone was characterized by clumps of Actinophyga echinites. The Coral and Sand Zone was generally characterized by Holothuria edulis, although H. flavomaculata was very common at the seaward edge of the Reef Margin which we have included in the Coral and Sand Zone (Table 4). Holothuria flavomaculata characterized the Reef Slope.

Holothuria atra, H. leucospilota and Stichopus chloronotus were widespread across the reef flat, but were never common. Holothuria atra was found out on open sandy areas. Holothuria leucospilota was under coral heads and would extend the anterior part of its body out from under the coral heads, especially when dusk approached in the late afternoon. Stichopus chloronotus was found both on sand and crawling up on head coral formations.

Four species in the genus Holothuria were present and showed a distinct pattern of zonation (Table 5). Holothuria atra was most frequent at the shoreward edge of the Enhalus-Thalassia Zone. Holothuria edulis was most common at the seaward edge of the Enhalus-Thalassia Zone and in the Coral and Sand Zone. Holothuria leucospilota was most common under coral heads on the inner Reef Margin while H. flavomaculata was common under coral heads on the outer Reef Margin and on down the Reef Slope.

It is interesting to note that there was no significant difference between zones in terms of total abundance of holothurians taken as a group. Throught the subtidal area of the study site, the mean and standard error of the mean number of holothurians per 10 m^2 quadrat ($n = 72$) was 4.6 ± 1.0, or about one holothurian every 2 m^2. Despite the relative uniformity in abundances, there were six species present in the Enhalus-Thalassia Zone and seven species present in the Coral and Sand Zone but only two on the Reef Slope (Table 4). Ninety-five percent of the holothurians on the Reef Slope were of the one species, H. flavomaculata.

Synaptid holothurians were also present in the study area, but they are generally nocturnal and so they were not sampled.

Table 4. The frequency and abundance of large echinoderms along the transects on the subtidal reef flat and reef slope at the study site. No large echinoderms were observed in the intertidal Boulder and Rubble Zone although twenty-two 10 m^2 were examined along the transects in the intertidal zone. In columns under the heading "F" are frequencies of occurrence, the number of 10 m^2 quadrats in which the species occurred as a ratio to the number of quadrats examined. Under "No./10 m^2" are the means and standard deviations of the counts in the quadrats. If a species did not occur in a sampled quadrat but was observed to occur in the zone, its presence is indicated by "+."

	Enhalus-Thalassia Zone		Coral and Sand Zone		Reef Slope	
	F	(No./10 m^2)	F	(No./10 m^2)	F	(No./10 m^2)
Culcita novaeguineae Müller & Troschel				+		+
Echinaster luzonicus (Gray)		+		+		
Protoreaster nodosus (Linnaeus)	12/32	0.6 ± 1.2	7/24	0.4 ±0.7		+
Fromia monilis Perrier						
Actinopyga echinites (Jaeger)	11/32	3.9 ±10.3	6/24	0.5 ±1.2		
Holothuria atra Jaeger	6/32	0.3 ± 0.7	1/24	0.04±0.2		
Holothuria edulis Lesson	10/32	0.8 ± 1.6	16/24	1.5 ±2.1	2/16	0.2±0.8
Holothuria leucospilota Brandt	1/32	0.03± 0.2	6/24	0.2 ±0.4		
Holothuria flavomaculata Semper	1/32	0.03± 0.2	5/24	1.6 ±4.2	6/16	3.8±6.0
Stichopus chloronotus Brandt	2/32	0.7 ± 3.5	9/24	0.5 ±0.8		
Stichopus variegatus Semper			1/24	0.04±0.2		

