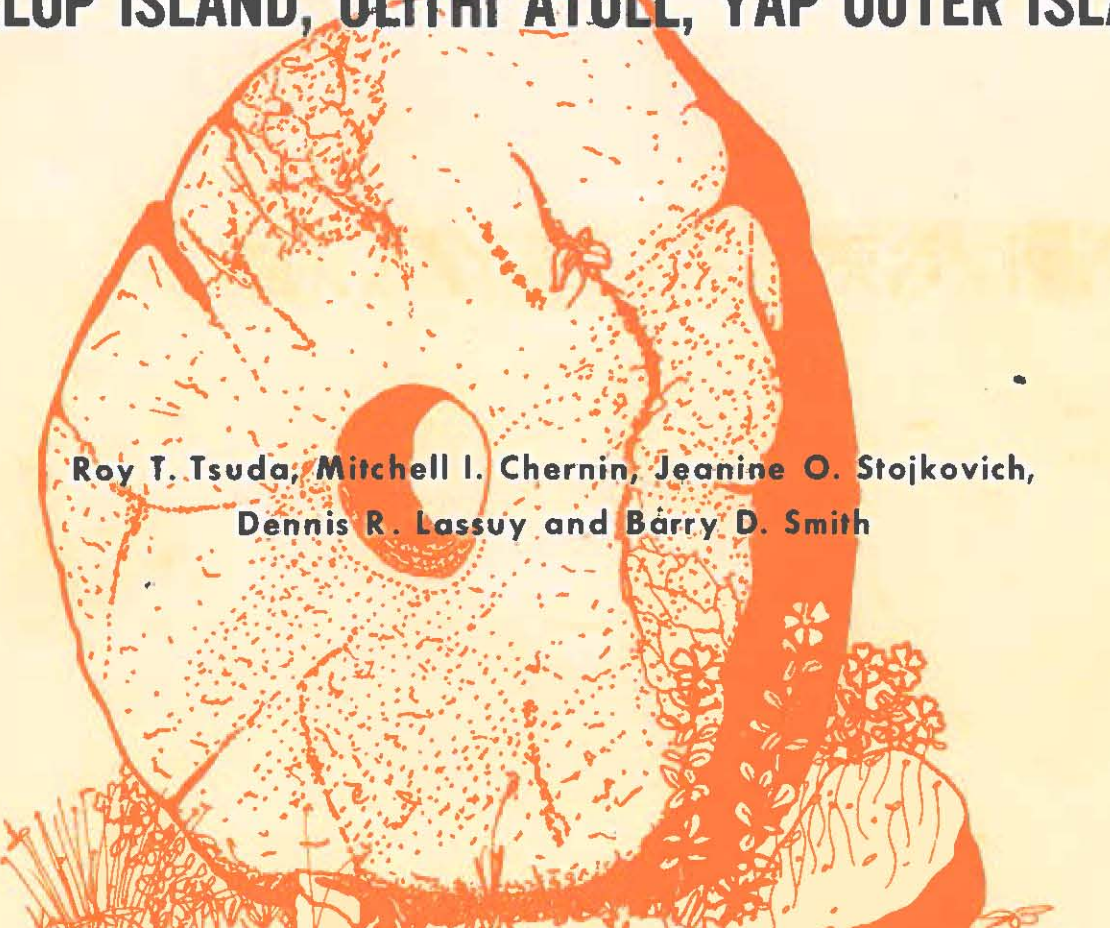
MARINE ENVIRONMENTAL STUDIES OF SELECTED SEWER OUTFALL SITES IN THE YAP CENTRAL ISLANDS AND ON FALALOP ISLAND, ULITHI ATOLL, YAP OUTER ISLANDS



Roy T. Tsuda, Mitchell I. Chernin, Jeanine O. Stojkovich,
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UNIVERSITY OF GUAM MARINE LABORATORY

Technical Report No. 46

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By

Roy T. Tsuda, Mitchell I. Chernin, Jeanine O. Stojkovich,
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Prepared for

LYON ASSOCIATES, INC.

HONOLULU, HAWAII

As Per

SUBCONTRACT AGREEMENT

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INTRODUCTION

Background

Sewage facilities in Yap presently consist of an Imhoff tank with sludge drying beds and a chlorinator. The initial design is for an average flow of 0.17 million gallons per day (MGD) and a peak capacity of 1.20 MGD, which will accomodate a population of 2,150 (Amesbury et al., 1976). In January 1976 the facility was still under construction on Donitsch Island but the outfall pipe had been laid 140 m out to the lagoon reef margin and to a depth of six meters. Although the facility was already completed as of our recent visit in March 1978, the sewage facility was still not functioning due to the lack of sewage connections to private and governmental buildings in Colonia.

Thus, the disposal of domestic sewage on Yap continues to be in a raw state through outfall pipes emptying into shallow lagoon waters. In the main commercial and administrative center of Colonia, the raw sewage either empties into Chamorro Bay or into Tomil Harbor. The inhabitants of coastal villages continue to use "benjos" built along the shore.

On Falalop Island located on the northeast corner of Ulithi Atoll, the primary objectives for our visit were to look at the present sewage facilities off the Outer Islands High School (OIHS) and to submit recommendations on a sewer scheme for this seaward area. Our recommendations would be based upon a biologist's point of view.

The Outer Islands High School presently has an enrollment of about 300 students which represents about one-half of the population of this small island. The sewage from this school is handled through three systems. Some of the sewage is disposed through two pipes (6" cast iron pipe and 8" asbestos-cement pipe) which terminate on the beach in the intertidal zone. The majority of the sewage is probably fed into the septic tank. Contrary to information provided by Lyon Associates, Inc., there is no ocean outfall associated with the septic tank.

As part of the Yap Wastewater Facilities Plan being conducted by Lyon Associates, Inc., through a contract with the Trust Territory of the Pacific Islands, the University of Guam Marine Laboratory was subcontracted on March 1, 1978 to conduct environmental assessments on two other potential sewage outfall sites at Balabat and Pelak on the east coast of Yap. In addition, the Marine Laboratory team was requested to fly to Falalop Island, Ulithi Atoll, to initiate a marine survey off the Outer Islands High School.

Scope of Work

Yap Central Islands - The two sites to be studied were located in the Balabat area (Fig. 1) just south of Tomil Harbor and in the Pelak Channel area (Fig. 2) located just north of Tomil Harbor. The former site had previously been recommended as a better site over Donitsh Island by Hawaii Architects and Engineers (1968). The University of Guam Marine Laboratory team was to address itself to the questions below and carry out the following work requests.

1. What effect will discharge of treated and untreated effluents have on the ecological condition, water quality, and aesthetics at the selected sites.

2. What effect will occur due to the construction of an outfall on the ecological condition and water quality along the proposed outfall line at the selected sites.

3. The extent and magnitude of surface and subsurface currents at the proposed outfall diffuser sites, along with predictions on plume dispersion and dilution.

4. Suggestions for potential alternate sites and outfall schemes adjacent to the proposed outfall sites if the present site is inadequate.

5. Baseline ecological data that can be utilized for future reference.

6. Provide a vertical depth and zonation profile along the proposed outfall routes to the harbor floor at the two sites.

7. Obtain profiles on salinity versus depth, and temperature versus depth at the proposed outfall diffuser sites.

8. Obtain and analyze samples of the following parameters at the proposed outfall diffuser sites.

    a. dissolved oxygen
    b. pH
    c. NO_3-N, NH_4-N, total-N, org-N
    d. PO_4-P, total-P

9. Conclusions and Recommendations

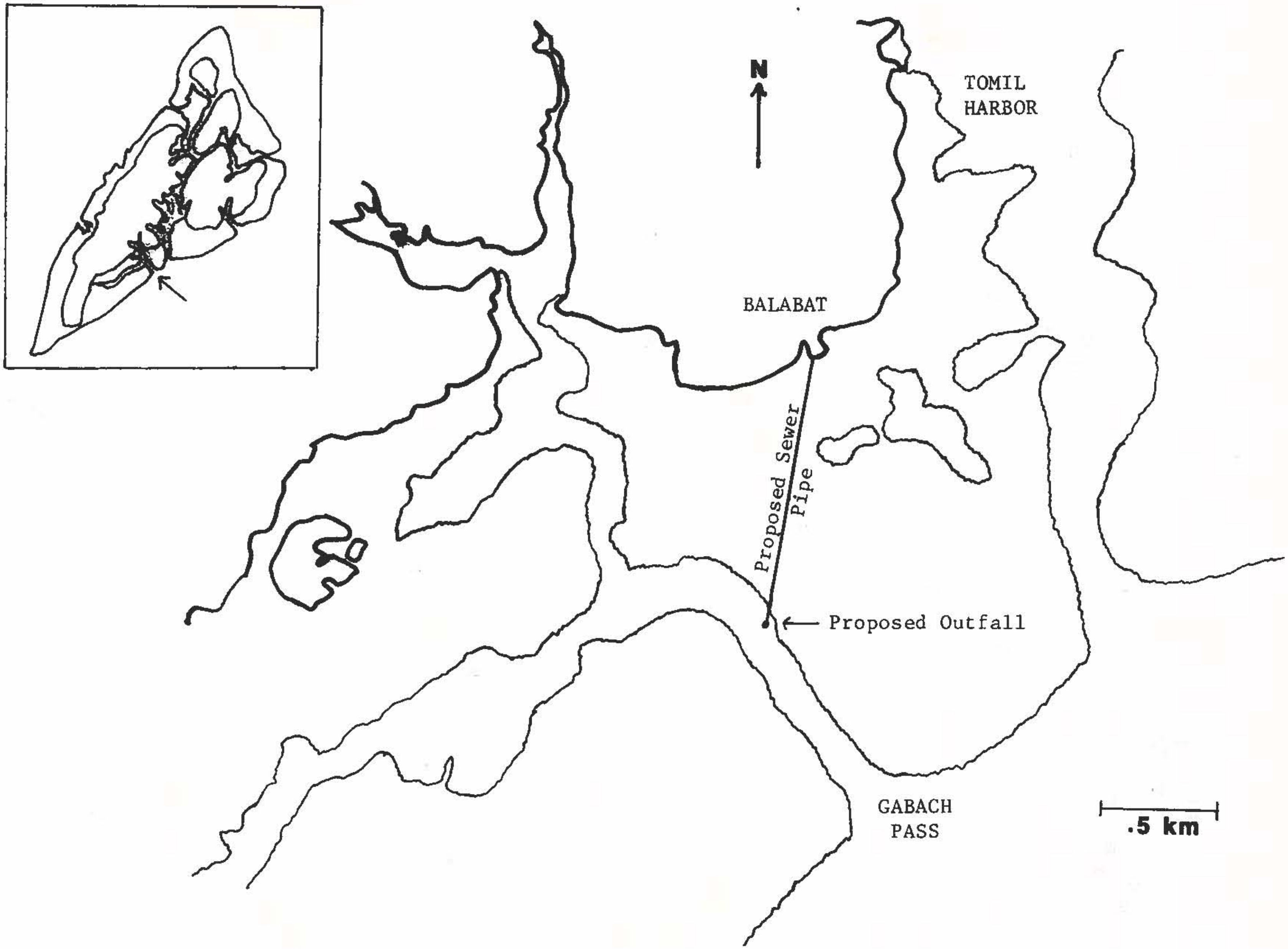

Figure 1. Map of study area of Balabat, Yap, showing route of the proposed sewer line and site of the proposed outfall. Insert shows the location of the area in Yap.

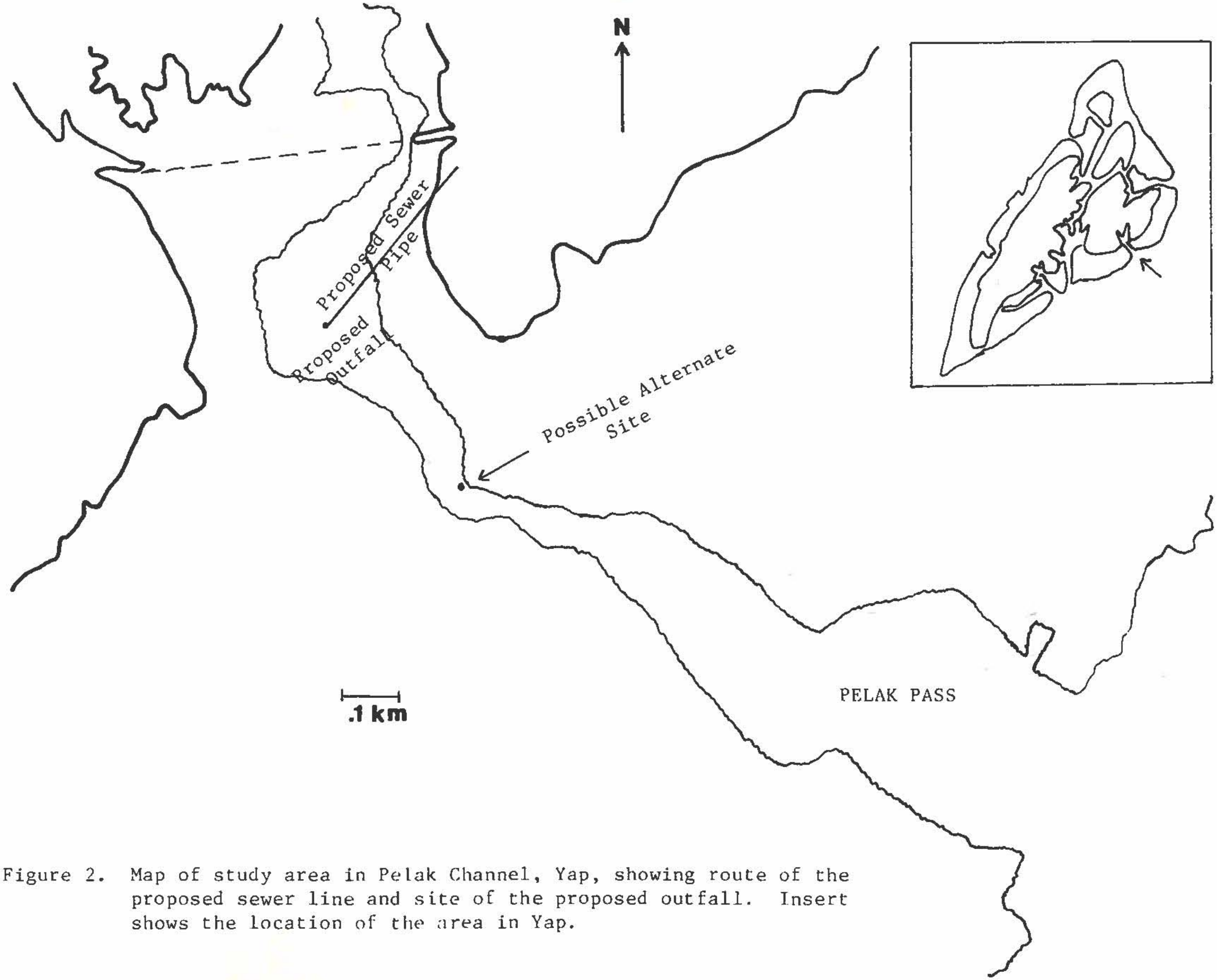

Figure 2. Map of study area in Pelak Channel, Yap, showing route of the proposed sewer line and site of the proposed outfall. Insert shows the location of the area in Yap.

Falalop Island, Ulithi, Yap Outer Islands - The primary area of study (Fig. 3) was just off the Outer Islands High School (OIHS). Here, the University of Guam Marine Laboratory team was to address itself to the questions below and carry out the following work requests.

1. What effect will the discharge of treated and untreated effluents have on the general ecological conditions, water quality, and aesthetics of Falalop Island.

2. What effect will the discharge of untreated effluents have on the ecological condition, water quality, and aesthetics of the septic tank outfall sites near the Outer Islands High School.

3. The extent and magnitude of surface and subsurface currents at the OIHS outfall diffuser sites, along with predictions on plume dispersion and dilution for any submerged diffuser sites.

4. The general extent and magnitude of surface and subsurface currents for Falalop Island.

5. Suggestions for potential alternate sites and outfall schemes adjacent to the OIHS outfall sites if the present sites are inadequate.

6. Suggestions for possible outfall schemes for Falalop Island.

7. General baseline ecological data that can be utilized for future reference.

8. Conclusions and recommendations.

Personnel

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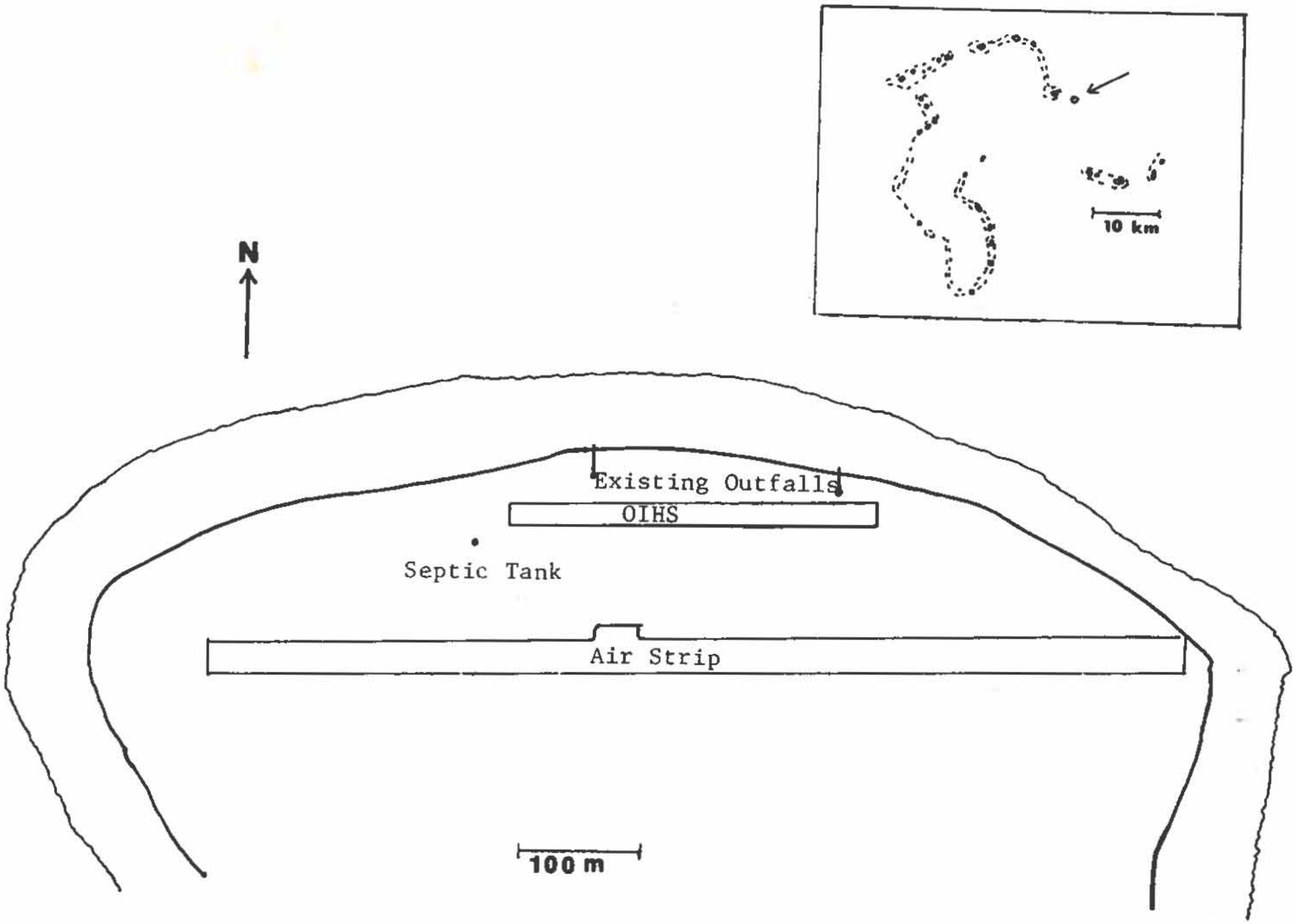


Figure 3. Map of study area off the Outer Islands High School, Falalop Island, Ulithi Atoll, showing locations of the two existing sewer outfalls and septic tank. Insert shows the location of Falalop Island in Ulithi Atoll.

Acknowledgements

Our study on Yap could not have been carried out efficiently without the help of the following individuals - Mr. Charles Jordon, District Planner, for his logistic aid; Mr. Henning Gatz, District Fishery Officer, and Mr. Jesse Marehalau, Fishery Specialist, for the loan of buoys, use of the reefer for our nutrient samples, and transportation needs upon our return from Ulithi; Mr. Bob Green, Chief of the Land Commission, for loan of his gasoline containers; Mr. Harold Temmy, Chief of Land Management, for showing us maps of our study areas; Mr. Philip Kloulubak, Chief District Sanitarian, for the loan of his boat and for assigning Mr. Vincent Mareyeg as our guide and boat operator; Mr. Vincent Mareyeg for his overall aid during our study on Yap; Reverend and Mrs. Heinz Hengstler, for seeing to our scuba air needs; Mr. Silbester Alphonso, proprietor of the ESA Hotel, who served as our helpful host during our stay in Yap; and Mr. Samuel Falanruw, Assistant to the District Administrator, for coming to our aid whenever we needed it.

We, likewise, extend our sincerest appreciation to those individuals who helped during our stay on Falalop Island, Ulithi Atoll - Mr. John Rulmal, District Administrator Representative for the Yap Outer Islands; Mr. John Horeg, Administrative Assistant to the District Administrator Representative, for coordinating our visit on Falalop Island and seeing to our various needs; and various other individuals, such as Mr. Mario Laichog, Mr. Philip Nery, Mr. Louis Rama, Mr. Siro Hachilir, and Mr. Hermand Amoud, who helped make our study on Falalop Island easier. We also acknowledge Mr. Morris Pickard, PMA Airlines, who flew us between Yap and Ulithi.

Our sincerest thanks to Yap's resident biologist and environmentalist, Ms. Marjorie V.C. Falanruw, who freely shared her knowledge on matters dealing with sewage disposal on Yap.

We also acknowledge the help provided by various members of the Marine Laboratory staff during the preparation of this report. Ms. Deborah A. Grosenbaugh, Dr. Lucius G. Eldredge, and Dr. Charles E. Birkeland helped verify the identification of certain echinoderms; Mr. Richard H. Randall helped in the coral identifications; Mr. William Zolan and Mr. Russell Clayshulte of the Water Resources Research Center analyzed all of the chemical samples; Mr. David Gardner printed the photographs; and Ms. Terry Balajadia, Ms. Elaine Faria and Ms. Kathy Meyer typed the final manuscript.

METHODS

Work Schedule

The environmental assessments of the three study sites were carried out between March 16 and 25, 1978 and approximately three days were spent at each site. The work schedule was as follows.

March 15 (W)	......	Guam to Yap (p.m.)
16 (Th) - 18 (S)	......	Balabat, Yap Central Islands
19 (Su) - 21 (T)	......	Pelak, Yap Central Islands
22 (W)	......	Yap to Ulithi (a.m.)
22 (W) - 24 (F)	......	Falalop, Ulithi
25 (S)	......	Ulithi to Yap (a.m.); Yap to Guam (p.m.)

Reef Profile and Biotic Transects

The reef profiles at both the Balabat and Pelak study areas in Yap were obtained by running a series of transects along the proposed route of the sewer pipe from shore to mid-channel. Depth measurements were taken at 10-meter intervals and the time recorded so that all depth could be corrected to a similar tide level. Concurrently, two other members of the team swam the length of the transect and recorded the limits of the different biotic zones.

The information obtained on the biotic zones formed the basis for the location of the series of 100-meter long transects which were run parallel to either the shore or channel margin. In this manner, the various seagrasses, algae, corals, fishes and other macroinvertebrates could be quantitatively analyzed in each of the zones. Thus, seven 100-meter long transects (A-G) were run at Balabat (Fig. 4) and four 100-meter long transects (A-D) were run at Pelak (Fig. 5).

On Falalop Island, three perpendicular transects (Fig. 6) were run from shore to the reef margin off the Outer Islands High School (OIHS). These transects were run off the septic tank and off the two existing outfalls. These locations were selected because it was possible that one of these sites could be proposed as the route of the ocean outfall. Two 100-meter long transects were run parallel to shore off the septic tank (A^1 and B^1) and two 50-meter long transects (A^2 and B^2) were run parallel to shore off the adjacent existing sewer outfall. Heavy surf action on the reef flat prevented the running of a third set of parallel transects on the reef margin. Here, qualitative assessments of certain reef organisms were made.