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	Enhalus-Thalassia Zone		Coral and Sand Zone		Reef Slope	
	F	(No./10 m^2)	F	(No./10 m^2)	F	(No./10 m^2)
<u>Culcita</u> <u>novaeguineae</u> Müller & Troschel				+		+
<u>Echinaster</u> <u>luzonicus</u> (Gray)		+		+		
<u>Protoreaster</u> <u>nodosus</u> (Linnaeus)	12/32	0.6 ± 1.2	7/24	0.4 ±0.7		+
<u>Fromia</u> <u>monilis</u> Perrier						
<u>Actinopyga</u> <u>echinites</u> (Jaeger)	11/32	3.9 ±10.3	6/24	0.5 ±1.2		
<u>Holothuria</u> <u>atra</u> Jaeger	6/32	0.3 ± 0.7	1/24	0.04±0.2		
<u>Holothuria</u> <u>edulis</u> Lesson	10/32	0.8 ± 1.6	16/24	1.5 ±2.1	2/16	0.2±0.8
<u>Holothuria</u> <u>leucospilota</u> Brandt	1/32	0.03± 0.2	6/24	0.2 ±0.4		
<u>Holothuria</u> <u>flavomaculata</u> Semper	1/32	0.03± 0.2	5/24	1.6 ±4.2	6/16	3.8±6.0
<u>Stichopus</u> <u>chloronotus</u> Brandt	2/32	0.7 ± 3.5	9/24	0.5 ±0.8		
<u>Stichopus</u> <u>variegatus</u> Semper			1/24	0.04±0.2		

Table 5. Number of echinoderms per 10 m^2 at 10 m intervals along four transect lines. Two 10 m^2 quadrats were taken at each 10 m interval. The data for only the seven most prevalent echinoderm species are included in this table. Data for less prevalent species are given in the text. The extent of each zone along each transect is indicated by the underline: .... = Intertidal Boulder Rubble Zone, ____ = Enhalus-Thalassia Zone, and ------ = Coral and Sand Zone.

Species	Transect	10	20	30	40	50	60	70	80	90	100	110	120
		10 m Intervals from High Tide Level on Shore											
Protoreaster nodosus	Transect 1			.5									
	Transect 2						1.0	2.5	.5	1.0	.5		
	Transect 3					.5	.5	3.0	1.5		1.0		
	Transect 4						.5	.5		1.0			
Actinopyga echinites	Transect 1			2.5	2.0	1.0							
	Transect 2								2.0	1.0			
	Transect 3					4.5	22.5	23.0					
	Transect 4					.5		.5		3.5	4.5	.5	
Holothuria atra	Transect 1												
	Transect 2						1.5						
	Transect 3					1.5	1.0	.5					
	Transect 4				.5							.5	
Holothuria edulis	Transect 1				.5	.5							
	Transect 2							.5					
	Transect 3							.5	1.5	.5	.5		1.5
	Transect 4					1.0	1.5			4.0	5.0	5.0	4.0
Holothuria leucospilota	Transect 1					.5							
	Transect 2												
	Transect 3										.5	1.0	.5
	Transect 4										.5	.5	
Holothuria flavomaculata	Transect 1					13.0							
	Transect 2												
	Transect 3							.5					4.5
	Transect 4												1.5
Stichopus chloronotus	Transect 1				2.0								
	Transect 2												
	Transect 3							.5	.5			.5	.5
	Transect 4						.5					.5	1.0

Protoreaster nodosus was the only common asteroid in the area with a mean and standard error of the mean abundance of 0.5 ± 0.1 per 10 m^2 quadrat, or about one Protoreaster every 20 m^2. The density of Protoreaster was not significantly different between the Enhalus-Thalassia Zone and the Coral and Sand Zone. Large ophiuroids in the genus Ophiothrix were present, and were seen extending their arms out of crevices in coral heads and also out of beer cans. Only two Ophiothrix were observed in quadrats but this is probably a great underestimation because Ophiothrix generally feeds nacturnally and is very reclusive during the day.

Soft corals of the Order Alcyonacea were remarkably scarce. Only one patch of 30 rather small colonies of Sinularia were observed on the Reef Margin. Transect 4 intersected the patch and seven colonies were contained within the transect.

A particularly toxic anemone (Actinodendron sp.) was encountered in the Enhalus-Thalassia Zone along Transect 2.

The scyphozoan medusae, Cassiopea, were rarer than usually expected. Only two Cassiopea were found in thirty-two 10 m^2 quadrats taken in the Enhalus-Thalassia Zone.