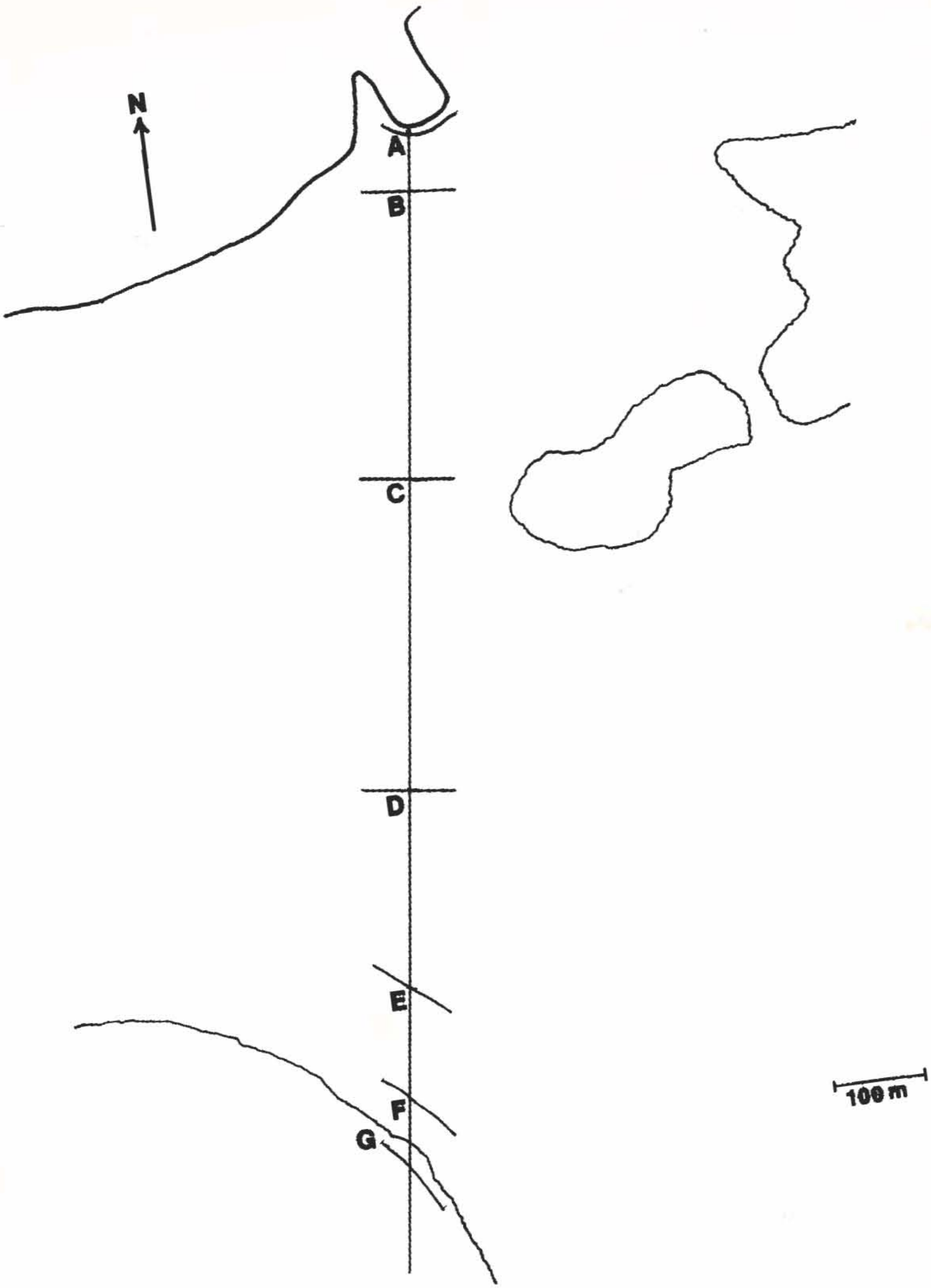


Figure 4. Location of the seven 100-meter long transects (A - G) which were run parallel to shore or channel margin along the route of the proposed sewer line off Balabat, Yap, March 17 and 18, 1978.

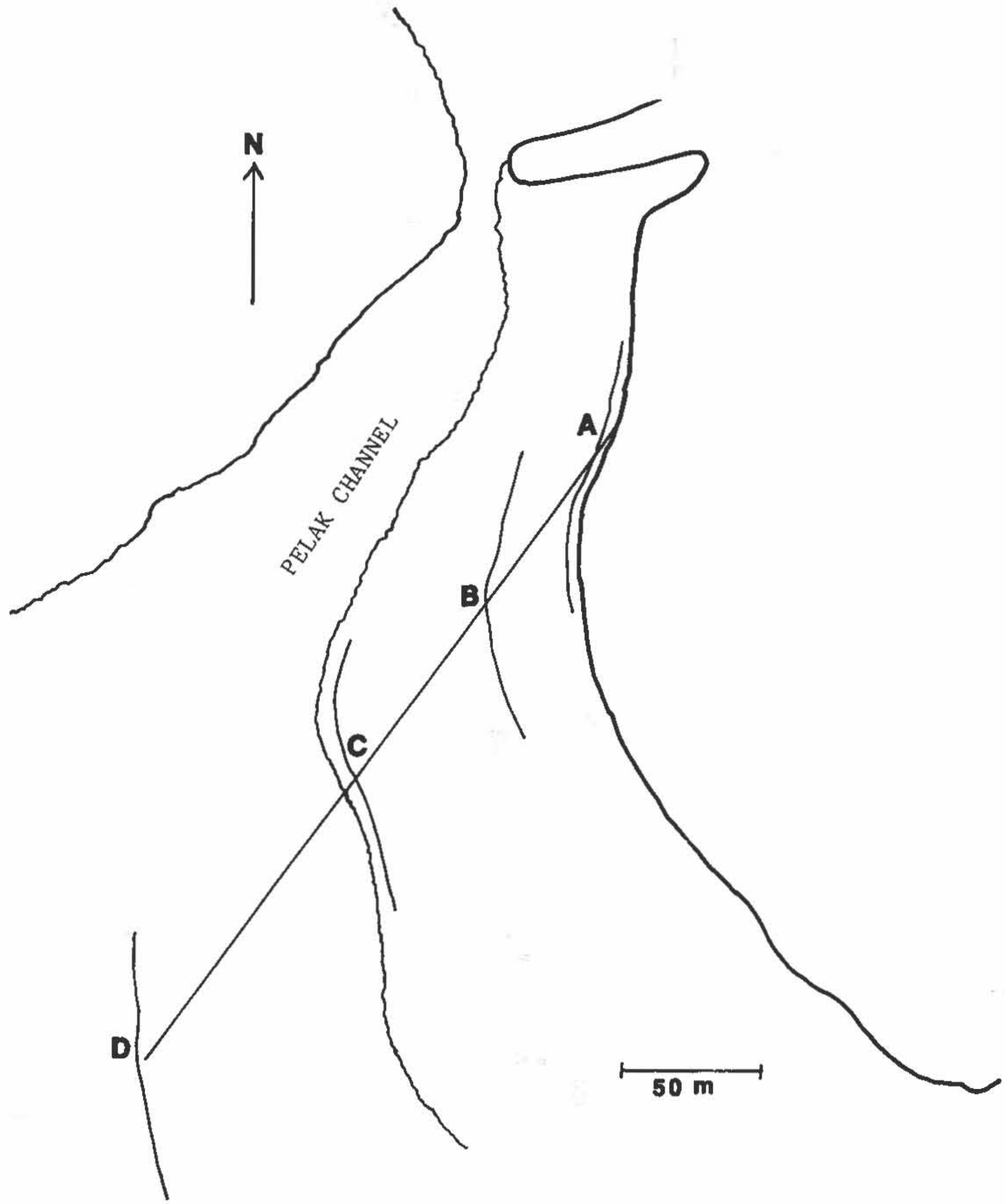


Figure 5. Location of the four 100-meter long transects (A - D) which were run parallel to shore or channel margin in the Pelak Channel area, Yap, March 19 and 20, 1978.

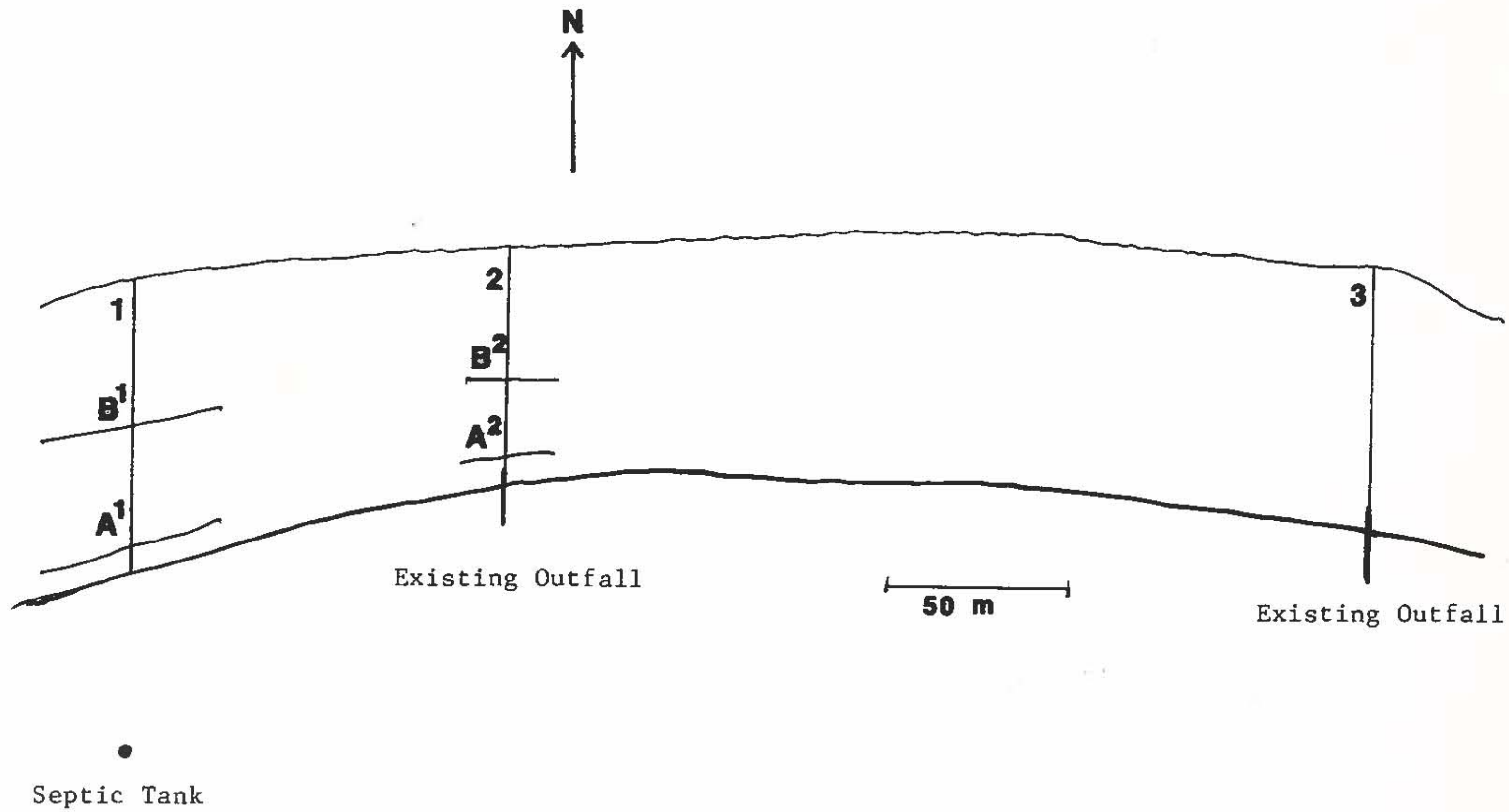


Figure 6. Location of the two 100-meter long transects (A^1 and B^1) and the two 50-meter long transects (A^2 and B^2) which were run parallel to shore north of the septic tank and north of the western sewer outfall, off the Outer Islands High School, Falalop Island, Ulithi Atoll, March 23 and 24, 1978.

Water Circulation

Duplicate pairs of drift drogues, 1 meter and 2.5 meters deep, were periodically released at the site of the proposed sewer outfall at Balabat, and at the site of the proposed outfall and another alternate site at Pelak, (see Figs. 1 and 2). Only a single pair of drift drogues (1 m and 2.5 m deep) was periodically released on the seaward coast of Falalop Island (see Fig. 3) because of heavy seas. After appropriate time intervals (ca. one hour), the positions of the drogues were determined by sighting three fixed points with a hand-bearing compass. These data were then recorded and plotted. The establishment of three fixed point positions at the three sites was difficult at times since local topographical features and available maps did not coincide; therefore, best estimates were made. Wind speed and direction, and tide height were measured to determine the possible effects of these factors on drogue movement.

The general water circulation patterns on the shallow reef flat were also obtained with the use of fluorescein dye. The direction and distance the dye traveled within a given time period (usually 10 minutes) were recorded. In most cases, the dye studies were carried out prior to and after an extreme tide level, so that water movement during both flood and ebb tides could be obtained. In certain cases this became impractical because of local fishermen in the area. We felt it best to lose this one piece of information than have irate fishermen ban us from carrying out our other studies on their reefs.

Physicochemical Analyses

During the reef profile study, salinity and temperature values were obtained at Balabat (100-meter intervals), Pelak (50-meter intervals) and Falalop Island (10-meter intervals). In addition to these values, water samples for physicochemical analyses were obtained at selected sites on the reef flat and at the sites of the proposed outfalls at Balabat and Pelak.

The method of collection employed a 2-liter capacity Van Dorn sampler, which was lowered to predetermined depths at each station. Appropriate aliquots for dissolved oxygen, temperature, salinity and pH were drawn off first; followed by those for NO_2-N, NO_3-N, NH_4-N + amino acids, total-N, organic-N, PO_4-P and total-P. Oxygen determinations were performed in Yap while the latter nutrient subsamples were frozen immediately and later assayed by the University of Guam's Water Resources Research Center.

Dissolved oxygen was measured according to the azide modification of the standard Winkler method (American Public Health Association, 1971). Temperature and salinity were measured in the field by a hand-held mercury thermometer and refractometer, respectively. The pH of the water was determined in the field with a portable meter calibrated against a known standard.

Orthophosphate (PO_4-P), NO_2-N, NO_3-N and NH_4N + amino acids were analyzed according to the standard techniques outlined by Strickland and Parsons (1968).

Total-P was analyzed according to the methods outlined by the American Public Health Association (1971). Kjeldahl nitrogen (TKN) or more commonly referred to as total-N, which is the sum of organic-N and NH_4N, was analyzed according to a modification of the Strickland and Parsons (1968) Kjeldahl method for determining soluble organic-N. In this analysis filtering of the samples was omitted and the bottle shook vigorously just prior to withdrawing the 25-ml aliquot for analyses. The digestion period was doubled from 1.5 hours to 3 hours.

All assays were done in replicate. All values obtained are within normal precision limits.

Biota

Marine Plants - Marine plants were quantified by a modified point-quadrat method (Tsuda, 1972), which consisted of randomly tossing a 25-cm x 25-cm gridded quadrat with 16 internal points two times at each 5-m transect interval. Percent cover was calculated by dividing the number of points at which each species occurred by the total number of points, i.e., 16 times the number of tosses, and multiplying by 100 to obtain percent values. These values were rounded to the nearest percent. Frequency was calculated by dividing the number of tosses in which a species occurred by the total number of tosses per transect. The range of possible values is from 0.0 - 1.0. Those marine plant species occurring in the vicinity of the transects are denoted by an "X".

Corals - Coral communities were quantified along transects at Balabat and Pelak, Yap, by using the point-quarter technique (Cottam et al., 1953). For this technique a series of sample points at 5-m intervals was selected along a transect line. A line bisecting the sample point at right angles to the transect line established four quadrants around the point. The coral nearest the sample point in each quadrant was located and the specific name, diameter of the colony, and the distance from the center of the colony to the sample point was recorded. If no colony was observed within the maximum distance of one meter from the sample point, the quadrant was recorded as having no colony with a diameter of zero and a sample point to colony distance of one meter.

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

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

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

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

total percent coverage = total density of all species X average coverage value for all species

percent coverage = density of a species X average coverage value for the species

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

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

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

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

Qualitative assessments of coral species not encountered along the transects were made by repeated random swims in the specific study areas. The relative abundance of corals was determined by using a modified system designed by R. H. Randall. From the viewpoint of the investigator, a relative abundance value was assigned as follows: dominant (D), a species occurring most frequently throughout the study area; abundant (A), a species generally distributed throughout the study area; common (C), a species generally present but with a patchy distribution pattern within the study area; occasional (O), a species with only localized distribution within the study area; and rare (R), a species whose occurrence is reflected in one or two observations within a study area. Species not identifiable in situ were brought back to the University of Guam Marine Laboratory for identification by R. H. Randall.

Other Macroinvertebrates - Two methods were used in the quantitative assessment of macroinvertebrates. In areas of low animal density, abundances of invertebrates were determined in plots of 20 m^2 by counting the numbers of individuals within 1 m of the transect line to either side. Counts were made while swimming along the transects and holding a meter stick perpendicular to the transect line.

In areas of higher animal density, abundances were determined in plots of 10 m^2 by counting invertebrates within 50 cm of the transect line to either side. A meter stick was held perpendicular to the transect line with the 50-cm mark touching the line as the observer swam along the transect.

The neritid gastropods found on basaltic rocks above the limestone platform at Falalop, Ulithi, were quantified by counting the numbers occurring in a randomly thrown 25 X 25 cm quadrat. Counts were made in 30 samples.

Fishes - At each site, a diver equipped with snorkeling gear first swam the length of a transect which ran generally perpendicular to the pattern of reef zonation recording all fish species observed within the field of view on either side of the line and noted their relative abundances. This allowed the compilation of a preliminary checklist for each zone. The diver, equipped with snorkeling or scuba gear as depth required, then swam the length of one or a pair of 50-m or 100-m transects within each zone, approximately parallel to its borders, and enumerated the fishes observed within one meter to either side of the transect line. An area of either 100 m^2 or 200 m^2 was thus sampled along each of the parallel transects. The numerical abundance of fishes along each transect was then calculated by dividing the total number of fish recorded by the appropriate value. Very cryptic or nocturnal species may not be accurately represented in the counts as all transects were run in the daytime and without the use of ichthyocides. A small multipronged spear was used to collect specimens of several species not readily identifiable in the field. These specimens were preserved in formalin or frozen and returned to the University of Guam Marine Laboratory for identification.

RESULTS AND DISCUSSION

BALABAT, YAP

Reef Profile

Fig. 7 depicts the vertical reef profile along the proposed route of the sewer line at Balabat. The reef divisions, types of substrata and distribution of dominant reef organisms are also shown.

Water Circulation

Current determinations for 17 March 1978 at the Balabat site show definite tidal influence. During a rising tide the 1-meter and 5-meter drogues (tracts 1a-d and 2a-d, Fig. 8) traveled in a northwest direction at an average speed of 0.18 and 0.17 knots, respectively (Table 1). It should be noted that after these two runs the 5-meter drogues were shortened to 2.5 meters because of constant grounding on the channel margin. At the onset of high tide, the 1-m and 2.5-m drogues began to reverse direction (Fig. 8, Nos. 3 and 4) and the average speeds decreased to 0.06 and 0.09 knots, respectively. During the falling tide the drogues traveled southeast at the same average rates as on the rising tide. The existence of only one direct seaward opening and the relatively narrow width of the channel may explain the similarity in the rates of water movement during the flood and ebb tides. The relationship between tide cycle and current speed for the 1-m drogues is illustrated in Fig. 9.

Wind speed and direction appeared to have little, if any, influence on drogue movement, except possibly for tracts 6c and 6d. At this time, the 2.5-m drogues traveled in a westerly direction as did the wind. In a previous report on water circulation in the major harbors of Yap (Chernin, 1978), it was shown that winds in excess of 12 knots were sufficient to affect drogue movement. The present study seems to contradict this; the drogues traveled against an average wind speed of 13.7 knots (Table 1). However, the prior study was conducted in large embayments and, therefore, water movement may not have been under the same influences as in the relatively narrow channel at this site.

Fluorescein dye studies conducted during ebb tide (Fig. 10) show water movement toward the southwest at a rate of .04 to .06 m/sec. Other dye releases made at four sites along the proposed route of the sewer on March 18, 1978 also show water movement in the same direction during flood tide.

Physicochemical Characteristics of the Water

The physicochemical measurements obtained at the proposed outfall site are presented in Tables 2 and 3. The temperature and pH values are normally what one would expect in lagoon waters. Dissolved oxygen values ranged from 6.27 to 10.59 µg-at/l. The lower end of this range

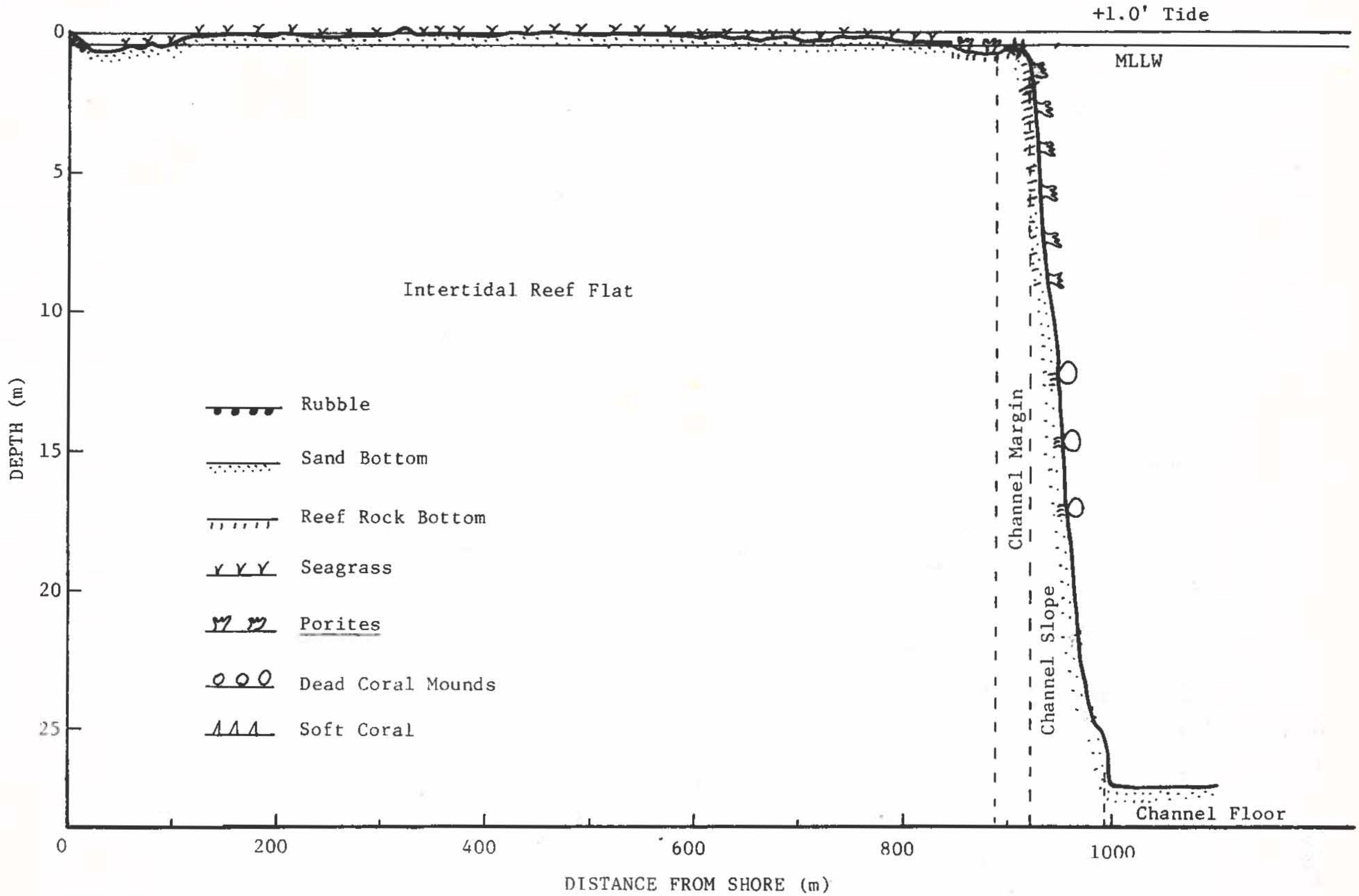


Figure 7. Vertical profile of proposed sewer route off Balabat, Yap, showing reef divisions, distribution of dominant reef organisms and types of substrata. Vertical exaggeration is X8.6.

Table 1. Distance and speed of 1-meter and 2.5-meter/5-meter drift drogues, and direction and speed of wind, Balabat, Yap. March 17, 1978.

Water Movement					Wind	
Drogue	Start	T (hrs.)	Dist. (NM)	Speed (knots)	Dir.	Speed (knots)
1a (1 m)	0850	0.98	.08	.08	66°	14
1b (1 m)	0850	1.22	.07	.06		
1c (5 m)	0850 (Grd.)	1.08	.05	-		
1d (5 m)	0850	1.32	.19	.14		
2a (1 m)	1012	0.80	.20	.25	85°	17
2b (1 m)	1012	0.80	.18	.22		
2c (5 m)	1012 (Grd.)	0.80	.23	-		
2d (5 m)	1012 (Grd.)	0.80	.22	-		
3a (1 m)	1105	1.42	.30	.21	66°	14
3b (1 m)	1105	1.42	.33	.23		
3c (2.5 m)	1105	1.42	.27	.19		
3d (2.5 m)	1105	1.42	.26	.18		
4a (1 m)	1240	1.75	.12	.07	78°	14
4b (1 m)	1240	1.93	.12	.06		
4c (2.5 m)	1240	2.03	.18	.09		
4d (2.5 m)	1240	2.03	.18	.09		
5a (1 m)	1442	0.92	.19	.21	49°	14
5b (1 m)	1442	0.88	.20	.23		
5c (2.5 m)	1442	0.80	.26	.32		
5d (2.5 m)	1442	0.83	.38	.46		
6a (1 m)	1544	1.18	.30	.25	86°	10
6b (1 m)	1544	1.18	.30	.25		
6c (2.5 m)	1544	1.27	.05	.04		
6d (2.5 m)	1544	1.27	.05	.04		

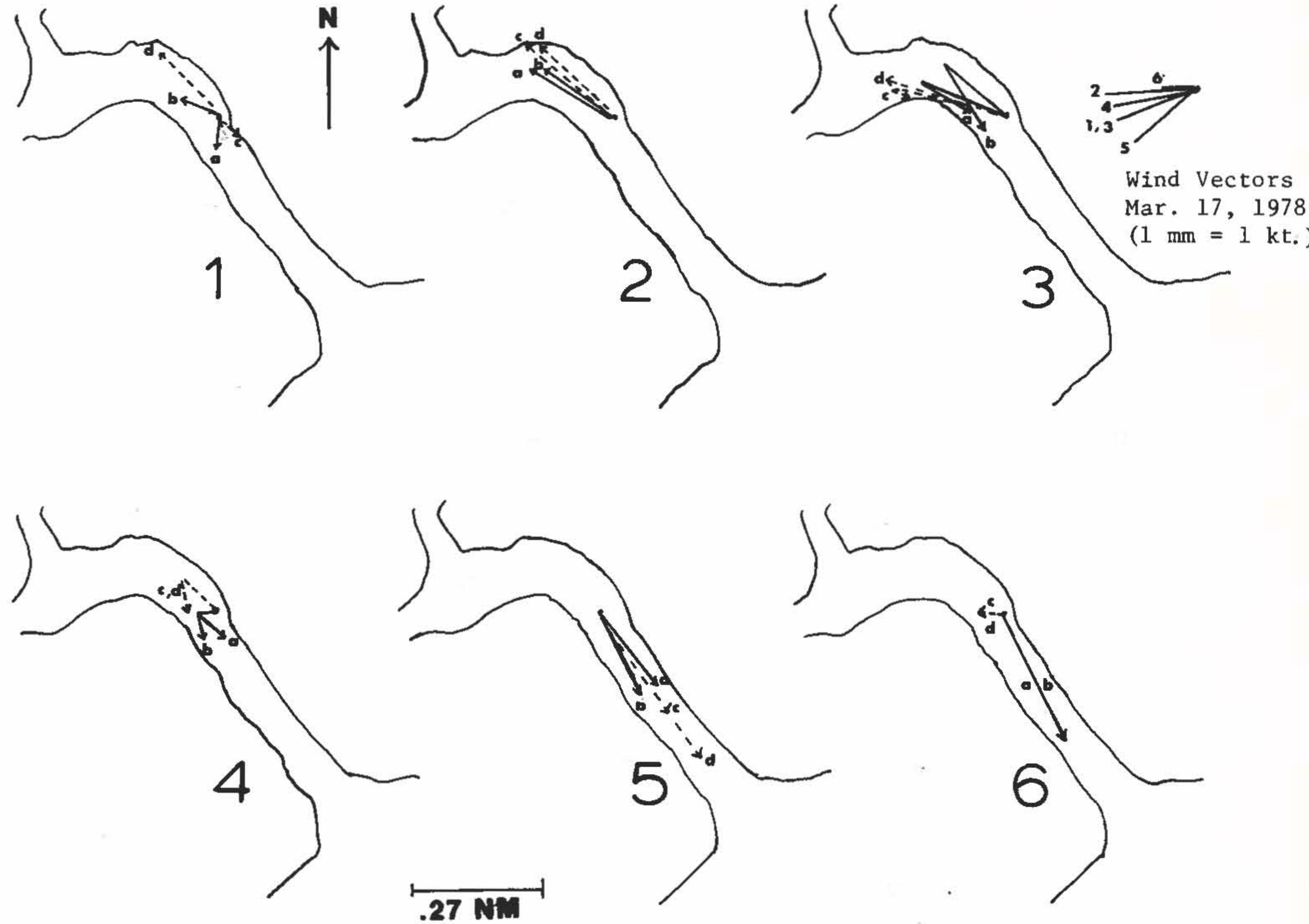


Figure 8. Drift patterns of 1-meter (a and b) and 2.5-meter/5-meter (c and d) drogues in Gabach Channel off Balabat, Yap. Wind vectors are shown in upper right-hand corner. March 17, 1978.

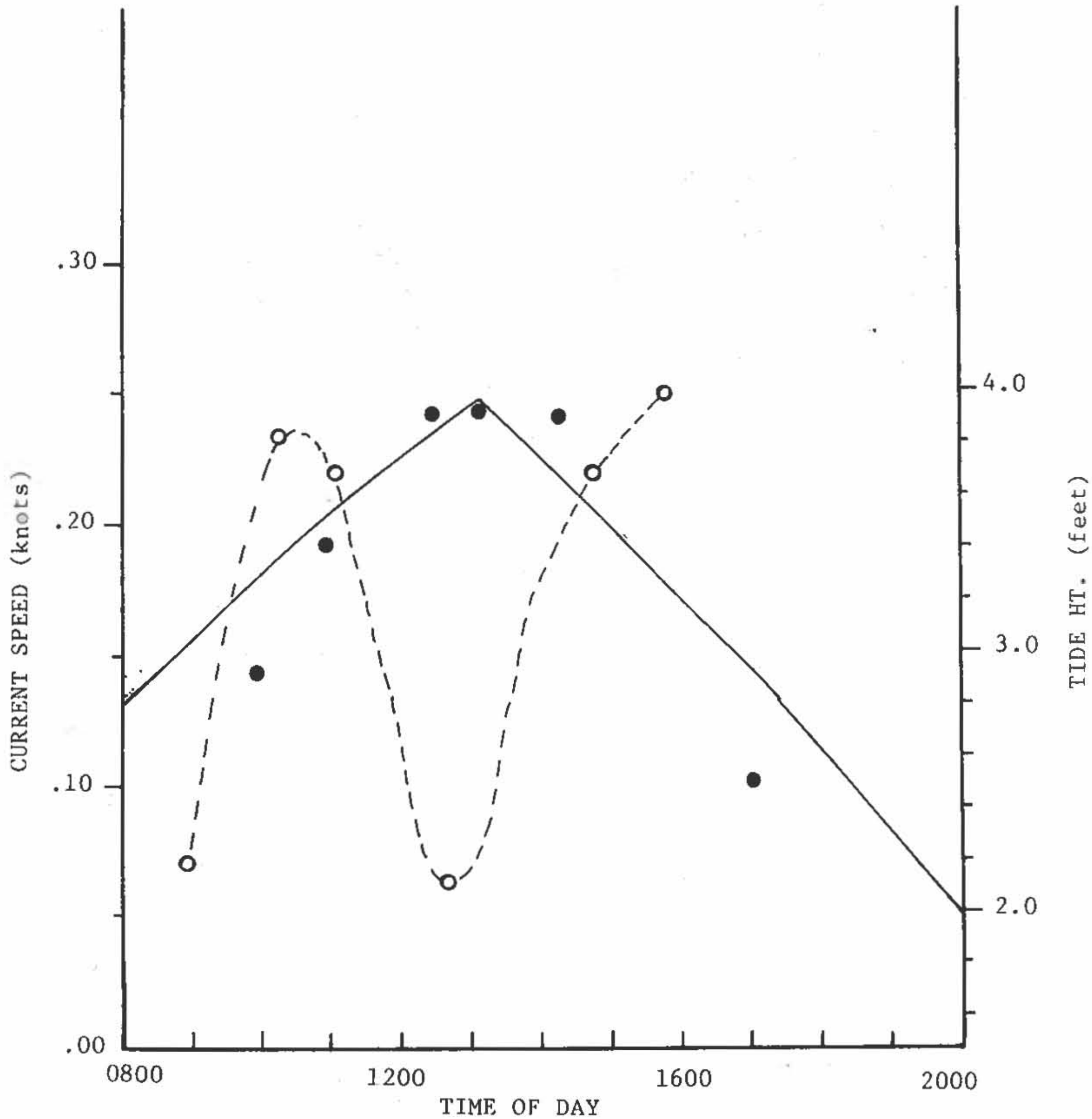


Figure 9. Relationship of tide height (solid line) and current speed (dashed line) of 1-meter drogues in Gabach Channel, off Balabat, Yap. Closed circles: tide height measured in study area; open circles: speed of 1-meter drift drogues. March 17, 1978.

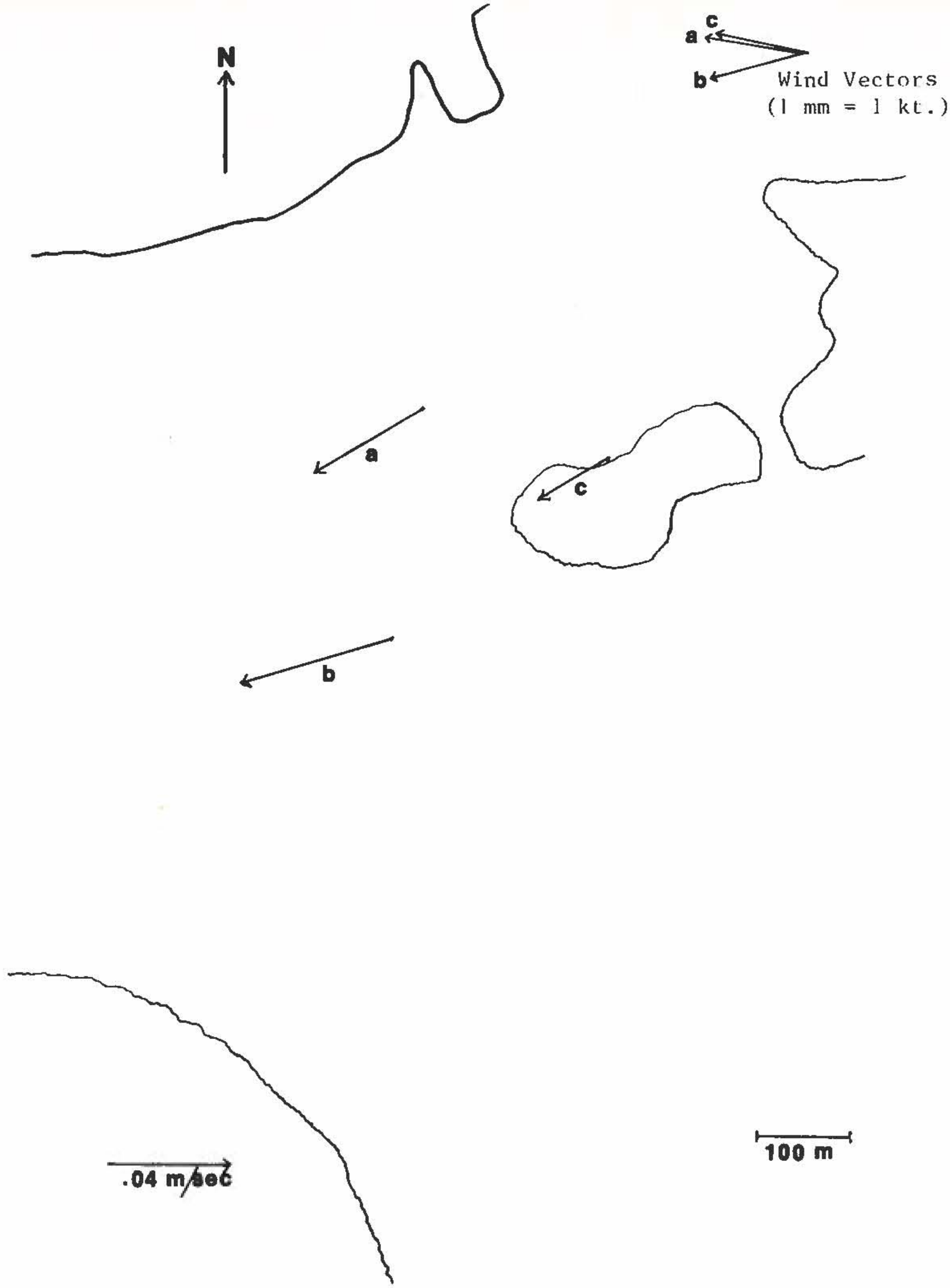


Figure 10. Current vectors on reef flat measured with fluorescein dye during ebb tide off Balabat, Yap. Site a, 0930 - 0942; Site b, 0949 - 1001; Site c, 1152 - 1202. High tide occurred at 0620 (+3.9 ft.) and low tide occurred at 1208 (+2.1 ft.). March 21, 1978.

Table 2. Selected physicochemical characteristics of seawater samples collected in Gabach Channel, Balabat, and Pelak Channel, Yap.

Location/Depth	Temp. (°C)	Sal. (°/oo)	pH	Dis. O_2 (µg-at/l)
BALABAT (March 17, 1978; 1600-1635)				
0 m (seagrass bed, 100 m shoreward of channel margin)	29	33.9	8.2	10.59
0 m (mid-channel)	28	34.4	8.1	9.29
5 m (mid-channel)	27	34.4	8.1	6.52
10 m (mid-channel)	27	38.3	8.0	6.43
15 m (mid-channel)	27	37.2	7.8	6.43
20 m (mid-channel)	27	34.4	7.8	6.27
PELAK (March 20, 1978; 1415-1540) Proposed Outfall Route				
0 m (mangrove fringe)	29.9	33.3	7.9	5.87
0 m (seagrass bed, 100 m from mangrove)	29.2	40.0	7.8	5.70
0 m (channel margin)	29.1	33.9	8.0	7.66
0 m (mid-channel)	29.6	33.9	8.3	9.13
2 m (mid-channel)	29.5	33.9	8.3	8.88
4 m (mid-channel)	29.0	33.9	8.3	7.33
Alternate Site				
0 m (mid-channel)	29.8	33.9	8.3	10.43
8 m (mid-channel)	28.0	33.9	8.0	5.38

Table 3. Selected chemical characteristics of seawater samples collected in Gabach Channel, Balabat and Pelak Channel, Yap. All values are in µg-at/l. * = significant difference between PO_4-P and total-P. Others not significantly different within precision limits of test. ** = one sample only.

Location/Depth	PO_4-P	Tot.-P	NO_2-N	NO_3-N	NH_4-N	Tot.-N	Org.-N
BALABAT (March 17, 1978; 1600-1635)							
0 m (seagrass bed, 100 m shoreward of channel margin)	.24	.76*	.00	.31	1.73	3.36± .82	1.63
0 m (mid-channel)	.26	.21	.04	.22	1.78	4.59±2.42	2.81
10 m (mid-channel)	.33	.26	.02	.46	1.26	4.55±3.22	3.29
20 m (mid-channel)	.09	.56*	.06	.24	1.21	6.20± .08	4.99
PELAK (March 20, 1978; 1415-1540) Proposed Outfall Route							
0 m (mangrove fringe)	.10	.46*	.06	.41	1.19	2.70± .20	1.51
0 m (seagrass bed)	.07	.43*	.02	.60	1.66	3.54**	1.88
0 m (reef margin)	.08	.44*	.00	.22	1.27	7.77± .46	6.50
0 m (mid-channel)	.08	.38*	.02	.20	0.85	3.99± .37	3.14
2 m (mid-channel)	.09	.26*	.04	.24	1.43	6.52±1.45	5.09
4 m (mid-channel)	.16	.34*	.04	.14	1.43	3.11**	1.68
Alternate Site							
0 m (mid-channel)	.88	.97	.10	.24	1.14	2.12**	0.98
8 m (mid-channel)	.11	.30	.08	.21	1.93	6.18±5.33	4.25

Table 4. Surface temperature and salinity values obtained at 100-meter intervals along proposed sewer pipe route off Balabat, Yap, March 16, 1978. Measurements were taken during ebb tide between 1215 and 1645 (+4.3 feet to +1.8 feet). See Fig. 4 for location of sewer pipe route.

Distance From Shore (m)	Depth (cm)	Temp. (°C)	Sal. (°/oo)
1 (Shore)	10	28.7	33.9
100	130	28.2	33.9
200	95	28.9	33.9
300	99	28.7	33.9
400	100	28.7	34.4
500	104	28.6	35.0
600	112	28.6	34.4
700	110	28.5	34.4
800	105	28.5	34.4
900	195	28.9	34.4
920 (Channel Edge)	-	-	-

is still close to the saturation limit of oxygen at 27°C. The supersaturated values above 8 µg-at/l found in those samples taken from the surface of the seagrass bed and channel are typical of the high photosynthetic rates (production of oxygen) present in seagrass beds. Except for the high salinity values obtained at the 10-meter and 15-meter depth, the other values seem within normal range for waters exposed to freshwater runoff. The values of 38.3 and 37.2°/oo at the 10- and 15-meter depths, respectively, cannot be explained and may be due to faulty reading of the refractometer.

Nitrogen and phosphorus fractions were low and typical of reef ecosystems. The high organic nitrogen values in the deeper depths of the channel indicate accumulation of organic matter, probably from the seagrass beds.

Temperature and salinity readings (Table 4) taken at 100-meter intervals from shore to the channel edge at Balabat seem normal for a reef flat environment. Temperature ranged from 28.2 to 28.9°C; salinity ranged from 33.9 to 35.0°/oo. Higher salinity values were obtained nearer the channel.

Biota

Biotic Zones - Five distinct biotic zones are present on the reef flat off Balabat. See Fig. 7 for vertical profile. The seven transects run here sampled these five zones as well as a site on the channel slope in 10-meters of water. The zones in which each of the transects were run and the length of each zone are as follows.

Transect A - Boulder-Rubble Zone (0-14 m from shore)
Transect B - *Enhalus* Zone (14-140 m from shore)
Transect C - Mixed Seagrass and Algae Zone (140-865 m from shore)
Transect D - Mixed Seagrass and Algae Zone (140-865 m from shore)
Transect E - *Porites*-*Favites*-Sand Zone (865-900 m from shore)
Transect F - Soft Coral Zone (900-920 m from shore)
Transect G - Silt-Coral Zone (Channel Slope)

Marine Plants - A total of 51 species of marine benthic plants (Table 5) was observed on Balabat reef flat. This compares favorably with the 41 and 51 species, respectively, reported by Amesbury et al. (1976, 1977) in Tomil Harbor, Yap. Tsuda (1978) lists 143 species of marine benthic algae from Yap. Marine plant cover ranged from a high of 97 percent in the mixed seagrass zone (Transect D), to a low of <34 percent (Transect E). A summary histogram of major functional components along each transect is illustrated in Figure 11.

Table 5. Checklist of marine plants observed and/or quantified along seven transects at Balabat, Yap on March 16-18, 1978. The locations of the transects are shown in Figure 4. Plain numbers indicate relative percent cover. Numbers in parentheses represent frequency. X = observed in the vicinity of the transect. * = see specific designation at end of table.

	TRANSECTS						
SPECIES	A	B	C	D	E	F	G
CYANOPHYTA (blue-green algae)							
Hormothamnion enteromorphoides Bornet & Flahault	X	X	2(.09)	2(.09)			
Microcoleus lyngbyaceus (Kutz.) Crouan	64(.61)	X	X	X	X	1(.05)	3(.12)
Schizothrix calicola (Ag.) Gomont	14(.09)	1(.16)	3(.16)	X	X	1(.10)	1(.02)
Schizothrix mexicana Gomont		X	X	X			X
CHLOROPHYTA (green algae)							
Avrainvillea obscura J. Ag.	X						
Boergesenia forbesii (Harv.) Feldmann	X						
Boodlea composita (Harv.) Brand			X	X		1(.02)	
Bryopsis pennata Lamx.						1(.02)	
Caulerpa cupressoides (West) C. Ag.			X	X			
Caulerpa racemosa (Forskal) J. Ag.		4(.19)	1(.09)	5(.30)			
Caulerpa serrulata (Forskal) J. Ag.			X	X			
Caulerpa sertularioides (Gmel.) Howe		X	X	X			
Caulerpa taxifolia (Vahl.) C. Ag.			X	X			
Caulerpa urvilliana Montagne		X	X	X			
Chaetomorpha sp.		X	X				
Dictyosphaeria cavernosa (Forskal) Boerg.	X	X	X	X			
Halimeda discoidea Decaisne			3(.33)	3(.33)			
Halimeda incrassata (Ellis) Lamx.			X	X	X		
Halimeda macroloba Decaisne		2(.14)	3(.21)	5(.38			
Halimeda macrophysa Askenasy					X	X	
Halimeda opuntia (L.) Lamx.	X	3(.09)	2(.28)	1(.16)	X	1(.02)	
Halimeda taenicola Taylor						X	
Neomeris annulata Dickie	1(.04)	X	X	X	X		X

Table 5. Continued.

SPECIES	A	B	C	D	E	F	G
				TRANSECTS			
Tydemannia expeditionis Weber van Bosse						1(.07)	
Ulva lactuca L.			X	X			
Valonia fastigiata Harvey							
Valonia ventricosa J. Ag.			X	X		X	
PHAEOPHYTA (brown algae)							
Dictyota bartayresii Lamx.		X	X	X			
Dictyota divaricata Lamx.			X	X		1(.07)	1(.05)
Hydroclathrus clathratus (C. Ag.) Howe		5(.11)	1(.02)	X			
Lobophora variegata (Lamx.) Womersley			1(.04)	X			
Padina tenuis Bory	2(.04)	1(.09)	X	X			
Turbinaria ornata (Turner) J. Ag.						X	
RHODOPHYTA (red algae)							
Actinotrichia fragilis (Forskal) Boerg.			X	1(.07)		X	
Amphiroa fragilissima (L.) Lamx.			X	X		1(.10)	
Ceramium sp.							X
Gelidium pusillum (Stackh.) Le Jolis		1(.04)				3(.12)	*
Gracilaria salicornia (Mert.) Grev.			X	X			
Hypoglossum attenuatum Gardner							*
Jania capillacea Harv.						X	
Laurencia papillosa (Forskal) Grev.			X	X		1(.02)	*
Mastophora rosea (C. Ag.) Setchell						1(.02)	
Metagoniolithon sp.			X	1(.02)		1(.07)	
Polysiphonia sp.						13(.25)	*
Porolithon onkodes (Heyd.) Foslie						9(.12)	

Table 5 . Continued.