Although large gastropods were conspicuous, the data from our sampling indicate that they were not as common as we might have guessed. In the fifty-six 10 m^2 quadrats in the Enhalus-Thalassia Zone and the Coral and Sand Zone combined, only three Cypraea tigris, two Lambis lambis, one large Conus sp. and one large Vasum sp. were encountered.

Our study found no particularly outstanding aspect of this area in terms of populations of the macro-invertebrates.

Fishes - Although fish abundance is rather low at the study site (Fig. 5), the number of species observed was surprisingly high (54 species, Table 6). This diversity is quite comparable to the similar reef flat area off Donitsch Island, where 63 fish species were observed (Amesbury et al., 1976). Although considerably fewer fish species were observed at channel marker B on the north side of the channel (26 species) and at the reef-flat platform area (39 species), the time spent surveying these areas was quite short (approximately 30 minutes at each site), and many more species would undoubtedly be recorded if more thorough surveys were made in these area.

At the principal study area, the fish fauna was clearly most abundant and diverse in the Sand and Coral Zone (Fig. 5). There was also a relatively rich fish fauna in the Enhalus-Thalassia Zone on Transect 4, which seems to be related to the presence of a depression in the reef flat in this area (Fig. 2). Fewer sea grasses and some-

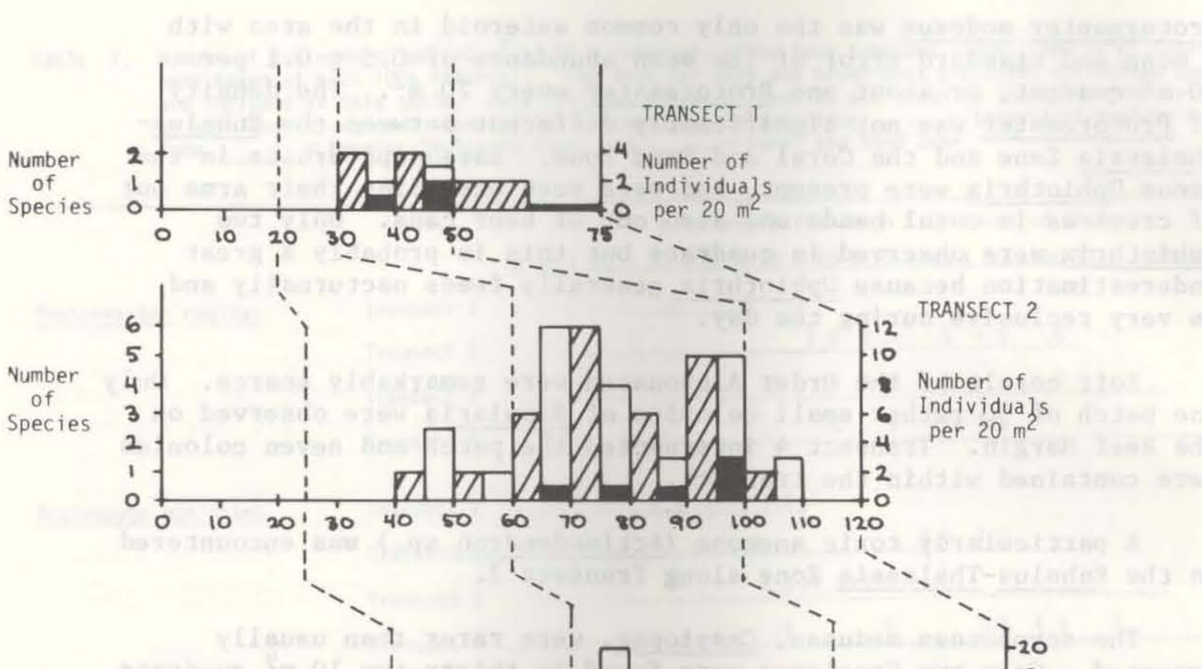

Figure 5. Number of fish species and abundance of fishes in each 10-meter transect interval. Each 10-meter interval contains two bars: the one on the left (down-left hatching) indicates number of species; the one on the right (unshaded or black) indicates abundance. Black bar indicates abundance of the dominant pomacentrid Dischistodus perspicillatus. Zone boundaries (dashed lines) are approximate.