SPECIES	TRANSECTS A	B	C	D	E	F	G
ANTHOPHYTA (seagrasses)							
Cymodocea rotundata Ehrenb. & Hempr.	4(.11)		2(.04)	8(.45)			
Cymodocea serrulata (R. Br.) Aschers.			2(.04)	X			
Enhalus acoroides (L.f.) Rich.	X	29(.92)	27(.080	8(.57)	X		
Halophila ovalis (R. Br.) Hook.			X	1(.02)	X		
Syringodium isoetifolium (Aschers.) Dandy			1(.07)	14(.57)	X		
Thalassia hemprichii (Ehrenb.) Aschers.			44(.83)	48(1.0)	26(.57)		
OTHER							
Soft corals (Alcyonacea)					4(.70)	44(.45)	1(.70)
Hard corals (Scleractinia)		2(.04)			10(.24)	9(.30)	28(.25)
Sand/rubble substrate	15(.16)	52(.90)	8(.23)	3(.21)	60(.64)	13(.20)	30(.35)
*Red algal turf							37(.30)

TOTAL SPECIES = 51

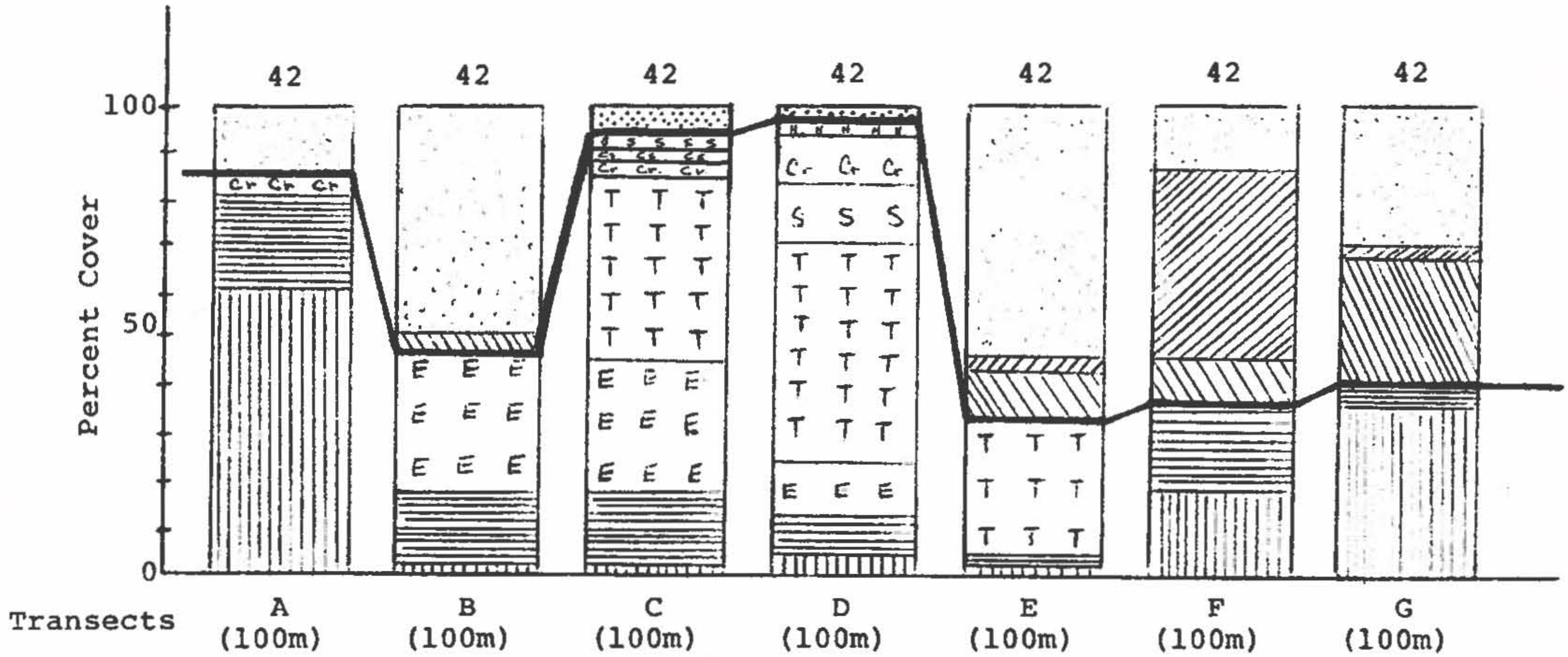
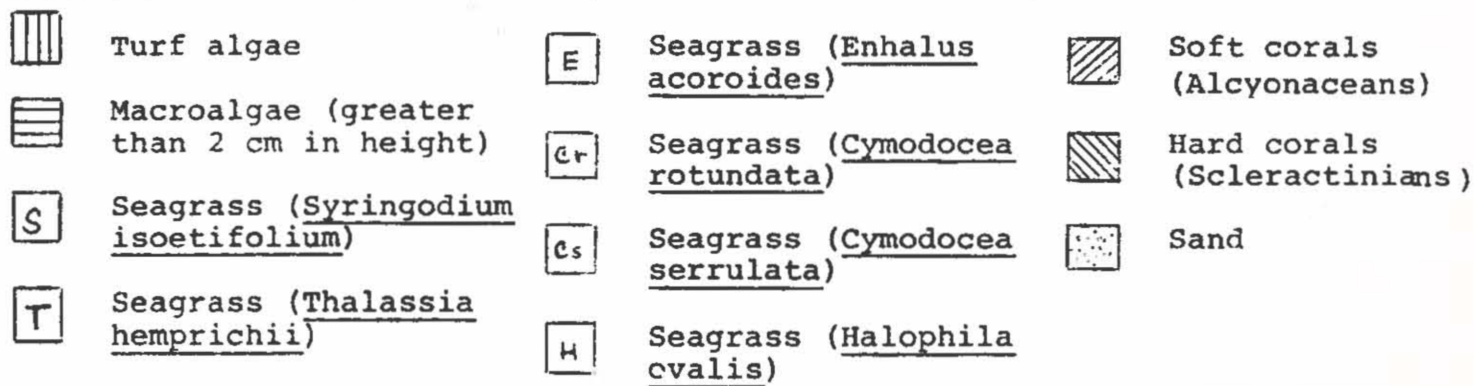


Figure 11. Summary histogram showing percent cover of various functional groups along the seven transects off Balabat, Yap. The number above each bar denotes the number of tosses on which the analyses are based. The heavy black line separates marine plants from sand and corals.



Transect A consisted of 64 percent Microcoleus lyngbyaceus. This blue-green alga provided a thick supportive matrix for the fine silt substrate. Scattered small clumps of Avrainvillea obscura, Halimeda opuntia, Neomeris annulata and Padina tenuis were also present but accounted for less than 20 percent of the total cover. A few individual seagrass plants (Cymodocea rotundata) were observed, accounting for less than 5 percent.

The seagrass Enhalus acoroides accounted for 29 percent of the total cover along Transect B. Intermixed with the seagrass were Caulerpa racemosa, Halimeda opuntia, Halimeda macroloba, Hydroclathrus clathratus and a few other occasional species.

Transects C and D consisted of mixed seagrass species and a tremendous array of macroalgae. Cover approached 100 percent. The richness and diversity of these zones are reflected in the six seagrass species present and some 30 algal species. Both zones were dominated by the seagrass Thalassia hemprichii, accounting for 44 and 48 percent, respectively. Kock and Tsuda (1978) cite this seagrass species as the most dominant in the lagoon of Yap. The percentage of Enhalus cover decreased seaward, being gradually replaced by Cymodocea rotundata and Syringodium isoetifolium. The major algal understory species consisted of Caulerpa racemosa, Dictyota bartayresii and four Halimeda species. Locally distinct patches of Ulva lactuca, Hydroclathrus clathratus, Padina tenuis and Gracilaria salicornia were also abundant. The presence of the green alga genus Ulva in abundance here is unique since this genus is rare in Micronesia (Tsuda, 1968).

Transect E roughly delineated the end of the seagrass zone. Thalassia hemprichii accounted for 26 percent of the cover with scattered algal individuals accounting for less than 10 percent. The area was largely dominated by large mounds of the coral Porites lutea and expanses of sand.

Transect F was dominated by alcyonacean soft corals, accounting for 44 percent of the total cover. Algal cover, accounting for 34 percent, was evenly divided between turf and macroalgal species. Polysiphonia and Gelidium species accounted for most of the turf, while Halimeda opuntia, Halimeda taenicola and Dictyota divaricata accounted for most of the macroalgae.

Transect G primarily consisted of coral and rubble, of which approximately 37 percent was covered by a fine Gelidium/Polysiphonia algal turf.

The Balabat reef flat extends over a thousand meters from shore to channel margin. Approximately 800 meters can be classified as mixed algal-seagrass beds. Six species of seagrasses and 45 species of marine benthic algae were identified. The area is very rich and diverse with floral cover approaching 100 percent in many places.

Corals - The qualitative transect, perpendicular to shore, at Balabat (Fig. 4) showed an increasing coral diversity and percent cover towards the channel margin. A subsequent decrease in diversity and percent cover was apparent on the channel slope and channel floor which was primarily silt and therefore not suitable for coral settlement.

There were no corals in the intertidal zone along the perpendicular transect at Balabat. This lack of coral probably results from elevated temperatures and exposure at low tide (see Fig. 7). Within the Enhalus and mixed seagrass zones, Porites lutea and Montipora divaricata were common. Other less common species in this area included Pocillopora damicornis, Favites melicerum and Favia sp. An area of transition between the mixed seagrass community and channel margin (approximately 20 m wide) had Porites lutea and Favites melicerum as the dominant corals. This area was also characterized by vast areas of coral fragments and coarse unconsolidated substrate. The highest species diversity occurred along the channel margin with 45 species recorded (Table 6). The dominant corals in this area included Porites andrewsi, P. (Synaraea) iwayamaensis, P. lutea, Pavona obtusata and numerous Acropora and Montipora species. Corals of the family Fungiidae were also locally abundant on the uppermost part of the channel margin. The upper channel slope was characterized by large colonies of P. andrewsi and P. (Synaraea) iwayamaensis. Scattered colonies of Favia sp. and Porites lutea were also observed. The lower slope was primarily covered by unconsolidated sand and coral-algal rubble.

Seven quantitative transects (Fig. 4), parallel to shore, were established at the Balabat site. Only four of these transects (B, E, F, and G) contained coral species. On the reef flat transects, P. lutea was dominant with a 2.1 and 6.5 percent cover on Transects B and E, respectively (Table 7). These data are in agreement with data obtained by R. H. Randall (Amesbury et al., 1976) in similar zones off Donitsch Island, Yap. Transect E was in the area of transition between the seagrass communities and channel margin and had a higher diversity and overall percent cover than Transect B in the Enhalus zone (6 species, 10.9 percent vs 1 species, 2.1 percent). This is reflective of the variation in substrate; Transect B was primarily sand, while Transect E had a coarser, more consolidated substrate. The channel zones varied slightly in coral cover from 10.7 percent (Transect F) to 11.0 percent (Transect G). This slight variation does not adequately show the difference in coral community development along the two transects. A comparison of the number of species recorded and the overall densities between the transects gives a better indication of the existing differences. Transect F, along the channel margin, had 19 species with an overall density of 8.5 corals/m^2. These data, along with an overall percent cover of 10.7 indicate the presence of small colonies. In comparison, only eight species were recorded from Transect G along the channel slope with an overall density of 3.65 corals/m^2 and percent cover of 11.0 indicating large colonial formations.

Table 6. List of corals observed within the Balabat site, Yap, by physiographic zones and Transects A-G. Symbols indicate their relative abundance within the various physiographic zones: D=dominant, A=abundant, C=common, O=occasional, and R=rare.

CORALS	PHYSIOGRAPHIC ZONES: Reef Flat	Channel Margin	Channel Slope	TRANSECTS: A	B	C	D	E	F	G
CLASS - ANTHOZOA										
ORDER - SCLERACTINIA										
SUBORDER - ASTROCOENIINA										
FAMILY - ASTROCOENIIDAE										
Stylocoeniella armada (Ehrenberg)	R	R	O							
FAMILY - THAMNASTERIIDAE										
Psammocora contigua (Esper)	O	O								
Psammocora (Stephanaria) togianensis Umbgrove		O	R							
FAMILY - POCILLOPORIDAE										
Stylophora mordax (Dana)		O	O						X	
Seriatopora hystrix Dana	O	O						X	X	
Pocillopora damicornis (Linnaeus)	O	O								
FAMILY ACROPORIDAE										
Acropora formosa (Dana)		O	R						X	
Acropora humilus (Dana)		R						X		
Acropora palifera (Lamarck)		R								
Acropora sp.		O							X	
Astreopora myriophthalma (Lamarck)		R	R							
Montipora berryi Hoffmeister	R	O								
Montipora digitata (Dana)	O									
Montipora divaricata Brueggeman	C									

Table 6. Continued.

CORALS	PHYSIOGRAPHIC ZONES: Reef Flat	Channel Margin	Channel Slope	TRANSECTS: A	B	C	D	E	F	G
FAMILY ACROPORIDAE										
Montipora sp. cf. *M. ehrenbergii* Verrill	R	O								X
Montipora lobulata Bernard		O								
Montipora turgescens Bernard		R								
Montipora verrilli Vaughan		O								
SUBORDER - FUNGIINA										
FAMILY - AGARICIIDAE										
Pavona frondifera Lamarck		R								
Pavona (Polyastra) obtusata (Quelch)	O	C						X	X	
Pavona variens Verrill		O							X	
Pachyseris rugosa (Lamarck)		O	R							
Pachyseris speciosa (Dana)			R							X
FAMILY - FUNGIIDAE										
Fungia (Fungia) fungites (Linnaeus)		A	O						X	
Herpolitha limax (Esper)		O								
Herpentoglossa simplex (Gardiner)		O							X	
Parahalomitra robusta (Quelch)		O								
FAMILY - PORITIDAE										
Porites andrewsi Vaughan		C	A						X	X
Porites lobata Dana		O								
Porites lutea Milne-Edwards and Haime	A	A	C		X			X	X	X
Porites (Synaraea) convexa Verrill		O	O							
Porites (Synaraea) horizontalata Hoffmeister		O								

Table 6. Continued.

CORALS	PHYSIOGRAPHIC ZONES: Reef Flat	Channel Margin	Channel Slope	TRANSECTS: A	B	C	D	E	F	G
FAMILY - PORITIDAE										
Porites (*Synaraea*) *iwayamaensis* Eguchi		D	C						X	X
SUBORDER - FAVIINA										
FAMILY - FAVIIDAE										
Favia pallida (Dana)	O	O	R							
Favia sp. cf. *F. rotumana* (Gardiner)		O							X	X
Favia speciosa (Dana)	R	O	O							
Favites abdita (Ellis and Solander)		O							X	
Favites melicerum (Ehrenberg)	C	A	O					X	X	
Goniastrea edwardsi Chevalier	O	C						X	X	
Platygyra lamellina (Ehrenberg)		R								
Diploastrea heliopora (Lamarck)		O								
Leptastrea purpurea (Dana)		O	O							
Leptoria phrygia (Ellis and Solander)		R							X	
FAMILY - OCULINIDAE										
Galaxea fascicularis (Linnaeus)			R							
Acrhelia horrescens (Dana)		R	R						X	
FAMILY - MERULINIDAE										
Merulina ampliata (Ellis and Solander)	R	O	O							X
Merulina laxa (Dana)		C	O						X	X

Table 6. Continued.

CORALS	PHYSIOGRAPHIC ZONE: Reef Flat	Channel Margin	Channel Slope	TRANSECTS: A	B	C	D	E	F	G
FAMILY - MUSSIDAE										
Lobophyllia costata (Dana)		O	O							
FAMILY - PECTINIIDAE										
Mycedium elephantotus (Pallus)			O							
FAMILY - CAROPHYLLIIDAE										
Physogyra lichtensteini Milne-Edwards and Haime			O							
CLASS - HYDROZOA										
ORDER - MILLEPORINA										
FAMILY - MILLEPORIDAE										
Millepora exaesa Forskaal		R	O						X	
Millepora intricata Milne-Edwards and Haime			R							
TOTAL GENERA	12	26	18	0	1	0	0	6	13	5
TOTAL SPECIES	15	45	25	0	1	0	0	6	19	8
Total Genera for Study Site 29										
Total Species for Study Site 52										

Table 7. Living coral density, percent of substratum coverage, and frequency of occurrence along the seven transects at Balabat, Yap. Relative values of these three measures are summed to give an importance value. Overall density and percent cover are given for each transect zone where corals occurred. Species are arranged in order of their importance value.

TRANSECT A	Fre-quency	Relative Fre-quency	Density	Relative Density	Percent Cover	Relative Percent Cover	Impor-tance Value
NO CORALS ENCOUNTERED							
TRANSECT B							
Porites lutea	0.1	100	1.1	100	2.1	100	300
TRANSECT C							
NO CORALS ENCOUNTERED							
TRANSECT D							
NO CORALS ENCOUNTERED							
TRANSECT E							
Porites lutea	0.7	38.9	1.3	37.5	6.5	59.6	136.0
Favites melicerum	0.7	38.9	1.6	45.8	4.3	39.4	124.0
Goniastrea edwardsi	0.1	05.5	0.15	04.2	0.04	00.37	10.1
Acropora humilus	0.1	05.5	0.15	04.2	0.03	00.27	10.0
Pavona obtusata	0.1	05.5	0.15	04.2	0.02	00.18	9.9
Seriatopora histrix	0.1	05.5	0.15	04.2	0.01	00.09	9.8
Overall density 3.5 corals/m^2							
overall percent of cover 10.9%							

Table 7. Continued.

TRANSECT F	Frequency	Relative Frequency	Density	Relative Density	Percent Cover	Relative Percent Cover	Importance Value
Porites (Synaraea) iwayamaensis	0.4	14.2	1.4	16.9	3.5	32.7	63.8
Pavona (Polyastra) obtusata	0.4	14.2	1.4	16.9	3.5	30.8	61.9
Porites andrewsi	0.4	14.2	1.1	12.3	1.9	17.7	44.2
Porites lutea	0.2	7.1	0.7	7.7	0.6	5.6	20.4
Seriatopora histrix	0.2	7.1	0.5	6.2	0.3	2.8	16.1
Favites melicerum	0.1	3.5	0.5	6.2	0.2	1.9	11.6
Pavona variens	0.1	5.3	0.4	4.6	0.1	0.9	10.8
Merulina laxa	0.1	3.5	0.3	3.1	0.2	1.9	8.5
Millepora exaesa	0.1	3.5	0.3	3.1	0.2	1.9	8.5
Favia sp. cf. F. rotumana	0.1	3.5	0.3	3.1	0.1	0.9	7.5
Favites abdita	0.1	3.5	0.3	3.1	0.05	0.5	7.1
Herpentoglossa simplex	0.1	3.5	0.3	3.1	0.05	0.5	7.1
Goniastrea edwardsi	0.1	3.5	0.3	3.1	0.03	0.3	6.9
Stylophora mordax	0.1	3.5	0.3	3.1	0.03	0.3	6.9
Acropora formosa	0.05	1.7	0.1	1.5	0.1	0.9	4.1
Acropora sp.	0.05	1.7	0.1	1.5	0.01	0.1	3.3
Acrhelia horrescens	0.05	1.7	0.1	1.5	0.01	0.1	3.3
Fungia (Fungia) fungites	0.05	1.7	0.1	1.5	0.01	0.1	3.3
Leptoria phrygia	0.05	1.7	0.1	1.5	0.01	0.1	3.3

Overall density 8.5 corals/m^2
Overall percent cover 10.7%

TRANSECT G	Frequency	Relative Frequency	Density	Relative Density	Percent Cover	Relative Percent Cover	Importance Value
Porites andrewsi	0.4	32.0	1.6	40.7	9.7	87.9	160.6
Porites (Synaraea) iwayamaensis	0.2	16.0	0.6	14.8	0.6	5.2	36.0
Porites lutea	0.2	16.0	0.4	11.1	0.3	3.0	30.1
Favia sp. cf. F. rotumana	0.2	16.0	0.4	11.1	0.2	1.4	28.5
Montipora sp. cf. M. ehrenbergii	0.1	8.0	0.3	7.4	0.05	0.5	15.9
Pachyseris speciosa	0.05	4.0	0.2	3.7	0.1	1.2	8.9
Merulina ampliata	0.05	4.0	0.2	3.7	0.05	0.5	8.2
Merulina laxa	0.05	4.0	0.2	3.7	0.04	0.4	8.1

Overall density 3.65 corals/m^2
Overall percent cover 11.03%

The percent of substrate coverage for Transects F and G appears low compared with similar areas investigated in Palau (Birkeland et al., 1976; Randall et al., 1978), Yap (Amesbury et al., 1976) and Truk (Amesbury et al., 1977). This low hard coral coverage may be partially explained by the high abundance of Alcyonacea (soft corals) along the channel margin.

Other Macroinvertebrates - The reef at Balabat was characterized by a diverse fauna of macroinvertebrates, but the various species present were found in low abundance (Table 8). Smith (1978) provides a listing of gastropods and bivalves known from Yap. An attempt to adjust quantification to these conditions was made. Using a 10-m^2 quadrat, Amesbury et al. (1976) found sample variances to be large compared with the means. As a result, these authors recommended the use of 25-m^2 quadrats. In a modification of that recommendation, quadrats of 20 m^2 were used wherever necessary in this study.

The boulder-rubble zone was very sparsely populated. Single specimens of the holothurian Bohadschia marmorata and the scyphozoan Cassiopeia (cf. medusa Light) and two Holothuria atra were found near the more sheltered southern end of the transect. The more exposed northern end was entirely devoid of macroinvertebrates. The gastropods Strombus gibberulus gibbosus, Cypraea annulus, and Conus ebraeus were observed in the vicinity, but did not occur on the transect.

Holothurians were the predominant invertebrates of the Enhalus zone. Holothuria leucospilota was recorded from one quadrat, where 13 specimens occurred in association with small Porites colonies. It is interesting to note that no other holothurians were present in quadrats where Holothuria atra occurred.

Two transects were established in the mixed seagrass-algae zone. Echinoderms were seldom found on Transect C. The holothurian Actinopyga echinites occurred only on this transect and was not present in sufficient numbers to indicate the clumped distributions previously reported (Amesbury et al., 1976; Grosenbaugh, 1978). Transect C demarcated the outer limit in distribution of Cassiopeia sp.

The asteroid Protoreaster nodosus was the most conspicuous invertebrate on Transect D. Holothuria atra was relatively abundant, but its range did not extend seaward beyond the mixed seagrass-algae zone. The holothurian Stichopus chloronotus and the spider conch Lambis lambis were encountered only ocassionally.

The small collumbellid gastropod Pyrene scripta was abundant throughout the mixed seagrass-algae zone. The snails were observed on the seagrasses and on the undercover of algae. Because they tended to fall into the algae during attempts to count them, accurate quantification of these animals was considered not possible.

Table 8. Invertebrates along the seven transects at Balabat, Yap. Transects, with the exception of Transect F, consist of ten quadrats of 20 m^2. Transect F consists of ten quadrats of 10 m^2. Values represent means and standard errors of the means, respectively, of numbers of organisms per quadrat. A "+" indicates the species was observed in the zone, but did not occur on the transect.

Class/Species	Transects						
	A	B	C	D	E	F	G
Class Scyphozoa							
Cassiopeia (cf. *medusa* Light)	0.1 ± 0.1	0.8 ± 0.3	0.5 ± 0.2				
Class Gastropoda							
Trochus niloticus Linnaeus						0.2 ± 0.1	
T. maculatus Linnaeus						0.2 ± 0.1	
Tectus pyramis (Born)						0.3 ± 0.2	
T. fenestratus (Gmelin)						0.2 ± 0.1	
Turbo argyrostomus Linnaeus						0.3 ± 0.2	
Astraea rhodostoma (Lamarck)						0.3 ± 0.2	
Cerithium echinatum (Lamarck)						0.5 ± 0.3	
C. zonatus (Woode)					+		
Strombus gibberulus gibbosus (Roeding)	+	+					
Lambis lambis (Linnaeus)				0.1 ± 0.1			
Cypraea annulus Linnaeus	+						
C. moneta Linnaeus					0.1 ± 0.1	0.1 ± 0.1	
Drupa rubusidaeus Roeding						0.1 ± 0.1	
Drupella cornus (Roeding)						1.6 ± 0.7	
D. ochrostoma (Blainville)						0.1 ± 0.1	
Morula granulata (Duclos)					0.2 ± 0.2	0.1 ± 0.1	
M. biconica (Blainville)						1.0 ± 0.9	
M. uva (Roeding)					+		
M. spinosa (H. & A. Adams)					+	+	
Coralliophila violacea (Kiener)						0.5 ± 0.4	

Table 8. Continued.

Class/Species	Transects						
	A	B	C	D	E	F	G
Class Gastropoda continued							
Pyrene testudinaria (Link)						0.1 ± 0.1	
P. turturina (Lamarck)						0.1 ± 0.1	
P. scripta (Lamarck)			+	+	0.1 ± 0.1		
Vexillum cadaverosum (Reeve)					+		
V. granosum (Gmelin)					+		
Conus distans Hwass						0.3 ± 0.2	
C. marmoreus Linnaeus						0.1 ± 0.1	
C. miles Linnaeus						0.2 ± 0.2	
C. ebraeus Linnaeus	+						
C. musicus Hwass					0.1 ± 0.1	0.7 ± 0.3	
C. sponsalis Hwass					0.2 ± 0.1	0.6 ± 0.4	
C. litteratus Linnaeus			+	+			
Otopleura nodicincta (A. Adams)					+		
Class Bivalvia							
Tridacna maxima (Roeding)						0.1 ± 0.1	
Hippopus hippopus (Linnaeus)						0.1 ± 0.1	
Barbatia sp.					+		
tellinid sp.					+		
Class Asteroidea							
Linckia laevigata (Linnaeus)					0.1 ± 0.1		
L. multifora (Lamarck)						0.3 ± 0.2	
Fromia monilis Perrier						+	+
Protoreaster nodosus (Linnaeus)			0.1 ± 0.1	0.8 ± 0.3	0.3 ± 0.2		
Echinaster luzonicus (Gray)							0.1 ± 0.1
asteroid sp.						0.1 ± 0.1	

Table 8. Continued.

Class/Species	Transects						
	A	B	C	D	E	F	G
Class Holothuroidea							
Stichopus chloronotus Brandt				0.1 ± 0.1			
S. variegatus Semper		0.3 ± 0.2					
Actinopyga echinites (Jaeger)			0.2 ± 0.1				
Bohadschia argus Jaeger					0.1 ± 0.1		
B. marmorata Jaeger	0.1 ± 0.1						
Holothuria atra Jaeger	0.2 ± 0.1	1.2 ± 0.5	0.3 ± 0.2	1.0 ± 0.4			
H. edulis Lesson		0.4 ± 0.3			0.3 ± 0.2	0.1 ± 0.1	
H. nobilis (Selenka)					0.1 ± 0.1		
H. flavomaculata Semper		0.1 ± 0.1					
H. hilla Lesson					+		
H. leucospilota (Brandt)		1.3 ± 1.3					

Several species of gastropods and echinoderms were observed in the Porites-Favites-sand zone, but none was present in numbers large enough to be considered dominant. The larger species of echinoderms were represented by single individuals of the asteroid Linckia laevigata and the holothurians Bohadschia argus and Holothuria nobilis. Small muricid and conid gastropods were occasionally found associated with colonies of Porites.

The soft coral zone parallel to the channel margin was characterized by a high diversity of gastropods. Many species were represented by single observations. Most species were small and cryptic. Therefore, counts contain some added component of error, at best.

Relatively few gastropods were found in association with the soft corals on this transect. Only Turbo argyrostomus was found directly attached to soft corals. Large Conus distans were observed on the limestone pavement between colonies of soft corals.

Scattered patches of live scleractinian corals and rubble largely featured grazing herbivores. Species of trochids and cerithiids were predominant in these localities. Present in smaller numbers were the carnivores of the conid and muricid families.

Of the echinoderms, the asteroid Linckia laevigata was most often observed, usually in association with live corals. An unidentified species of asteroid was collected from an area of live corals also. Holothuria edulis represented the only holothurian found in this zone.

Macroinvertebrates were essentially absent from the silt-coral zone of the channel slope. The asteroid Echinaster luzonicus was collected from a coral outcrop in one quadrat on the transect. Shells of dead gastropods were commonly observed on the substratum. Most of the shells examined were species of the soft coral zone on the channel margin, and they probably were deposited on the channel slope by wave action.

Fishes - The observed fish fauna at the Balabat study site was very diverse with 123 species from 28 families being recorded (Table 9). Amesbury (1978) presents a checklist for the fishes of Yap. This is nearly comparable to the diversity found by Randall et al. (1978) at Arakabesan Island, Palau and considerably higher than that found by Amesbury et al. (1976) in the area of Donitsch Island, Yap (63 species, 17 families). The diversity within each of the reef zones ranged from a low of nine species in the boulder-rubble zone to a high of 62 species in the soft coral zone. It seemed apparent during field observations that the diversity of the fish fauna tended to increase with an increase in the amount of coral in the area. Calculation of a product-moment correlation coefficient (r) relating total coverage (both soft and hard corals) to fish diversity within each of the seven zones proved the observation correct yielding a highly significant r-value of .976 ($p < .01$).

Table 9. Distribution and density of fishes at Balabat, Yap. The number of individuals observed for each species is followed by its density (fish/m^2) along each of the transects. An X denotes species encountered in the vicinity of each transect but not within one meter of either side.

	TRANSECT						
FAMILY/SPECIES	A	B	C	D	E	F	G
ACANTHURIDAE (Surgeonfish)							
Acanthurus glaucopareius Cuvier						1(.005)	
A. nigrofuscus (Forsskal)					2(.01)	9(.045)	
A. cf. *pyroferus* Kittliz						7(.035)	1(.005)
A. xanthopterus (Cuvier & Valenciennes)	1(.005)						
Acanthurus sp. 1						X	
Acanthurus sp. 2		1(.005)					
Acanthurus sp. 3						1(.005)	
Ctenochaetus striatus (Quoy & Gaimard)					7(.035)	2(.01)	
Zebrasoma scopas (Cuvier)						4(.02)	
APOGONIDAE (Cardinalfish)							
Apogon orbicularis Cuvier & Valenciennes		X					
Apogon sp.		4(.02)	X				
Cheilodipterus quinquelineatus Cuvier		X					
BALISTIDAE (Triggerfish)							
Balistipus undulatus (Mungo Park)						X	
Rhinecanthus aculeatus (Linnaeus)		1(.005)					
BLENNIIDAE (Blennies)							
Cirripectes sp.					X		
Ecsenius oculus Springer					1(.005)	11(.055)	4(.02)
E. yaeyamaensis (Aoyagi)					X	3(.015)	
Entomacrodus decussatus (Bleeker)						1(.005)	
Meiacanthus grammistes (Valenciennes)					1(.005)		
cf. *Petroscirtes breviceps* (Bleeker)				3(.015)			6(.03)

Table 9. Continued.

FAMILY/SPECIES	TRANSECT A	B	C	D	E	F	G
Plagiotremus tapeinosoma (Bleeker)						2(.01)	
cf. Praealticus margaritarius (Snyder)					1(.005)		
blenniid sp.							17(.085)
CALLIONYMIDAE (Dragonets)							
Amora sp.			2(.01)				
CARCHARINIDAE (Requiem Sharks)							
Carcharinus mennisorah (Muller & Henle)							X
CHAETODONTIDAE (Butterflyfish)							
Chaetodon auriga Forsskal						X	
C. kleini Bloch						2(.01)	
C. melanotus Bloch & Schneider					1(.005)	2(.01)	
C. trifasciatus Mungo Park						3(.015)	2(.01)
Heniochus chrysostomus Cuvier & Valenciennes						X	
Megaprotodon trifascialis (Quoy & Gaimard)					1(.005)		
ELEOTRIDAE (Sleepers)							
eleotrid sp.					X	4(.02)	
GOBIIDAE (Gobies)							
Acentrogobius cf. criniger (Cuvier & Valenciennes)	1(.005)						
A. ornatus (Ruppell)	2(.01)				15(.075)		
Amblygobius albimaculatus (Ruppell)	3(.015)	11(.055)					
A. decussatus (Bleeker)							1(.005)
Cryptocentrus koumansi (Whitley)	29(.145)	64(.315)	22(.11)	8(.04)			
Gobiodon citrinus (Ruppell)					1(.005)		

Table 9. Continued.

FAMILY/SPECIES	A	B	C	D	E	F	G
				TRANSECT			
gobiid sp. 1					1(.005)		
gobiid sp. 2			1(.005)				
gobiid sp. 3		1(.005)					
HOLOCENTRIDAE (Squirrelfish & Soldierfish)							
Adioryx diadema (Lacepede)						1(.005)	
A. spinifer (Forsskal)						X	
Flammeo sp. 1						X	
Flammeo sp. 2					2(.01)		
Flammeo sp. 3							1(.005)
Myripristis cf. *kuntee* Cuvier							2(.01)
LABRIDAE (Wrasses)							
Cheilinus chlorurus (Bloch)					X		
C. rhodochrous Gunther							1(.005)
Cheilio inermis (Forsskal)			X	1(.005)			
Choerodon anchorago (Bloch)	1(.005)					X	
Cirrhilabrus sp.							2(.01)
Epibulus insidiator (Pallas)						X	
Gomphosus varius Lacepede						4(.02)	1(.005)
Halichoeres hoeveni (Bleeker)						1(.005)	1(.005)
H. margaritaceus (Cuvier & Valenciennes)					1(.005)		
H. cf. *scapularis* (Bennett)					X		
H. trimaculatus (Quoy & Gaimard)			X	2(.01)	3(.015)	1(.005)	
Hemigymnus melapterus (Bloch)						2(.01)	
Labrichthys unilineata (Guichenot)						2(.01)	1(.005)
Labroides bicolor Fowler & Bean							2(.01)
L. dimidiatus (Cuvier & Valenciennes)						1(.005)	1(.005)
Pseudocheilinus evanidus Jordan & Evermann							1(.005)
P. hexataenia (Bleeker)						4(.02)	1(.005)
Stethojulis bandanensis (Bleeker)				1(.005)		1(.005)	

Table 9. Continued.

FAMILY/SPECIES	A	B	C	D	E	F	G
				TRANSECT			
S. strigiventer (Bennett)		1(.005)	1(.005)	16(.08)			
Thalassoma amblycephala (Bleeker)						28(.14)	
T. hardwickei (Bennett)					4(.02)	20(.1)	
juv. *Thalassoma* sp.						1(.005)	
juv. labrid sp.				1(.005)			
LETHRINIDAE (Emperors)							
Gnathodentex aureolineatus (Lacepede)	1(.005)						
Monotaxis grandoculis (Forsskal)							1(.005)
LUTJANIDAE (Snappers)							
Lutjanus fulvus (Bloch & Schneider)		3(.015)					
L. johni (Bloch)		X					
MUGILOIDIDAE (Sandperches)							
Parapercis cephalopunctata (Seale)			2(.01)				
MULLIDAE (Goatfish)							
Parupeneus barberinus (Lacepede)		X					
P. trifasciatus (Lacepede)					3(.015)		1(.005)
PLATYCEPHALIDAE (Flatheads)							
Suggrundus (?) sp.						X	
POMACANTHIDAE (Angelfish)							
Centropyge bicolor (Bloch)							2(.01)
C. vrolicki (Bleeker)						1(.005)	

Table 9. Continued.

	TRANSECT						
	A	B	C	D	E	F	G
Pygoplites diacanthus (Boddaert)						X	1(.005)
POMACENTRIDAE (Damselfish)							
Abudefduf sordidus (Forsskal)	1(.005)						
Amblygliphidodon curacao (Bloch)						56(.28)	17(.085)
Chromis cf. atripes Fowler & Bean							2(.01)
C. bicolor Macleay						11(.055)	
C. caerulea (Cuvier)					160(.8)	X	
C. cf. lepidolepis (Bleeker)						2(.01)	26(.13)
Chromis sp. 1							20(.1)
Chromis sp. 2						1(.005)	
Dascyllus aruanus (Linnaeus)		19(.095)			62(.31)		
D. reticulatus (Richardson)							11(.055)
Dischistodus notopthalmus (Bleeker)					2(.01)	1(.005)	
D. perspicillatus (Cuvier)		3(.015)			1(.005)		
Eupomacentrus lividus (Bloch & Schneider)						11(.055)	
E. nigricans (Lacepede)					1(.005)	15(.075)	
Glyphidodontops cyaneus (Quoy & Gaimard)						2(.01)	
G. leucopomus (Lesson)		1(.005)	1(.005)		10(.05)		
Paraglyphidodon melas (Cuvier)					1(.005)	4(.02)	
Plectroglyphidodon lacrymatus (Quoy & Gaimard)						4(.02)	
P. leucozona (Bleeker)		1(.005)					
Pomacentrus pavo (Bloch)		3(.015)			6(.03)	X	1(.005)
P. vaiuli Jordan & Seale					1(.005)	5(.025)	1(.005)
PSEUDOCHROMIDAE (Dottybacks)							
Pseudochromis sp.				1(.005)	1(.005)	6(.03)	
SCARIDAE (Parrotfish)							
Bolbometapon bicolor (Ruppell)						X	

Table 9. Continued.

FAMILY/SPECIES	A	B	C	TRANSECT D	E	F	G
B. muricatus (Cuvier & Valenciennes)							X
Scarus chlorodon Jenyns				X			
S. cf. *frenatus* Lacepede							1(.005)
S. oviceps Cuvier & Valenciennes						2(.01)	
S. sordidus Forsskal					1(.005)	5(.025)	2(.01)
S. venosus Cuvier & Valenciennes							9(.045)
Scarus sp.						1(.005)	
juv. scarids			X	3(.015)		2(.01)	
SCATOPHAGIDAE (Scats)							
Scatophagus argus (Boddaert)	2(.01)						
SCOLOPSIDAE (Monocle Breams)							
Scolopsis bilineatus (Bloch)							1(.005)
S. cancellatus (Cuvier & Valenciennes)		X	X				
SERRANIDAE (Groupers or Sea Bass)							
Cephalopholis urodelus (Bloch & Schneider)							2(.01)
Epinephelus merra Bloch						1(.005)	
SIGANIDAE (Rabbitfish)							
Siganus virgatus (Cuvier & Valenciennes)						1(.005)	
SYNGNATHIDAE (Pipefish)							
Corythoichthys intestinalis (Jordan & Seale)					2(.01)	2(.01)	
Corythoichthys sp.				1(.005)			

Table 9. Continued.

FAMILY/SPECIES	TRANSECT A	B	C	D	E	F	G
SYNODONTIDAE (Lizardfish)							
Synodus variegatus (Lacepede)					1(.005)	1(.005)	
TETRAODONTIDAE (Puffers)							
Canthigaster bennetti (Bleeker)		1(.005)					
TRIPTERYGIIDAE (Triplefins)							
Tripterygion sp.						1(.005)	
Total No. of Fish	41	113	29	37	293	254	144
Total Density/m^2	.205	.565	.145	.185	1.465	1.27	.72
Total Species/Transect	9	14	6	10	28	49	33
Total Species/Zone	9	19	11	11	33	62	35
Total Species: 123							

Visibility along approximately the first 5 m of transect A in the boulder-rubble zone was extremely poor, thus a few species normally present in the area may not have been enumerated. The remainder of the transect, however, indicates that the single species Cryptocentrus koumansi, a small, shrimp-associated goby, accounted for over 70 percent of the observed fish fauna in this zone. Most of the remaining species in this zone inhabit the holes and crevices within a boulder embankment at the shoreline.

An increase in depth (see Fig. 7) and the presence of scattered Porites and Pocillopora corals in the Enhalus zone provide a somewhat more complex environment along transect B. This added complexity is reflected in the increased density and diversity of the fishes. Several small damselfishes (Pomacentridae), particularly Dascyllus aruanus, aggregate around these coral heads. Cryptocentrus koumansi, however, and other small gobiids were the numerically dominant species, comprising over 66 percent of the fishes observed.

The observed fish fauna within the mixed seagrass-algae zone maintained a nearly constant level of species diversity as 11 species were recorded from the vicinities of both transects C and D. There is, however, a shift in relative dominance of the contributing species. Cryptocentrus koumansi and other gobiids are clearly the dominant species along transect C, comprising over 79 percent of the fishes enumerated. This drops to 21 percent for the same group of fishes along transect D as they are replaced, for the most part, by juvenile parrotfishes (Scaridae) and small wrasses (Labridae). Especially abundant is the labrid species Stethojulis strigiventer.

Transect E, within the Porites-Favites-sand zone, had the highest density of fishes observed for the Balabat study site (1.45 fish/m^2). The elevated density in this zone is attributed to the presence of several large colonies of the ramose corals Stylophora mordax and Seriatopora hystrix which provide ideal habitats for small aggregate-forming damselfishes. Two such species, Chromis caerulea and Dascyllus aruanus, account for over 75 percent of the fishes counted in this zone.

The demonstrated correlation between the coral community and its associated ichthyofauna is perhaps most evident along the reef margin. Transect F, within what we have termed the soft coral zone, runs adjacent to the reef margin and had an observed fish diversity nearly twice as high as any other zone. No single species or species complex could appropriately be termed dominant. However, the families with the greatest representation, both in terms of numbers and species diversity, were the Labridae and the Pomacentridae. These two families represent ca. 26 and 44 percent of the total number of fishes encountered and ca. 23 and 20 percent of the species, respectively.

The pomacentrids are also important contributors to the fish community of the channel slope, representing ca. 54 percent of the fishes counted along transect G. Lassuy (1978) reports particularly high zooplankton concentrations from the harbor channels of Yap. It is not surprising to note, then, that several members of the predominantly zooplanktivorous genus Chromis comprise ca. 61 percent of those fishes belonging to the family Pomacentridae and 33 percent of all fishes on this transect. Holocentrids, scarids, labrids and blenniids were also quite common along the channel slope.

From the data presented by Amesbury et al. (1976) a mean density of .52 fish/m^2 from a total of 25 species in the rubble-seagrass dominated zones near the Donitsch Island sewer outfall can be calculated. Treated as a similarly dominated unit, transects A, B, C and D of the Balabat study site have a mean density of .28 fish/m^2 from a total of 36 species. The coral dominated zones discussed by Amesbury et al. (1976) are calculated to have a mean density of .83 fish/m^2 from a total of 31 species. Again treated as a similarly dominated unit, transects E and F of this study have a mean density of 1.27 fish/m^2 from a total of 76 species.

Reef Profile

Fig. 12 depicts the vertical reef profile along the proposed route of the sewer line at Pelak. The reef divisions, types of substrata, and distribution of dominant reef organisms are also shown.

Water Circulation

Current determinations at the north (19 March 1978) and south (20 March 1978) stations at the Pelak site (Fig. 13) showed a similar tidal influence as the Balabat site. On a rising tide the drogues traveled west-northwest and on a falling tide they traveled southeast. At the north station there was little variation in current speed regardless of tide (Table 10). In contrast, the south station showed a marked increase in average current flow for the 1-m and 2.5-m drogues on an ebb tide as compared with current flow during a flood tide (0.15 knots, 1 m and 0.18 knots, 2.5 m vs 0.05 knots, 1 m and 2.5 m; Table 11).

The apparent lack of flow rate change during the tide cycle at the north station, and increased flow rate during a falling tide at the south station may be explained by a "funnel" effect. The north station, centrally located in a wide area of the channel, allowed for increased spreading of the water mass in either direction in relation to the tide cycle. The south station, located at the head of the narrow portion of the channel, allowed for increased spreading of the water mass into the wide area on a rising tide; whereas, on a falling tide the water mass was forced into the narrow area of the channel creating a more directed flow and consequently an increased flow rate. The relationship between tide cycles and current speeds for the 1-m drogues at both stations appears in Fig. 14.

The average wind speeds for the north and south stations were 9.0 and 11.8 knots, respectively. Wind speed and direction did not appear to have any influence on drogue movement at either station.

Water movement on the reef flat of Pelak (Fig. 15) as measured with fluorescein was in a southwesterly direction during both flood and ebb tides. Water movement during flood tide was more toward a southerly direction at a speed of .03 m/sec.; water movement was slightly slower during ebb tide at a speed of .02 m/sec.

Physicochemical Characteristics of the Water

The physicochemical measurements obtained at the proposed outfall site in Pelak Channel (see Tables 2 and 3) showed similar magnitude to those obtained at Balabat. The dissolved oxygen values in the channel were higher than those on the reef flat which seems especially odd since samples were collected during 1415-1540, the usual period of high photo-

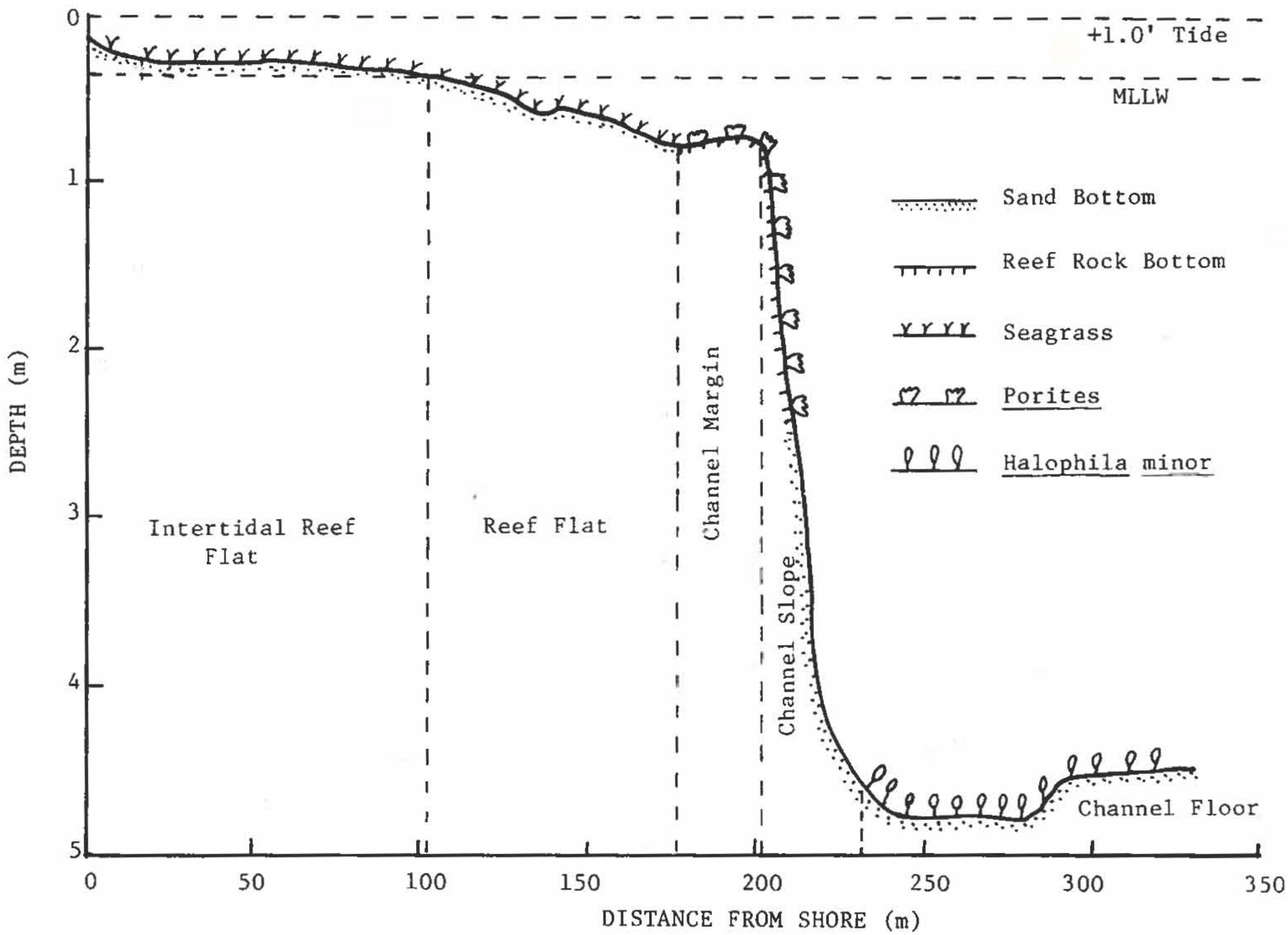


Figure 12. Vertical profile of proposed sewer route in the Pelak Channel area, Yap, showing reef divisions, distribution of dominant reef organisms and types of substrata. Vertical exaggeration is X5.2.

Table 10. **Distance and speed of 1-meter and 2.5-meter drift drogues, and direction and speed of wind, Pelak** (proposed outfall site), Yap. March 19, 1978.

Water Movement					Wind	
Drogue	Start	T (hrs.)	Dist. (NM)	Speed (knots)	Dir.	Speed (knots)
1a (1 m)	0905	1.22	.06	.05	68°	9.0
1b (1 m)	0905	1.23	.06	.05		
1c (2.5 m)	0917	1.05	.05	.05		
1d (2.5 m)	0917 (Grd.)	1.05	.05	-		
2a (1 m)	1022	1.22	.07	.06	35°	8.5
2b (1 m)	1022	1.22	.07	.06		
2c (2.5 m)	1022	1.18	.06	.05		
2d (2.5 m)	1022	1.23	.05	.04		
3a (1 m)	1139	0.98	.04	.04	72°	9.5
3b (1 m)	1139	0.98	.04	.04		
3c (2.5 m)	1139	1.02	.05	.05		
3d (2.5 m)	1139	1.02	.05	.05		
4a (1 m)	1245	1.15	.08	.07	76°	8.5
4b (1 m)	1245	1.15	.08	.07		
4c (2.5 m)	1245	1.08	.05	.05		
4d (2.5 m)	1245	1.08	.05	.05		
5a (1 m)	1357	0.73	.06	.08	54°	8.0
5b (1 m)	1357	0.73	.06	.08		
5c (2.5 m)	1357	0.68	.03	.04		
5d (2.5 m)	1357	0.68	.04	.06		
6a (1 m)	1445	0.82	.06	.07	49°	10.5
6b (1 m)	1445	0.82	.06	.07		
6c (2.5 m)	1445	0.83	.05	.06		
6d (2.5 m)	1445	0.87	.05	.06		
7a (1 m)	1538	1.30	.05	.04	49°	9.0
7b (1 m)	1538	1.30	.05	.04		
7c (2.5 m)	1538	1.28	.04	.03		
7d (2.5 m)	1538	1.28	.03	.02		

Table 11. Distance and speed of 1-meter and 2.5-meter drift drogues, and direction and speed of wind, Pelak (alternate site), Yap. March 20, 1978.