Table 6. Checklist of fishes observed at Yap dock site, March 4-7, 1977. First four columns indicate fishes observed along transects within the four zones. Fifth column includes all species seen in study area. Fishes observed on north side of channel and at an area on the reef flat platform are indicated in columns six and seven.

	Boulder Rubble Zone	*Enhalus-Thalassia* Zone	Sand and Coral Zone	Lagoon Slope	Entire Study Area	North Side of Channel	Reef Flat Platform
Acanthuridae							
Acanthurus nigrofuscus Forskal					+		+
A. nigroris Cuvier and Valenciennes				+	+		
A. triostegus (Linnaeus)							+
A. xanthopterus Cuvier and Valenciennes			+		+	+	
Ctenochaetus striatus (Quoy and Gaimard)					+	+	+
Naso sp. (juvenile)			+		+		
Zebrasoma scopas (Cuvier)						+	+
Z. veliferum (Bloch)						+	
Apogonidae							
Apogon leptacanthus Bleeker						+	
A. orbicularis Cuvier and Valenciennes						+	
A. trimaculatus Cuvier		+			+		
Archamia zosterophora (Bleeker)						+	
Cheilodipterus quinquelineatus Cuvier					+		
Balistidae							
Balistapus undulatus (Mungo Park)						+	
Balistoides flavimarginatus (Ruppell)					+		
Rhinecanthus aculeatus (Linnaeus)			+		+		
R. verrucosus (Linnaeus)			+	+			
Sufflamen chrysoptera (Bloch and Schneider)					+		
Blenniidae							
Meiacanthus grammistes (Valenciennes)					+		
Runula tapeinosoma (Bleeker)							+
unidentified blennies		+			+		
Canthigasteridae							
Canthigaster valentini (Bleeker)					+		
Chaetodontidae							
Centropyge bicolor (Bloch)				+	+		
C. flavissimus (Cuvier)			+		+		
C. tibicen Cuvier					+		
C. vroliki (Bleeker)						+	
Chaetodon auriga Forskal			+		+	+	+
C. citrinellus Cuvier			+		+		+
C. ephippium Cuvier					+	+	+
C. kleini Bloch			+	+	+	+	
C. melannotus Bloch and Schneider							+
C. rafflesi Bennett							+
C. semeion Bleeker							+
C. trifascialis Quoy and Gaimard					+		+
C. trifasciatus Mungo Park					+	+	+
C. unimaculatus Bloch							+
C. vagabundus Linnaeus			+		+		+
Gobiidae							
Amblygobius albimaculatus (Ruppell)			+		+		
goby sp. A	+	+	+		+		
goby sp. B		+	+		+		
goby sp. C				+	+		
other unidentified gobies		+	+	+	+		
Eleotridae							
Ptereleotris sp.			+		+		
Labridae							
Cheilinus sp.					+		
Choerodon anchorago (Bloch)					+		+
Halichoeres margaritaceous (Cuvier & Valenciennes)		+	+		+		
H. trimaculatus (Quoy and Gaimard)							+
Hemigymnus melapterus (Bloch)							+
Labroides dimidiatus (Cuvier & Valenciennes)					+	+	+
Macropharyngodon meleagris (Cuvier & Valenciennes)						+	+
M. pardalis (Kner)							+
Pseudocheilinus hexataenia (Bleeker)					+	+	
Stethojulis bandanensis (Bleeker)						+	+
Thalassoma hardwicki (Bennett)						+	+
juvenile labrids		+	+		+		

Table 6. Continued.