	Water Movement				Wind	
Drogue	Start	T (hrs.)	Dist. (NM)	Speed (knots)	Dir.	Speed (knots)
1a (1 m)	1020	0.90	.12	.13	36°	11.0
1b (1 m)	1020	0.90	.16	.18		
1c (2.5 m)	1020	0.90	.15	.17		
1d (2.5 m)	1020	0.90	.17	.19		
2a (1 m)	1123	0.58	.02	.03	44°	13.5
2b (1 m)	1123	0.60	.02	.03		
2c (2.5 m)	1123	0.62	.02	.03		
2d (2.5 m)	1123	0.62	.03	.05		
3a (1 m)	1200	0.98	.03	.03	42°	12.0
3b (1 m)	1200	0.98	.03	.03		
3c (2.5 m)	1200	1.00	.03	.03		
3d (2.5 m)	1200 (Grd.)	1.00	.03	-		
4a (1 m)	1303	0.87	.06	.07	36°	12.5
4b (1 m)	1303	0.87	.06	.07		
4c (2.5 m)	1303	0.92	.03	.03		
4d (2.5 m)	1303	0.92	.04	.04		
5a (1 m)	1400 (Grd.)	1.75	.04	-	17°	10.0
5b (1 m)	1400 (Grd.)	1.75	.05	-		
5c (2.5 m)	1400 (Grd.)	1.78	.03	-		
5d (2.5 m)	1400 (Grd.)	1.78	.04	-		

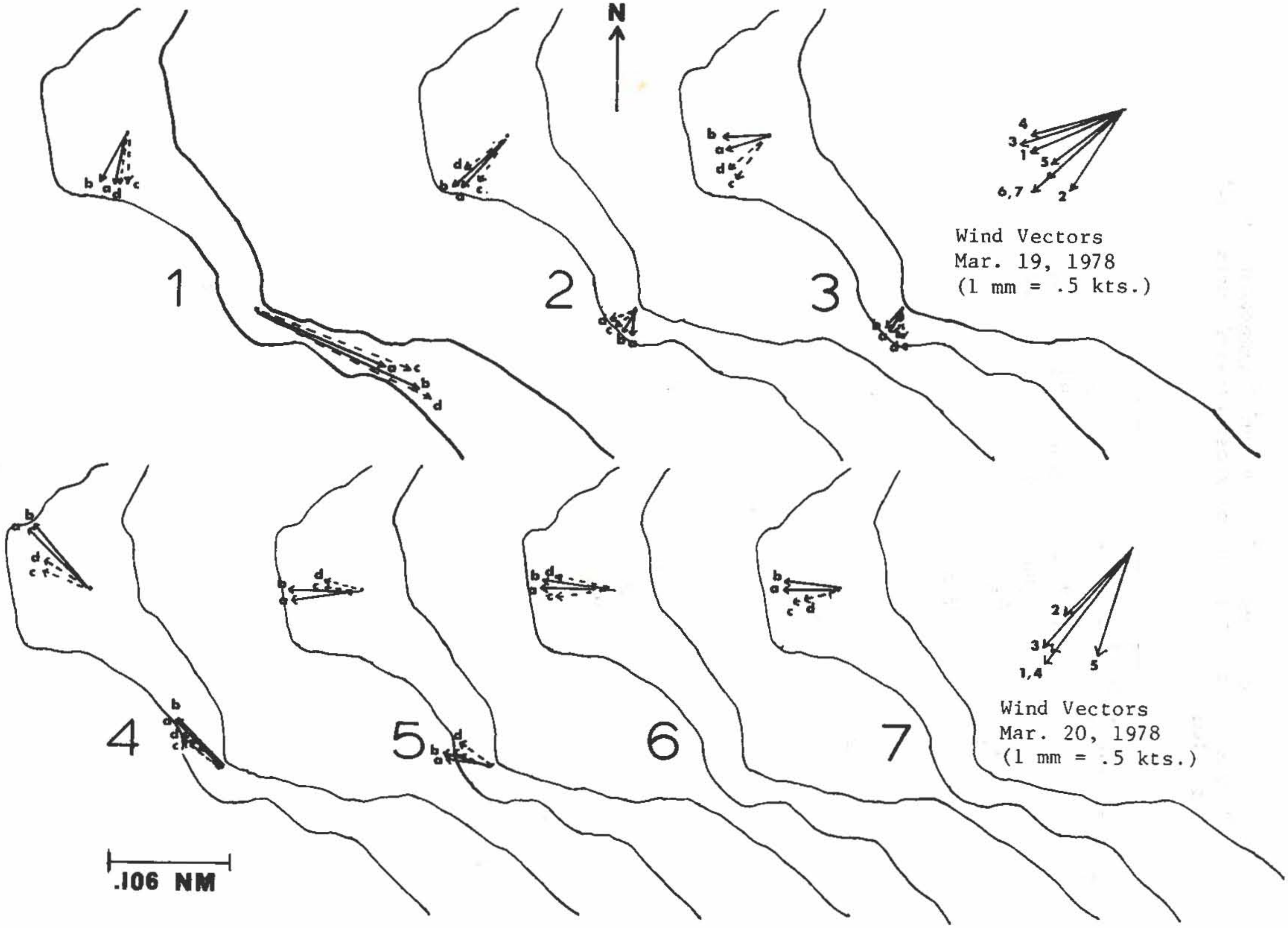


Figure 13. Drift patterns of 1-meter (a and b) and 2.5-meter (c and d) drogues in the proposed sewer outfall site (March 19, 1978) and a possible alternate site (March 20. 1978) in Pelak Channel, Yap. Wind vectors are shown on right-hand side.

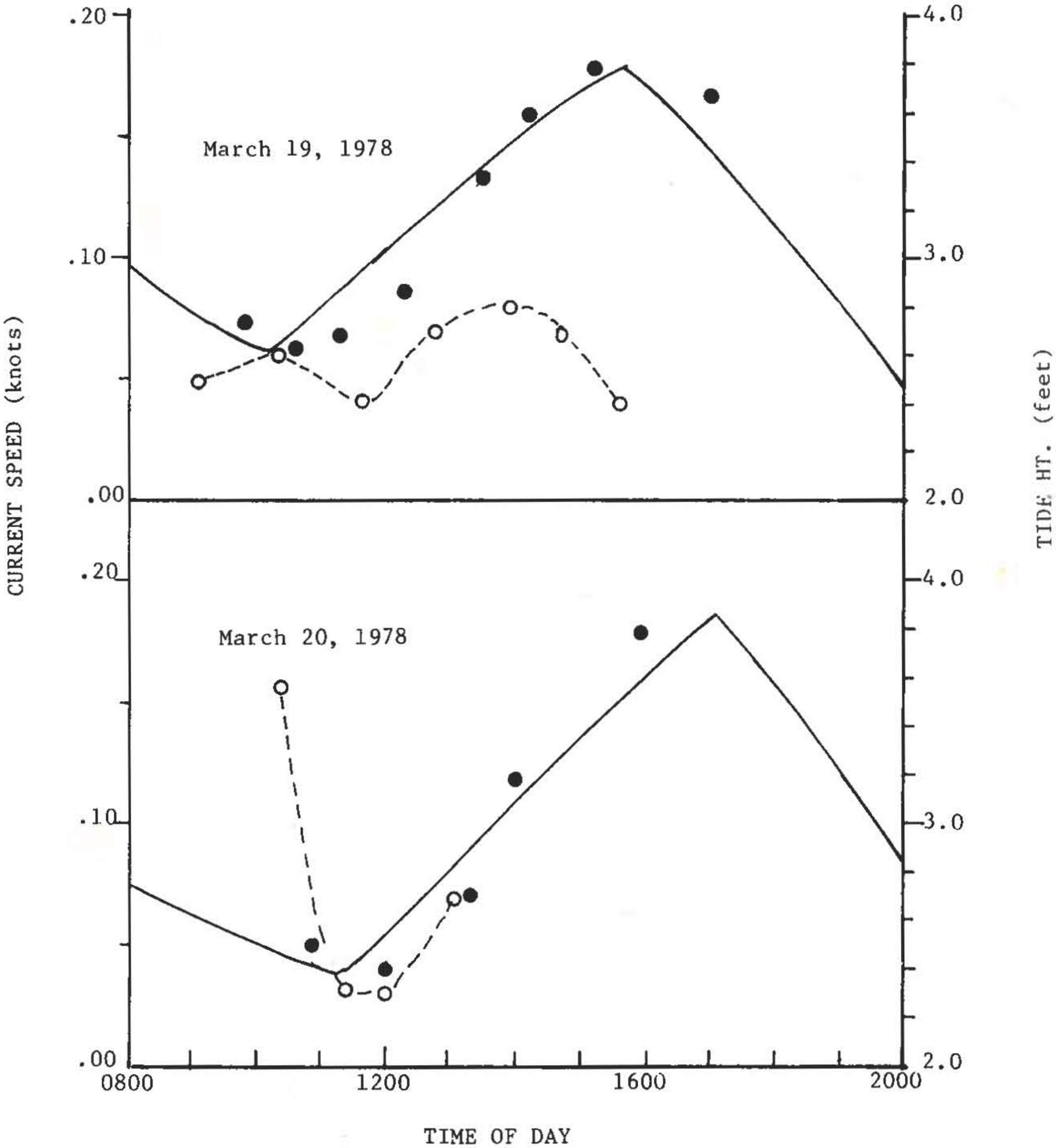


Figure 14. Relationship of tide height (solid line) and current speed (dashed line) of 1-meter drogues in the proposed sewer outfall site (March 19, 1978) and a possible alternate site (March 20, 1978) in Pelak Channel, Yap. Closed circles: tide height measured in study area; open circles: speed of 1-meter drift drogues.

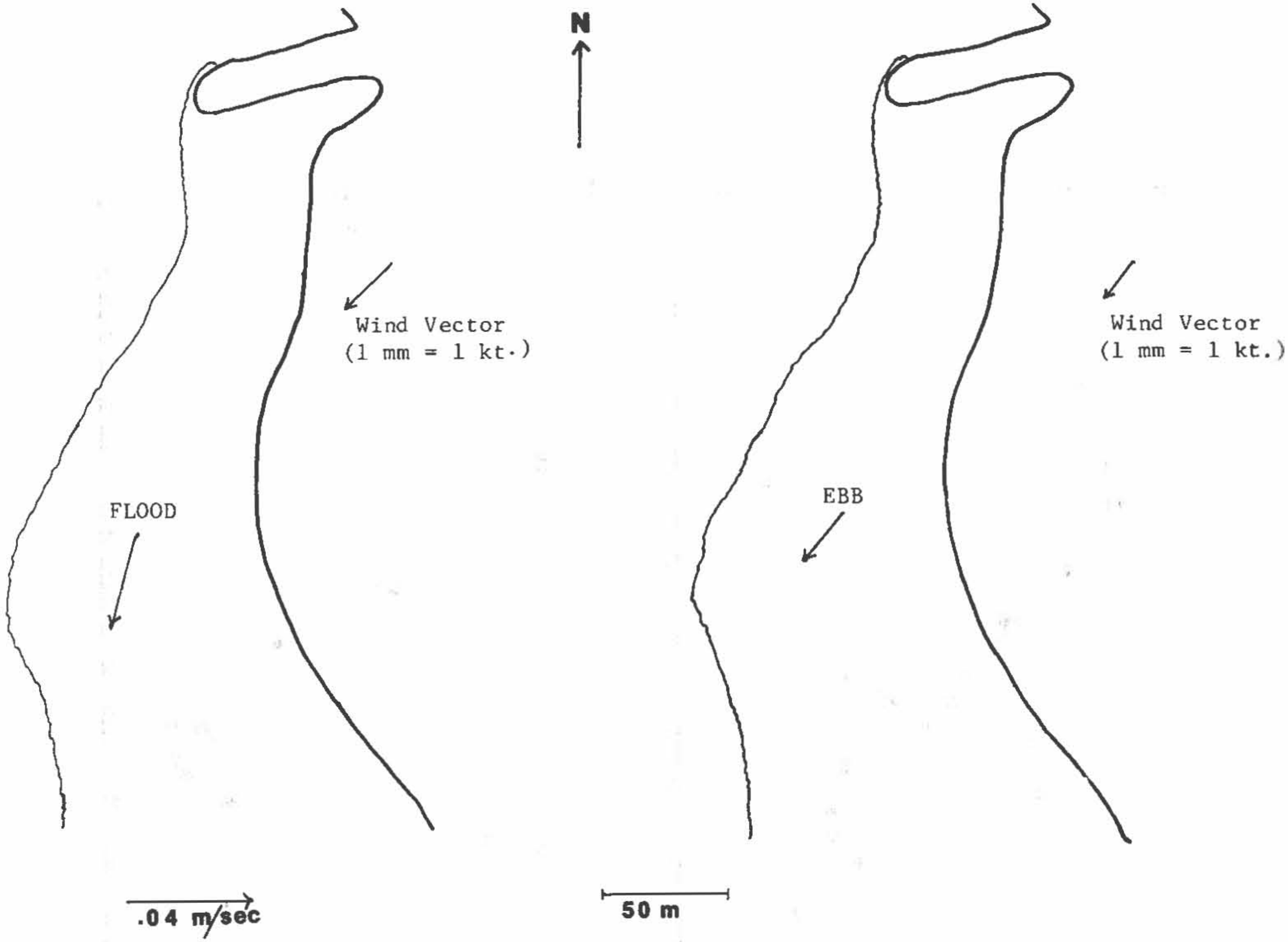


Figure 15. Current vectors on reef flat measured with fluorescein dye during flood tide (1421 - 1433) and ebb tide (1721 - 1732) at the Pelak Channel area, Yap. See tide curve on Fig. 14. March 19, 1978.

Table 12. Surface temperature and salinity values obtained at 50-meter intervals along proposed sewer pipe route at Pelak, Yap, March 19, 1978. Measurements were taken during flood tide between 1100 and 1315 (+2.8 feet to +3.3 feet). See Fig. 5 for location of sewer pipe route.

Distance From Shore (m)	Depth (cm)	Temp. (°C)	Sal. (°/oo)
0 (Mangrove)	62	28.4	33.3
50	77	28.2	34.4
100	91	28.0	34.4
150	117	28.1	34.4
200	133	28.1	34.4
205 (Channel Edge)	133	28.0	34.4
330 (Proposed Outfall Site in Channel)	518	28.1	34.4

synthesis. Even the dissolved oxygen obtained from the southern station showed a high value.

The PO_4-P values were lower than those off Balabat. The values for total-N and organic-N were highest in the surface samples at the reef margin.

Table 12 presents the temperature and salinity values taken at 50-meter intervals along the proposed route of the sewer line. These values are constant with temperature ranging from 28.0 to 28.4°C, and salinity values on the reef flat being constant at 34.4°/oo except for the sample taken in the mangroves (33.3°/oo).

Biota

Biotic Zones - Four biotic zones are recognized in the Pelak area. See Fig.12 for vertical profile. The zones in which each of the transects were run and the length of each zone are as follows.

Transect A - *Enhalus*-Silt Zone (0-14 m from shore)
Transect B - Mixed Seagrass Zone (14-175 m from shore)
Transect C - *Porites* Zone (175-207 m from shore)
Transect D - *Halophila* Zone (Channel Floor)

Marine Plants - A total of 27 species of marine plants (Table 13) was observed at Pelak. Algal diversity was significantly less than that observed at Balabat (51 species). The Pelak area may be broadly assessed as a mangrove fringe community and seagrass reef flat, the latter extending approximately 175 meters to the inner channel margin. Floral cover ranged from a low of 23 percent near the mangrove fringe to a high of 70 percent along Transect B, which cut through the central portion of the reef flat. Due to the presence of the mangrove community and relatively slow water motion (see Fig. 15), the high silt content may be, in part, responsible for the decreased algal diversity. A summary histogram of the major functional group components within each of the four parallel transects is represented in Figure 16.

Transect A consisted mostly of sand and mangrove silt with scattered patches of the seagrasses *Enhalus acoroides* and *Thalassia hemprichii*. A few epiphytic blue-green algae, *Hormothamnion enteromorphoides* and *Microcoleus lyngbyaceus*, and an occasional patch of the green calcareous alga, *Halimeda opuntia*, were the only other species observed in this zone.

Transect B traversed the middle reef flat and may be characterized as a mixed seagrass zone. The seagrass *Enhalus acoroides* was dominant, accounting for 51 percent of the floral cover. Smaller patches of *Thalassia hemprichii* and the relatively uncommon *Cymodocea serrulata* (Tsuda et al., 1977) were also observed. The bulk of the remaining algal species were observed along this transect though none were abundant. Some of the more notable species included *Caulerpa racemosa*, *Halimeda macroloba*, *Neomeris annulata* and *Dictyota bartayresii*.

Table 13. Checklist of marine plants observed and/or quantified along four transects at Pelak, Yap on March 19-20, 1978. The locations of the four transects are shown in Figure 5. Plain numbers indicate relative percent cover. Numbers in parentheses represent frequency. X = observed in the vicinity of the transect. * = see specific designation at end of table.

SPECIES	TRANSECTS A	B	C	D
CYANOPHYTA (blue-green algae)				
Hormothamnion enteromorphoides Bornet & Flahault	X			
Microcoleus lyngbyaceus (Kutz.) Crouan	X	X	X	
Schizothrix calcicola (Ag.) Gomont		2(.11)	2(.04)	
Schizothrix mexicana Gomont			X	
CHLOROPHYTA (green algae)				
Avrainvillea obscura J. Ag.	X			
Caulerpa racemosa (Forskal) J. Ag.		3(.16)	1(.04)	
Caulerpa taxifolia (Vahl) C. Ag.		X		X
Caulerpa urvilliana Montagne		X		
Dictyosphaeria cavernosa (Forskal) Boerg.		X		
Halimeda discoidea Decaisne		X		
Halimeda incrassata (Ellis) Lamx.		X		
Halimeda macroloba Decaisne		5(.47)		
Halimeda opuntia (L.) Lamx.	1(.02)	3(.14)		
Neomeris annulata Dickie		1(.02)	X	X
Tydemannia expeditionis Weber van Bosse			X	
Valonia ventricosa J. Ag.		X		
PHAEOPHYTA (brown algae)				
Dictyota divaricata Lamx.		1(.02)		
Hydroclathrus clathratus (C. Ag.) Howe		X		X
Lobophora variegata (Lamx.) Womersley		X	X	
Padina tenuis Bory		1(.04)		
RHODOPHYTA (red algae)				
Actinotrichia fragilis (Forskal) Boerg.				X
Gelidium pusillum (Stockh.) Le Jolis			*	
Polysiphonia sp.			*	

Table 13. Continued.

SPECIES	TRANSECTS A	B	C	D
ANTHOPHYTA (seagrasses)				
Cymodocea serrulata (R. Br.) Aschers		1(.02)		
Enhalus acoroides (L.f.) Rich.	20(.66)	51(.92)		
Halophila minor (Zool.) denHartog				41(.76)
Thalassia hemprichii (Ehrenb.) Aschers	2(.04)	2(.14)		
OTHERS				
Hard corals (Scleractinia)			10(.26)	
Sand/rubble substrate	77(.97)	30(.71)	59(.67)	59(.95)
*Red algal turf			28(.35)	

TOTAL SPECIES = 27

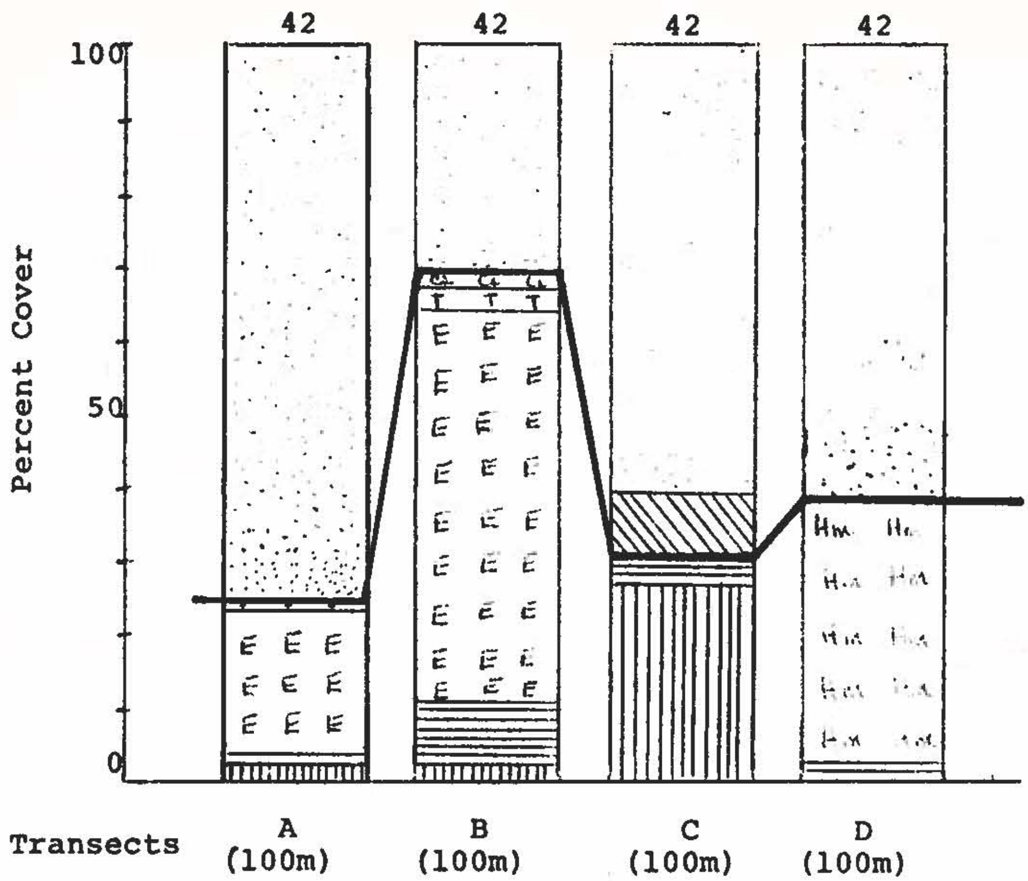
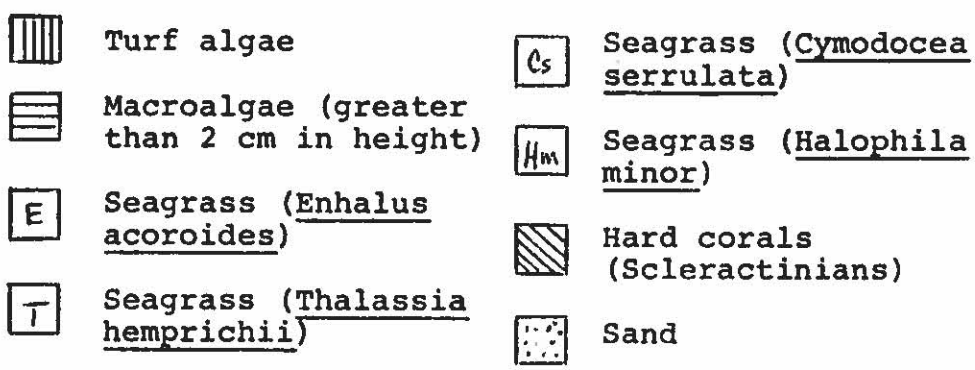


Figure 16. Summary histogram showing percent cover of various functional groups along the four transects at Pelak Channel, Yap. The number above each bar denotes the number of tosses on which the analyses are based. The heavy black line separates marine plants from sand and corals.



Transect C was run along the channel margin, an area of high silt and coral density. No seagrass species were observed. Most of the algal components fell into two groups - the blue-green alga Schizothrix calcicola, and a fine red mixed turf consisting of Gelidium and Polysiphonia species. The latter group accounted for 28 percent of the total algal cover. Occasional macroalgal individuals were also observed but accounted for less than 5 percent of the total.

Transect D was run along the channel floor and consisted of sand and the delicate seagrass Halophila minor with a few thalli of Halimeda macroloba. Halophila minor accounted for 41 percent of the total cover.

Corals - General coral diversity and percent cover was similar to the findings at the Balabat site with increasing diversity and coverage towards the channel margin and a decrease from the upper margin to the channel floor. There were no corals in the Enhalus-silt zone and only small scattered colonies of Porites lutea and Montipora divaricata in the mixed seagrass zone. The lack of coral diversity on the reef flat is reflective of the dense mangrove stands which accumulate large amounts of sediments; these sediments may in turn be flushed onto the reef flat on falling tides. The channel margin also had a low diversity in comparison with the channel margin at the Balabat site. The dominant corals were Porites lutea, Favites melicerum, and Pocillopora damicornis. Many of the P. lutea colonies were dead on the upper surfaces; living surfaces were usually covered with a heavy mucous coating indicative of heavy sedimentation. Table 14 lists the species observed at this site.

Corals were present only along Transect C of the four quantitative transects established at the Pelak site (Fig. 5). The lack of corals at Transects A, B, and D can be explained by the sand-silt substrate in the mangrove-Enhalus zone, mixed seagrass zone, and Halophila zone on the channel floor, respectively.

As with the reef zones of the Balabat site, Porites lutea was the dominant coral on Transect C comprising 26.4 percent cover out of an overall percent cover of 27.8, or a relative percent cover of 94.8 (Table 15). Many of the Porites colonies were greater than one meter in diameter which would account for the low density of 4.12 corals/m^2. Some of the corals in this area appeared to be under stress from heavy sedimentation; many were bleached and others had numerous dead surfaces.

Other Macroinvertebrates - The macroinvertebrate fauna of Pelak is noteworthy for its low diversity and low abundance (Table 16). The scyphozoan Cassiopeia sp. is predominant in all except the Porites zone. Large specimens (up to 30 cm in diameter) inhabited the Enhalus-silt zone and the mixed seagrass zone. The Halophila zone on the channel floor was populated with many juvenile Cassiopeia less than 2.5 cm in diameter.

Table 14. List of corals observed within the Pelak site, Yap by physiographic zones and Transects A-D. Symbols indicate their relative abundance within the various physiographic zones: D=dominant, A=abundant, C=common, O=occasional, and R=rare.

CORALS	PHYSIOGRAPHIC ZONES: Reef Flat	Channel Margin	Channel Slope	TRANSECTS: A	B	C	D
CLASS - ANTHOZOA							
ORDER - SCLERACTINIA							
SUBORDER - ASTROCOENIINA							
FAMILY - POCILLOPORIDAE							
Pocillopora damicornis (Linnaeus)		O	R			X	
FAMILY - ACROPORIDAE							
Acropora palifera (Lamarck)		O				X	
Montipora divaricata Brueggeman	O						
Montipora sp.		R					
SUBORDER - FUNGIINA							
FAMILY - PORITIDAE							
Porites lutea Milne-Edwards and Haime	O	D	A			X	
SUBORDER - FAVIINA							
FAMILY - FAVIIDAE							
Favites melicerum (Ehrenberg)		C	O			X	
Goniastrea edwardsi Chevalier		O				X	
Leptastrea purpurea (Dana)		R				X	
FAMILY - MUSSIDAE							
Symphyllia valenciennesii Milne-Edwards and Haime		R					
TOTAL GENERA	2	8	3	0	0	6	0
TOTAL SPECIES	2	8	3	0	0	6	0

Table 15. Living coral density, percent of substratum coverage, and frequency of occurrence along the four transects at Pelak, Yap. Relative values of these three measures are summed to give an importance value. Overall density and percent cover are given for each transect zone where corals occurred. Species are arranged in order of their importance values.

TRANSECT A	Frequency	Relative Frequency	Density	Relative Density	Percent Cover	Relative Percent Cover	Importance Value
NO CORALS ENCOUNTERED							
TRANSECT B							
NO CORALS ENCOUNTERED							
TRANSECT C							
Porites lutea	0.8	50.0	2.8	67.7	26.4	94.8	212.5
Favites melicerum	0.4	25.0	0.6	14.5	0.9	3.2	42.7
Pocillopora damicornis	0.3	19.0	0.5	12.9	0.5	1.8	33.7
Acropora palifera	0.05	3.1	0.07	1.6	0.01	0.03	4.7
Goniastrea edwardsi	0.05	3.1	0.07	1.6	0.01	0.03	4.7
Leptastrea purpurea	0.05	3.1	0.07	1.6	0.01	0.03	4.7
Overall density	4.12 corals/m^2						
Overall percent cover	27.83%						
TRANSECT D							
NO CORALS ENCOUNTERED							

Table 16. Invertebrates along transects at Pelak, Yap. Transects consist of ten quadrats of 20 m^2. Values represent means and standard errors of the means, respectively, of numbers of organisms per quadrat. A "+" indicates the species was observed in the zone, but did not occur on the transect.

CLASS/SPECIES	TRANSECTS			
	A	B	C	D
Class SCYPHOZOA				
Cassiopeia (cf. *medusa* Light)	0.8 ± 0.4	0.4 ± 0.3		3.1 ± 1.0
Class GASTROPODA				
Cerithium zonatus (Woode)		+		
C. patulum (Sowerby)	+			
Lambis lambis Linnaeus				0.1 ± 0.1
Cypraea tigris Linnaeus		+		
Natica gualtieriana Recluz				+
Pyrene scripta (Lamarck)		+		
Nassarius pullus (Linnaeus)				+
Latirus sp.			+	
Vexillum cruentatum (Gmelin)				+
Conus eburneus Hwass		+		
C. virgo Linnaeus		+		
C. quercinus Solander		+		
C. magus Linnaeus		+		
Class BIVALVIA				
Tridacna maxima (Roeding)			0.1 ± 0.1	
arcid sp.			0.1 ± 0.1	
Class HOLOTHUROIDEA				
Bohadschia argus Jaeger			0.1 ± 0.1	
B. marmorata Jaeger				0.1 ± 0.1
synaptid sp.		0.1 ± 0.1		

Other species of invertebrates were rarely encountered on the transects. Only *Cassiopeia* occurred on the transect in the *Enhalus*-silt zone. The gastropod *Cerithium patulum* was found in the mangroves fringing this zone, but it did not occur on the transect.

A single synaptid species occurred in addition to *Cassiopeia* in the mixed seagrass zone. Several species of gastropods were noted in the seagrass adjacent to the transect. *Rhinoclavis vertagus*, *Cypraea tigris*, *Pyrene scripta*, *Conus eburneus*, and *C. quercinus* were commonly observed.

The *Porites* zone contained two species of bivalves, both of which were embedded in large *Porites* colonies. A juvenile of the giant clam *Tridacna maxima* and an unidentified arcid species were found on the transect. The holothurian *Bohadschia argus* was observed on the substratum beside a *Porites* head.

The *Halophila* zone was characterized by the juvenile *Cassiopeia* previously mentioned. The spider conch *Lambis lambis* and the holothurian *Bohadschia marmorata* were also found on the transect. Smaller, sand-dwelling gastropods, *Natica gualtieriana*, *Nassarius pullus*, and *Vexillum cruentatum*, were collected adjacent to the transect.

Fishes - A total of 47 species from 19 families (Table 17) was collected or observed at the Pelak study site. This is very nearly comparable to the fish diversities reported for proposed sewer outfall sites in both Ebeye, Kwajalein Atoll (Amesbury et al., 1975) and Tuanmokot Channel, Ponape (Tsuda et al., 1974) of 45 species, but is slightly lower than the 63 species recorded for Donitsch Island, Yap (Amesbury et al., 1976). Species diversity within the reef zones at Pelak ranged from a low of three species in the *Halophila* zone to a high of 35 species in the *Porites* zone. As was the case at the Balabat site, a significant correlation between total coral coverage and the diversity of fishes was found ($r=.997$, $p<.01$).

Transect A in the *Enhalus*-silt zone was bordered on one side by a stand of mangroves and on the other by a rather well-developed seagrass bed. The fishes recorded along this transect thus reflect the influence of both of these habitats. Areas nearer the seagrass were dominated by the same shrimp-associated goby, *Cryptocentrus koumansi*, which dominated the nearshore zones of the Balabat study site. Small aggregations of a species of *Apogon* were observed amongst the tentacles of the benthic scyphozoan *Cassiopeia* in the silty area between the seagrass and the mangroves. Similar aggregations of the cardinalfish *Apogon orbicularis* were observed to inhabit the prop roots of the mangroves. This association of *A. orbicularis* with the prop roots of mangroves was also noted by J. A. Chase along the sides of Tuanmokot Channel, Ponape (Tsuda et al., 1974). Small schools of unidentified baitfish and a single archerfish (Toxotidae) were also observed in this zone.

Table 17. Distribution and density of fishes at Pelak, Yap. The number of individuals observed for each species is followed by its density (fish/m^2) along each of the transects. An X denotes species encountered in the vicinity of each transect but not within one meter of either side.

	TRANSECT			
FAMILY/SPECIES	A	B	C	D
ACANTHURIDAE (Surgeonfish)				
Acanthurus nigrofuscus (Forsskal)			X	
A. triostegus (Linnaeus)			X	
Acanthurus sp. 2			1(.005)	
Acanthurus sp. 3			7(.035)	
Ctenochaetus striatus (Quoy & Gaimard)			2(.01)	
APOGONIDAE (Cardinalfish)				
Apogon orbicularis Cuvier & Valenciennes	9(.045)			
Apogon sp.	20(.1)			
Cheilodipterus quinquelineatus Cuvier			19(.095)	
ATHERINIDAE (?) (Silversides)				
unidentified baitfish	10(.05)			
BLENNIIDAE (Blennies)				
Ecsenius oculus Springer			1(.005)	
E. yaeyamaensis Aoyagi			2(.01)	
CHAETODONTIDAE (Butterflyfish)				
Chaetodon auriga Forsskal			1(.005)	
C. trifasciatus Mungo Park			X	
ELEOTRIDAE (Sleepers)				
eleotrid sp.			9(.045)	
GOBIIDAE (Gobies)				
Acentrogobius ornatus (Ruppell)			33(.165)	
Amblygobius decussatus (Bleeker)			2(.01)	
A. cf. phalana (Cuvier & Valenciennes)		1(.005)		
Cryptocentrus koumansi (Whitley)	41(.205)	62(.31)		
cf. Stigmatogobius javanicus (Bleeker)			1(.005)	
gobiid sp. 4				23(.115)
gobiid sp. 5				12(.06)
gobiid sp. 6			13(.065)	
gobiid sp. 7			1(.005)	

Table 17. Continued.

FAMILY/SPECIES	TRANSECT A	B	C	D
HOLOCENTRIDAE (Squirrelfish & Soldierfish)				
Flammeo sammara Forsskal			1(.005)	
LABRIDAE (Wrasses)				
Choerodon anchorago (Bloch)			X	
Gomphosus varius Lacepede			1(.005)	
Halichoeres trimaculatus (Quoy & Gaimard)			1(.005)	
Labroides dimidiatus (Cuvier & Valenciennes)			1(.005)	
Stethojulis strigiventer (Bennett)		X		
LUTJANIDAE (Snappers)				
Lutjanus johni (Bloch)		X		
MULLIDAE (Goatfish)				
Parupeneus trifasciatus (Lacepede)			1(.005)	
POMACENTRIDAE (Damselfish)				
Dascyllus aruanus (Linnaeus)			15(.075)	
Dischistodus notopthalmus (Bleeker)			1(.005)	
D. perspicillatus (Cuvier)			6(.03)	
Eupomacentrus nigricans (Lacepede)			9(.045)	
Glyphidodontops leucopomus (Lesson)			1(.005)	
Hemiglyphidodon plagiometopon (Bleeker)			5(.025)	
Pomacentrus pavo (Bloch)			31(.155)	
PSEUDOCHROMIDAE (Dottybacks)				
Pseudochromis sp.			2(.01)	
SCARIDAE (Parrotfish)				
Scarus sordidus Forsskal			1(.005)	
juv. scarids		X	8(.04)	
SCOLOPSIDAE (Monocle breams)				
Scolopsis cancellatus (Cuvier & Valenciennes)			4(.02)	
S. ghanam (Forsskal)			X	
SIGANIDAE (Rabbitfish)				
Siganus fuscescens (Houttuyn)		X		

Table 17. Continued.

FAMILY/SPECIES	TRANSECT A	B	C	D
SYNGNATHIDAE (Pipefish)				
Corythoichthys intestinalis (Jordan & Seale)			1(.005)	
TETRAODONTIDAE (Puffers)				
Arothron immaculatus (Bloch & Schneider)				1(.005)
TOXOTIDAE (Archerfish)				
Toxodes sp.	1(.005)			
Total No. of Fish	81	63	181	36
Total Density/m^2	.405	.315	.905	.18
Total Species/Transect	5	2	30	3
Total Species/Zone	5	6	35	3
Total Species: 47				

The mixed seagrass zone, represented by transect B, was clearly dominated by C. koumansi as 62 of the 63 fishes recorded from this transect belonged to this single species. The only other fish recorded on the transect was also a gobiid. A few juvenile scarids and one species of labrid, lutjanid and siganid were also observed within this zone.

The Porites zone, at the reef margin, is by far the most diverse of the reef zones at the Pelak study site in terms of ichthyofauna. The most abundant species was the small goby Acentrogobius ornatus which accounted for ca. 18 percent of the total fishes encountered. Other important species include Pomacentrus pavo (17 percent) and Cheilodipterus quinquelineata (10 percent).

A sharp drop in species diversity upon reaching the floor of the channel is witnessed in the extreme paucity of fishes recorded along transect D. Only two species of gobies accounted for 35 of the 36 fishes recorded from this transect. The only other species observed was a single specimen of the puffer Arothron immaculatus.

Combining the data from transects A and B, a mean density of .36 fish/m^2 from a total of 10 species is calculated. Both values are somewhat lower than those calculated from data presented by Amesbury et al., (1976) for similar zones near Donitsch Island, Yap (.52 fish/m^2, 25 species). The data from transect C at Pelak (.91 fish/m^2, 35 species), a coral dominated zone, are very similar to those calculated for the coral dominated zones of the Donitsch Island study (Amesbury et al., 1976) of .83 fish/m^2 from a total of 31 species.

FALALOP ISLAND, ULITHI ATOLL

Reef Profile

Figure 17 depicts the vertical reef profiles at three sites off the Outer Islands High School. The profiles were run off the septic tank and the two existing outfalls. As can be seen on the profiles, the reef flat is exposed during MLLW and, thus, consists mainly of turf algae or fauna, e.g., sea urchins, which can tolerate exposure.

Description of Existing Outfalls

At present, very little sewage is being disposed through the two existing outfalls which terminate in the intertidal zone of the seaward reef flat. Our brief observations reveal that the majority of the sewage exits through cracks in the pipe located somewhere above the water line. During low tides, the presence of raw sewage is quite evident at both sites since the sewage accumulates in the stagnant tidepools of the raised limestone bench. On the other hand, sewage is not evident during high tides since heavy wave action upon the shore disperses the released sewage.

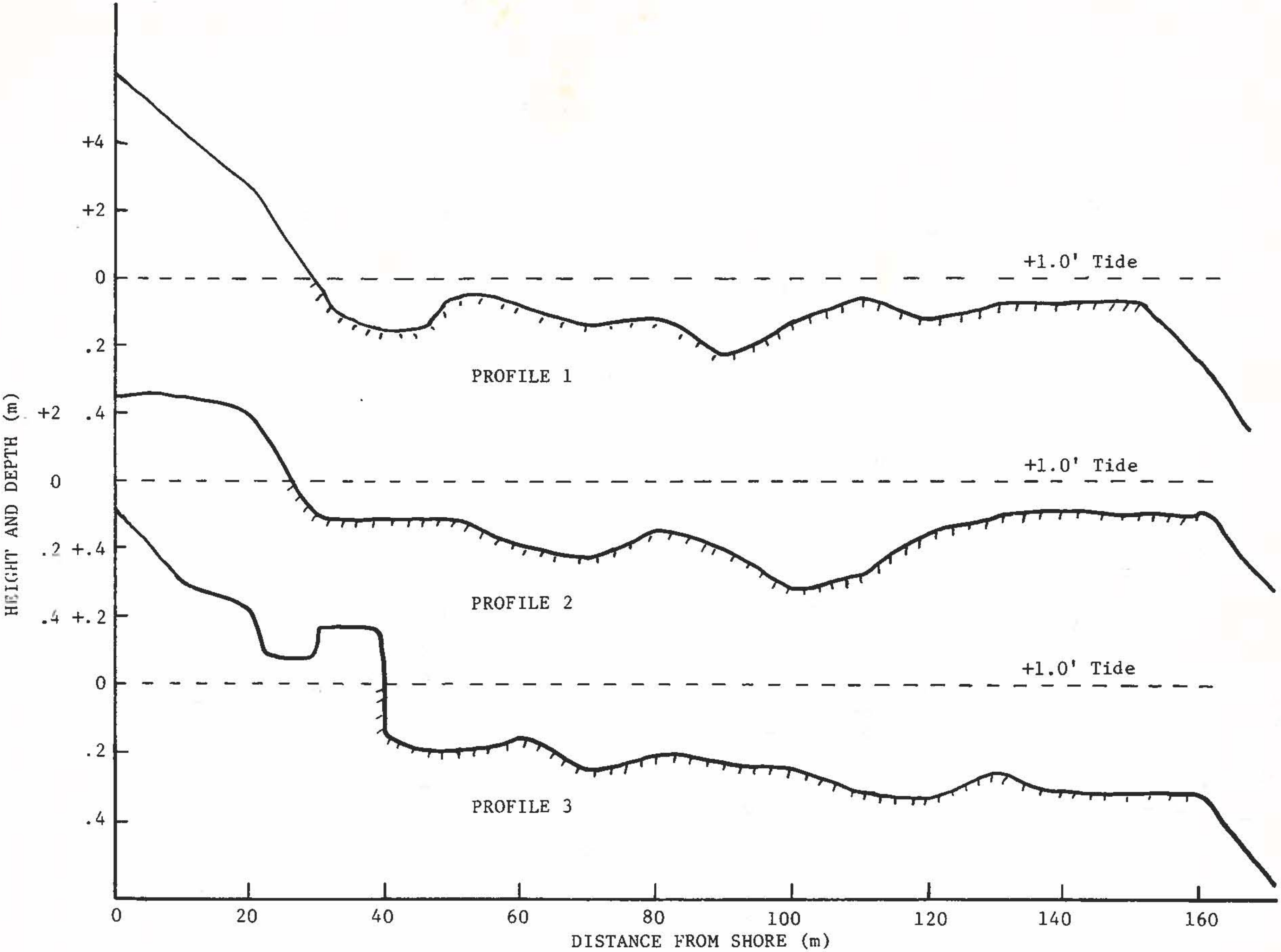


Figure 17. Vertical profile of the reef flat at three sites (see Fig. 6) off the Outer Islands High School, Falalop Island, Ulithi Atoll. Substrata basically consisting of reef rock covered with algal turf.

Water Circulation

Current determinations for 23 March 1978 on the seaward side of Falalop Island, Ulithi, did not show a current reversal with tide change (Fig. 18). However, the boat operator and District Administrator Representative did indicate that a current reversal does periodically occur. This reversal is probably evident only during extreme low tides. Initially, the 1-m and 5-m drogues for trials 1a,b and 2a,b, and the 1-m and 2.5-m drogues for the remaining runs traveled south towards the reef margin, then proceeded southwest into the lagoon. The 5-m drogues (1b and 2b) were shortened to 2.5 m in subsequent runs because of potential (1b) or actual (2b) grounding on the shallow reef front. A pair of drogues (1-m and 2.5-m deep) were also released at the south end of Falalop Island at 1235 (23 March 1978). These drogues also moved toward the lagoon. There was no significant difference in flow rates between the 1-m and 2.5-m drogues except for trial 2b (Table 18).

Even though the direction of flow was generally the same during both ebb and flood tides, there appeared to be a relationship between tide cycle and current speed (Fig. 19). Greatest speeds occurred approximately one hour following the high and low tides, then decreased to a minimal speed three hours before low tide.

Winds were generally out of the east with an average speed of 10.2 knots. It is difficult to determine what effect the wind may have had on drogue movement without conducting further studies during different wind conditions.

Fluorescein dye studies (Fig. 20) conducted during ebb and flood tides on the reef flats off the Outer Islands High School reveal water movement in several directions. Water movement off the septic tank is generally towards the west during both ebb and flood tides which is the same direction of the prevailing winds (see Fig. 18). However, water movement just 100 meters east of the septic tank site is toward the east during both ebb and flood tides. This water continues to move east until it reaches the site off the other sewer outfall and moves north towards the reef margin. This movement north can be explained by the lower reef margin here than off the western sewer outfall. No true reversal of water movement was observed on the reef flat.

Physicochemical Characteristics of the Water

Table 19 presents values for temperature and salinity taken at 10-meter intervals along the three transects run perpendicular to shore. The temperatures ranged from 28.6 to 31.2^{o}C on the reef flat, while salinity ranged from 33.4 to 35.0 o/oo. Higher temperatures of 33.3^{o}C was obtained in a supratidal pool off the septic tank.

Table 18. Distance and speed of 1-meter and 2.5-meter/5-meter drift drogues, and direction and speed of wind. Off Outer Islands High School, Falalop Island, Ulithi Atoll. March 23, 1978.

	Water Movement				Wind	
Drogue	Start	T (hrs.)	Dist. (NM)	Speed (knots)	Dir.	Speed (knots)
1a (1 m)	0755	0.17	.06	.35	47°	12
1b (5 m)	0755	0.17	.05	.29		
2a (1 m)	0810	0.67	.83	1.24	44°	11
2b (5 m)	0810 (Grd.)	0.25	.08	.32		
3a (1 m)	0909	0.90	.68	.76		
3b (2.5 m)	0909	0.85	.64	.75		
4a (1 m)	1018	0.50	.13	.26	73°	12
4b (2.5 m)	1018	0.50	.13	.26		
5a (1 m)	1050	1.08	.64	.59	96°	11
5b (2.5 m)	1050	1.15	.60	.52		
6a (1 m)	1210	0.80	.73	.91	87°	10
6b (2.5 m)	1210	0.82	.82	1.00		
7a (1 m)	1310 (Lost)				89°	9
7b (2.5 m)	1310 (Lost)					
8a (1 m)	1407	0.72	.90	1.25	61°	7
8b (2.5 m)	1407	0.72	.90	1.25		
9a (1 m)	1502	0.73	.68	.93	112°	10
9b (2.5 m)	1502	0.75	.70	.93		

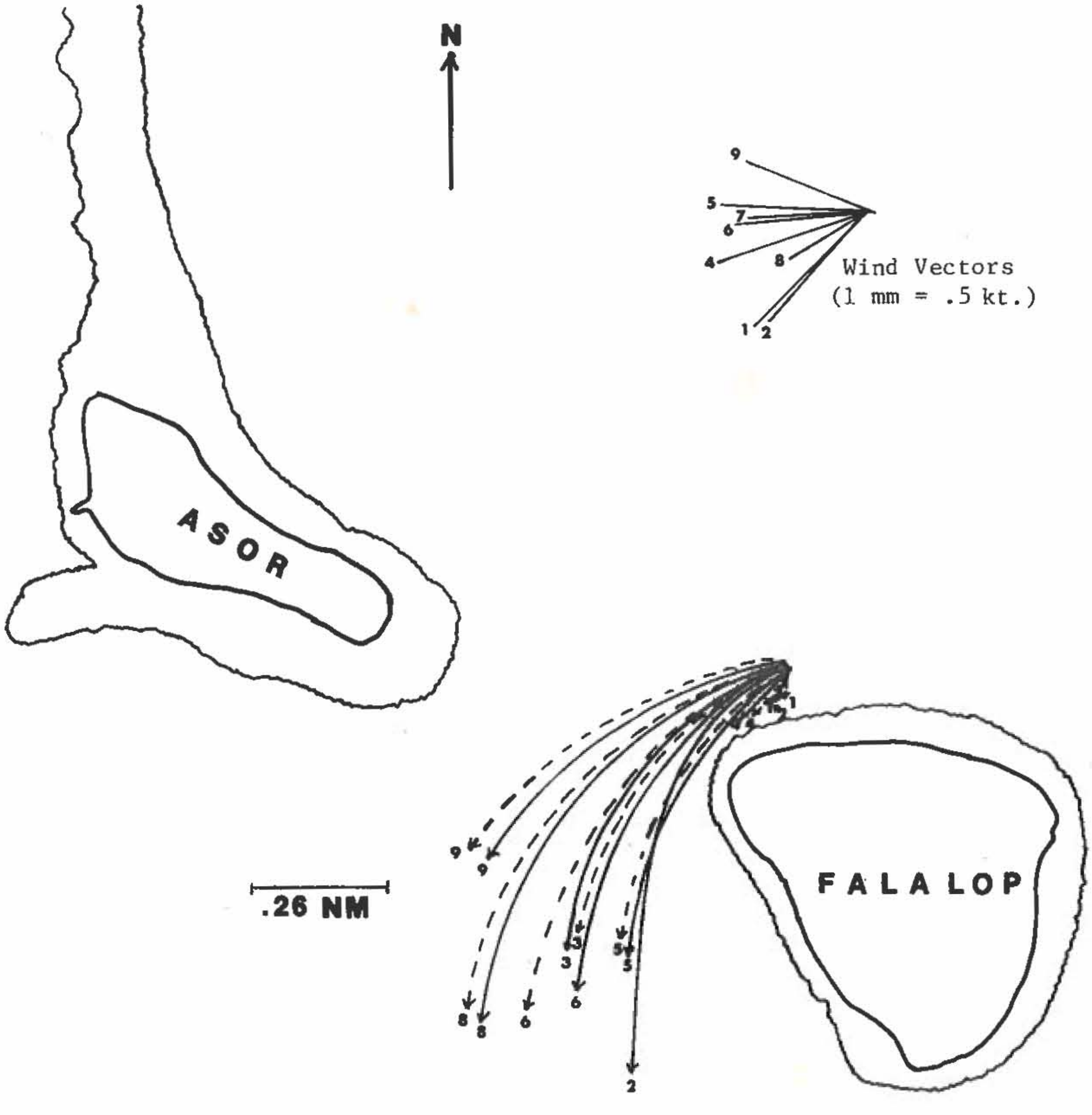


Figure 18. Drift patterns of 1-meter and 2.5-meter/5-meter drogues off the Outer Islands High School, Falalop Island, Ulithi Atoll. Wind vectors are shown in upper right-hand corner. March 23, 1978.

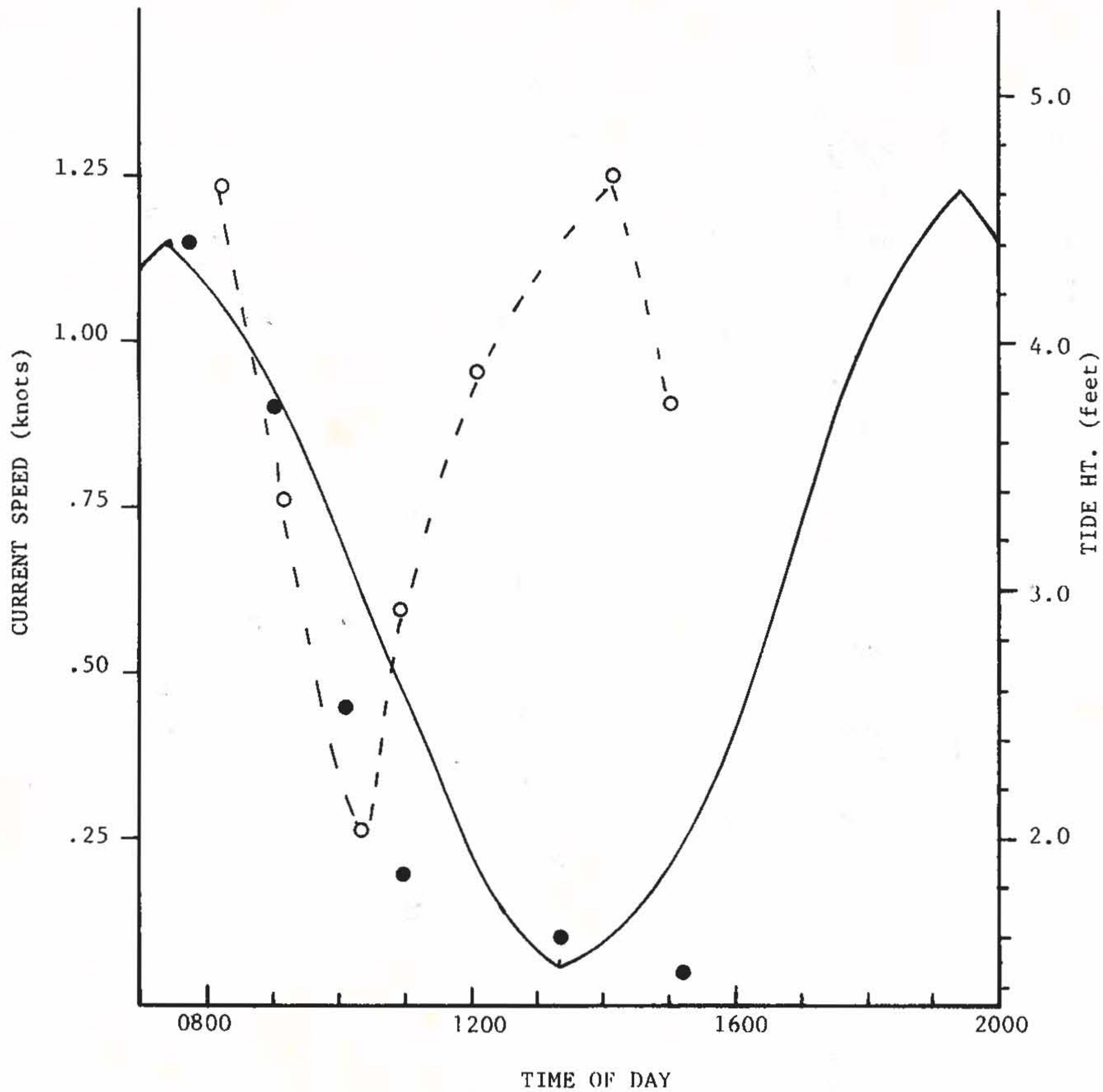


Figure 19. Relationship of tide height (solid line) and current speed (dashed line) of 1-meter drogues off the Outer Islands High School, Falalop Island, Ulithi Atoll. Closed circles: tide height measured in study area; open circles: speed of 1-meter drift drogues. March 23, 1978.