	Boulder Rubble Zone	Enhalus-Thalassia Zone	Sand and Coral Zone	Lagoon Slope	Entire Study Area	North Side of Channel	Reef Flat Plat-form
Lutjanidae							
Caesio pulcherimmus Smith				+	+		
Lutjanus fulviflamma (Forskal)		+			+		+
L. kasmira (Forskal)					+		
L. vaigiansis (Quoy and Gaimard)					+		
Scolopsis bilineatus (Bloch)							+
S. cancellatus (Cuvier and Valenciennes)			+	+	+		+
S. xenochrous Gunther						+	
Mullidae							
Mulloidichthys auriflamma (Forskal)							
M. samoensis (Gunther)					+		+
Parupeneus barberinoides (Bleeker)					+		
P. barberinus (Lacepede)					+		
P. pleurostigma (Bennett)		+			+		
Pomacentridae							
Amblyglyphidodon curacao (Bloch)					+	+	
A. tematensis (Bleeker)						+	+
Chromis atripectoralis Welander and Schultz						+	
C. caerulea (Cuvier)						+	+
C. lepidolepis Bleeker					+		
C. margaritifer Fowler					+		
Dascyllus aruanus (Linnaeus)					+	+	+
D. trimaculatus (Ruppell)					+		
Dischistodus notopthalmus (Bleeker)							+
D. perspicillatus (Cuvier)		+	+	+	+	+	
D. pseudochrysopoecilus (Allen and Robertson)					+		
Eupomacentrus albifasciatus (Schlegel and Muller)							+
E. nigricans (Lacepede)							+
Glyphidodontops biocellatus (Quoy and Gaimard)			+		+		+
G. cyaneus (Quoy and Gaimard)							+
Paraglyphidodon melanopus (Bleeker)							+
Pomacentrus pavo (Bloch)							
Scaridae							
Scarus sordidus Forskal							+
Scarus sp.							
Serranidae							
Variola louti (Forskal)					+		
Siganidae							
Siganus canaliculatus (Park)					+		
S. puellus (Schlegel)							+
Zanclidae							
Zanclus cornutus (Linnaeus)						+	+

what more corals were present in this depression than were typical of the Enhalus-Thalassia Zone on the other transects (Fig. 4, Table 3).

Beer Cans - After corals and sea grasses, the most conspicuous and predominant object in the Enhalus-Thalassia Zone and Sand and Coral Zone were the thousands of beer cans that served as substrata for algae and small corals and as shelters for ophiuroids and small fishes. The beer cans were found mostly in the Enhalus-Thalassia Zone and the Sand and Coral Zone; relatively few were found in the intertidal Boulder Rubble Zone or on the Reef Slope. Our survey found there to be no significant difference between the population densities of beer cans in the Enhalus-Thalassia Zone and in the Sand and Coral Zone.

One large patch of beer cans totally covered and area about five by seven meters in diameter near Transect 2. The cans were piled on top of each other so that there were about 300 cans per square meter or at least 10,000 cans in this particular aggregation. This is probably an underestimate because many cans were buried in the sand and no count was taken of these.

From counts in fifty-five 10 m^2 quadrats, we found the mean and standard error of the mean number of beer cans per square meter to be 4.1 ± 2.3. The Enhalus-Thalassia Zone and the Sand and Coral Zone together occupy about 19,000 m^2 in the study area so the number of beer cans present is probably about 80,000. Since these beer cans lay on sandy substrata, they add a considerable amount of substrata for algae and small corals and also add refuges for ophiuroids and fishes that would not be there otherwise.

Water Circulation - The results of the single dye study cannot be interpreted too broadly as many variables of tidal action, wind, and wave development will modify circulation patterns over time. The dye patch tended to move shoreward rather rapidly, curving toward the north-west. Within 45 minutes after placing the dye patch at channel marker A, it was approaching the northwest edge of the bay (Fig. 1), and would presumably have moved off the reef flat had it been tracked further. If this pattern is representative of the prevailing circulation in this area, suspended silt produced by the construction of the dock will probably be carried in this direction.

CONCLUSIONS AND RECOMMENDATIONS

Clearly the nature of the project is such that all attached and slow moving marine life in the construction area will be destroyed, and resident fishes will be destroyed or driven away. Comparison with other areas in Tomil Harbor suggests that the proposed dock site is moderately rich in marine life, and the well-developed seagrass beds indicate that the area is a reasonably productive one.

The single dye study indicates that the direction of water flow is toward the north west. Sediments which are resuspended by the dredging operations can be expected to move in this direction. As some 65,000 cubic yards of fill is to be dredged and deposited during the construction period, the amount of silt carried out of the construction area will probably be considerable. Should a significant silt plume develop during the construction period, it may be advisable to monitor the movement of this plume to determine whether marine communities in adjacent areas are being inundated with sediments.

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