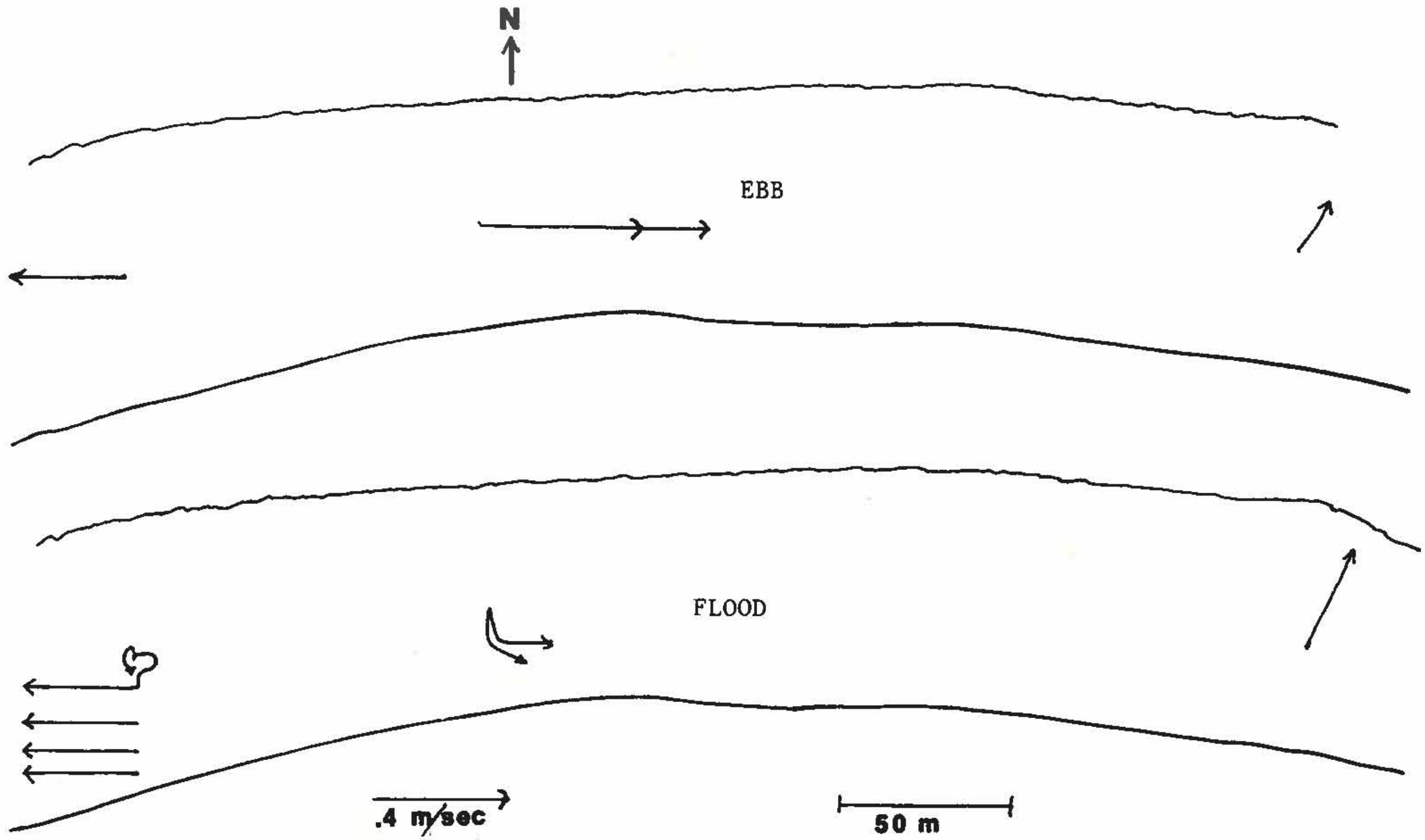


Figure 20. Current vectors on reef flat measured with fluorescein dye during ebb tide (0845 - 0930) and flood tide (1442 - 1524) at the three sites off the Outer Islands High School, Falalop Island, Ulithi Atoll. See tide curve on Fig. 19. March 23, 1978.

Table 19. Surface temperature and salinity values obtained at 10-meter intervals along three routes (1. off septic tank, 2. off existing outfall pipe ca. 100 meters east of septic tank route, 3. off existing outfall pipe near dormitories), Falalop Island, Ulithi Atoll, March 22, 1978. Measurements were taken between 1240 and 1445 (+1.8 feet to +2.6 feet). See Fig. 6 for locations of the three routes.

ROUTE 1				ROUTE 2				ROUTE 3			
Dist. From Shore (m)	Depth (cm)	Temp. (°C)	Sal. (°/oo)	Dist. From Shore (m)	Depth (cm)	Temp. (°C)	Sal. (°/oo)	Dist. From Shore (m)	Depth (cm)	Temp. (°C)	Sal. (°/oo)
10	2	33.2	33.9								
20	18	31.2	34.4	20	(Pool)	30.3	33.9	20	33	31.2	33.9
30	48	30.9	35.0	30	35	30.0	34.4	30	13	30.8	33.9
40	62	29.7	33.9	40	36	29.9	34.4	40	47	31.2	34.4
50	53	29.4	33.9	50	36	29.2	34.4	50	51	31.0	33.3
60	58	29.2	33.9	60	45	29.1	33.9	60	48	31.0	33.3
70	62	29.2	33.9	70	49	29.2	33.9	70	59	30.9	33.3
80	60	29.0	33.9	80	39	29.0	33.9	80	54	30.3	33.3
90	72	28.9	33.3	90	46	29.0	33.9	90	58	30.6	33.3
100	62	28.6	33.9	100	58	29.0	33.9	100	59	31.0	33.3
110	56	28.6	33.9	110	54	28.9	34.4	110	67	30.2	33.3
120	62	28.6	33.9	120	40	28.9	34.4	120	69	29.4	33.9
130	57	28.6	33.9	130	36	28.9	34.4	130	62	29.4	33.3
150(Reef Edge)				160 (Reef Edge)				160 (Reef Edge)			

Biota

Biotic Zones - The reef area consisted of a narrow raised limestone reef platform, approximately 160 meters wide. Two zones were distinguished, intertidal (A^1 and A^2) and the reef flat proper (B^1 and B^2). Only one other study (Gawel and Strong, 1977) has provided listings of marine organisms from this island; their study was conducted on the west coast of Falalop Island.

Marine Plants - Thirty species of marine plants (Table 20) were observed off the Outer Islands High School. Due to continuously heavy surf conditions, the bulk of the species were functionally classified as turf algae. Percent cover exceeded 90 percent along all four transects. No seagrasses were observed. The algal community was generally homogeneous as reflected in the summary histogram (Fig. 21) for each of the transects. No significant difference was found in the communities for either the sites off the septic tank or the existing outfall.

The turf communities were subclassified into two types. The intertidal turf (Turf 1) consisted primarily of Tolypiocladia glomerulata intertwined with Boergesenia forbesii. Additional species of Microcoleus lyngbyaceus, Schizothrix calcicola, Dictyosphaeria cavernosa and Padina minor were also abundant in this zone. A localized patch of Enteromorpha clathrata was found along Transect A^2.

Grading seaward the reef flat turf (Turf 2) became dominant. The major components of this turf included Gelidium divaricatum, Gelidium pusillum, Amphiroa fragilissima, Jania capillacea, Leveillea jungermannioides, Hypoglossum attenuatum and Pterocladia parva. This turf served as an understory matrix for a few locally abundant macroalgae. The more dominant macroalgae included Dictyota bartayresii, Padina minor, Lobophora variegata, Caulerpa urvilliana and Halimeda opuntia.

Corals - Qualitative observations of the corals at two sites on the windward side of Falalop Island showed uniform diversity. The corals present were Porites lutea, Favia speciosa, and Pocillopora meandrina (Table 21); these were usually found in deep holes and depressions in the otherwise flat reef pavement. Fragments of Pocillopora eydouxi, P. elegans, P. setchelli, and P. meandrina were also present. It is likely that these fragments were from the reef margin which is subject to heavy wave assault approximately eight months of the year.

No corals were observed along the four Falalop transects (A^1, B^1, A^2, B^2; see Fig. 6). Transect A^1, in the intertidal zone, is exposed for a long duration at low tide and therefore is not suitable for coral growth. The remaining three transects, located on the reef flat, lacked coral growth because of the instability of the environment. At low tides the flat is mostly exposed. Heavy rains during these times would also add freshwater to the flat. These conditions alone would be enough to prevent any substantial coral growth.

Table 20. Checklist of marine plants observed and/or quantified along four transects off the Outer Islands High School, Falalop Island, Ulithi Atoll, on March 22-24, 1978. The locations of the four transects are shown in Figure 6. Plain numbers indicate relative percent cover. Numbers in parentheses represent frequency. X = observed in the vicinity of the transect. * = see specific designations at end of table.

SPECIES	TRANSECTS A^1	B^1	A^2	B^2
CYANOPHYTA (blue-green algae)				
<u>Microcoleus lyngbyaceus</u> Bornet & Flahault	29(.76)	3(.19)	31(.80)	3(.30)
<u>Schizothrix calcicola</u> (Ag.) Gomont	2(.16)	2(.09)	4(.35)	
<u>Schizothrix mexicana</u> Gomont		X		X
CHLOROPHYTA (green algae)				
<u>Boergesenia forbesii</u> (Harv.) Feldmann	*		*	
<u>Boodlea composita</u> (Harv.) Brand	1(.04)	2(.21)		1(.15)
<u>Caulerpa urvilliana</u> Montagne		7(.26)		4(.30)
<u>Chlorodesmis fastigiata</u> (C. Ag.) Ducker		X		
<u>Cladophoropsis</u> sp.		2(.07)		
<u>Dictyosphaeria cavernosa</u> (Forskal) Boerg.	11(.42)	5(.45)	8(.25)	3(.30)
<u>Enteromorpha clathrata</u> (Roth) Ag.			X	
<u>Halimeda discoidea</u> Decaisne		X		
<u>Halimeda opuntia</u> (L.) Lamx.		3(.19)		2(.15)
<u>Neomeris annulata</u> Dickie		X		X
<u>Valonia fastigiata</u> (Harvey		X		X
<u>Valonia ventricosa</u> J. Ag.		X		X
PHAEOPHYTA (brown algae)				
<u>Dictyota bartayresii</u> Lamx.	2(.05)	2(.14)	4(.15)	5(.35)
<u>Dictyota friabilis</u> Setchell		4(.21)	X	
<u>Lobophora variegata</u> (Lamx.) Womersley	1(.11)	3(.30)		2(.15)
<u>Padina minor</u> Yamada	2(.16)	12(.66)	2(.20)	15(.45)
RHODOPHYTA (red algae)				
<u>Amphiroa fragilissima</u> (L.) Lamx.	**	**	**	**
<u>Antithamnion</u> sp.				X
<u>Asparagopsis taxiformis</u> (Delile) Collins & Hervey		1(.04)		X
<u>Gelidium divaricatum</u> Martens	**	**	**	**
<u>Gelidium pusillum</u> (Stackh.) Le Jolis	**	**	**	**
<u>Hypoglossum attenuatum</u> Gardner	**	**	**	**
<u>Jania capillacea</u> Harvey	**	**	**	**
<u>Jania tenella</u> Kutz.				X
<u>Leveillea jungermannioides</u> (Mart. & Hering) Harv.	**	**	**	**

Table 20. Continued.

SPECIES	TRANSECTS A^1	B^1	A^2	B^2
Pterocladia parva Dawson	**		**	
Tolypiocladia glomerulata (Ag.) Schmitz	*		*	
OTHER				
Sand/rubble substrate	7(.20)	4(.20)	4(.10)	3(.20)
*Turf 1	12(.45)		8(.40)	
**Turf 2	33(.69)	50(.90)	39(.75)	62(1.0)
TOTAL SPECIES = 30				

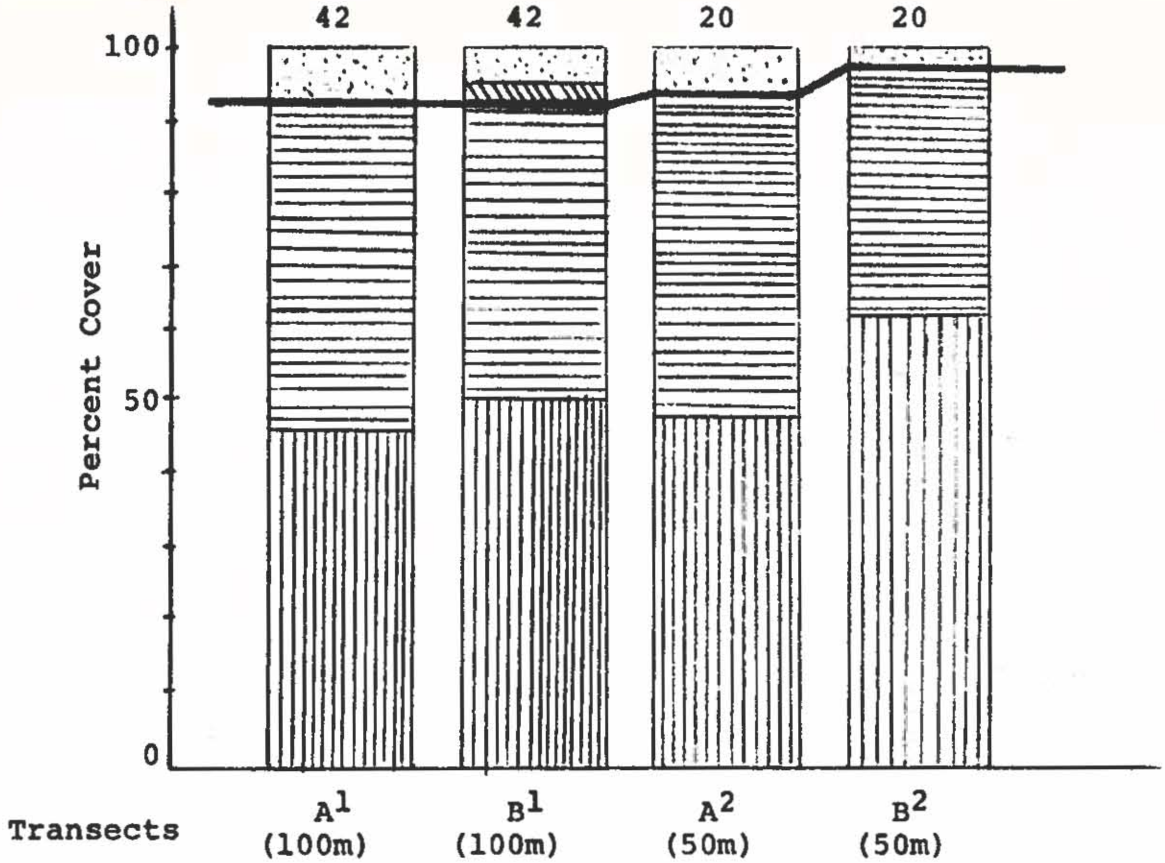


Figure 21. Summary histogram showing percent cover of various functional groups along the four transects off Outer Islands High School, Falalop Island, Ulithi. The number above each bar denotes the number of tosses on which the analyses are based. The heavy black line separates marine plants from sand and corals.

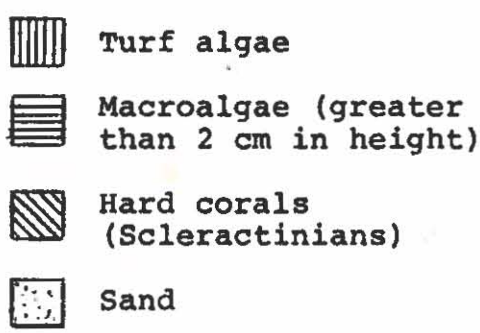


Table 21. List of corals observed within the Falalop Island sites, Ulithi Atoll, by physiographic zones and Transect A^1, B^1, A^2, B^2. Symbols indicate their relative abundance within the various physiographic zones: D=dominant, A=abundant, C=common, O=occasional, and R=rare.

CORALS	PHYSIOGRAPHIC ZONES: Reef Flat	Reef Margin	Reef Slope	TRANSECTS	A^1	B^1	A^2	B^2
CLASS - ANTHOZOA			UNABLE TO SURVEY					
ORDER - SCLERACTINIA								
SUBORDER - ASTROCOENIINA								
FAMILY - POCILLOPORIDAE								
Pocillopora elegans Dana		*						
Pocillopora eydouxi Milne-Edwards and Haime		*						
Pocillopora meandrina Dana	O	*						
Pocillopora setchelli Hoffmeister		*						
FAMILY - ACROPORIDAE								
Acropora sp.		*						
SUBORDER - FUNGIINA								
FAMILY - PORITIDAE								
Porites lutea Milne-Edwards and Haime	O							
SUBORDER - FAVIINA								
FAMILY - FAVIIDAE								
Favia speciosa (Dana)	O							
Favites sp.	R							

* Fragments found on reef flat assumed to be from reef margin.

Other Macroinvertebrates - The predominant macroinvertebrate on the seaward reef flat at Falalop, Ulithi was the holothurian Holothuria atra (Table 22). The limestone platform at the proposed sewer site was characterized by channels and pockets in the framework. The channels and pockets contained very high densities of small H. atra, ranging in size from about 10 cm to 15 cm. Several pockets containing more than 50 individuals were encountered.

The channels in the limestone platform were also inhabited by the echinoids Tripneustes gratilla and Echinometra mathaei. T. gratilla was cryptic due to a covering of rubble and other debris. A single E. mathaei was observed in a hole in the wall of a channel.

The limestone pavement near the middle of the reef at the proposed sewer outfall was also predominated by Holothuria atra. This zone was not marked by channels and pockets, and H. atra was less abundant there than on the platform. However, individuals seemed to be larger on this transect. Specimens up to 20 cm in length were observed.

Three species of echinoids were observed on the limestone pavement. Echinometra mathaei and Tripneustes gratilla were found in habitats similar to those they occupied on the platform. Echinometra mathaei occurred in all quadrats on the transect. Diadema sp. were found in association with a boulder in one quadrat.

Several species of gastropods appeared to be abundant on both the platform and the pavement. The abundance of the gastropods was not great enough to quantify by means of 1 m^2 quadrat. Larger quadrats were not used because waves crossing the reef flat made accurate counts impossible.

Transects similar to those discussed were established at the existing outfall for purposes of comparison. The reef platform at the existing outfall did not exhibit the large numbers of Holothuria atra observed at the proposed outfall site. This difference may be caused by the existence of fewer pockets on this transect.

The population structures of macroinvertebrates on the limestone pavement differed markedly between the two sites. Holothuria atra was much more abundant on the pavement at the existing outfall than at the proposed outfall. Perhaps the nutrient input in this area causes an increase in the food available to these detrital feeders.

The average number of echinoids per quadrat in the two areas was similar. However, at the existing outfall Tripneustes gratilla assumes the greater abundance shown by Echinometra mathaei at the proposed outfall site.

Table 22. Invertebrates along transects at Falalop Island, Ulithi Atoll. Transects off septic tank consist of ten quadrats of 10 m^2. Transects at the existing outfall consist of five quadrats of 10 m^2. A "+" indicates the species was observed on the reef in the study area.

CLASS/SPECIES	TRANSECTS			
	Proposed Outfall		Existing Outfall	
	A^1	B^1	A^2	B^2
Class GASTROPODA				
Trochus niloticus Linnaeus		+		
Turbo chrysostomus Linnaeus		+		+
Rhinoclavis sinensis (Gmelin)		+		
Cypraea annulus Linnaeus	+	+	+	+
C. helvola Linnaeus		+		
C. arabica Linnaeus	+			
Cymatium nicobaricum (Roeding)		+		+
Drupa ricinus (Linnaeus)		+		+
Cantharus undosus (Linnaeus)				+
Engina mendicaria (Linnaeus)	+			
Strigatella scutulata (Gmelin)	+			
Vasum turbinellus (Linnaeus)		+		+
Conus flavidus Lamarck		+		+
C. lividus Hwass		+		+
C. sponsalis Hwass		+		+
C. miliaris Hwass				+
Class ECHINOIDEA				
Echinometra mathaei (de Blainville)	0.1 ± 0.1	4.3 ± 0.7		2.6 ± 0.9
Tripneustes gratilla (Linnaeus)	0.4 ± 0.2	2.9 ± 0.2		4.8 ± 1.3
Diadema sp.		0.3 ± 0.1		
Class HOLOTHUROIDEA				
Holothuria atra Jaeger	102.8 ± 16.5	74.0 ± 4.0	2.8 ± 0.7	103.8 ± 7.5

Basaltic outcrops on the limestone platform near the existing outfall were occupied by large numbers of the gastropod Nerita plicata. The snails were present in 27 of 30 samples taken with a 25-cm X 25-cm quadrat. These data give a mean and standard error of 11.9 ± 5.1 per quadrat, or 190.4 per m^2.

Fishes - Field observations at the existing and proposed sewer outfall sites off the Outer Islands High School revealed a rather uniformly depauperate ichthyofauna. A total of only 17 species from 8 families (Table 23) was recorded for the entire study. Transects A^1 and B^1, run off the septic tank, each surveyed an area of 200 m^2 while transects A^2 and B^2 each surveyed an area of 100 m^2. Such a reduction in survey area for the latter transects may tend to bias the data from these transects toward lower species diversity. However, the monotonous nature of the observed fish fauna throughout the study site probably minimizes any such bias. Diversity along the transects varied from a low of three species on transect A^1 to a high of only five species on transect B^1.

A particularly low tide and relatively calm wave conditions on March 21 allowed a close investigation of the holes and pockets of the intertidal limestone platform. It was noted at this time that a very small gobiid species inhabits many of the tidepools throughout the intertidal zone at the site of the proposed sewer outfall, but it was absent in similar tidepools in the upper and mid-intertidal zones at the two existing outfall pipes. Increasingly severe wave conditions on subsequent days did not allow an accurate census of this tiny species. The remaining species observed within the intertidal zone were very similar in the vicinities of transect A^1, off the septic tank, and A^2, an existing outfall, with two species Glyphidodontops glaucus and Acanthurus triostegus being the major contributors.

The progression of species seaward from the point where the raised limestone platform drops slightly to the limestone pavement reef flat (see Fig. 17) is nearly identical for the entire study site. The small wrasse Halichoeres margaritaceus becomes more abundant at this point and is perhaps the codominant species along the ubiquitous damselfish Glyphidodontops glaucus for approximately the next 50 meters. Another small damselfish, G. leucopomus, then becomes more abundant and gradually replaces G. glaucus. H. margaritaceus is similarly replaced by several species of the labrid genus Thalassoma. G. leucopomus is known to exhibit two different color phases in nature, i.e., a blue or "leucopomus" phase, and a brown or "amabilis" phase. It is interesting to note that virtually every specimen of G. leucopomus observed at the study site was of the "amabilis" color phase. Allen (1975) suggests that the cause of this variation might be related to water motion with the "amabilis" phase predominating in areas of more severe surge conditions. Wave and current conditions at the study site were quite severe at the time of this study; thus, the predominance of the dark "amabilis" color phase seems to support Allen's suggestion.

Table 23. Distribution and density of fishes at the study site off the Outer Islands High School, Falalop, Ulithi. The number of individuals observed for each species is followed by its density (fish/m^2) along each of the transects. An X denotes species encountered in the vicinity of each transect but not within one meter of either side.

FAMILY/SPECIES	TRANSECT A^1	A^2	B^1	B^2
ACANTHURIDAE (Surgeonfish)				
Acanthurus triostegus (Linneaus)	1(.005)	5(.05)	1(.005)	1(.01)
APOGONIDAE (Cardinalfish)				
Apogon cf. novemfasciatus Cuvier & Valenciennes				X
BALISTIDAE (Triggerfish)				
Rhinecanthus aculeatus (Linnaeus)			X	X
CHAETODONTIDAE (Butterflyfish)				
Chaetodon citrinellus Cuvier & Valenciennes				X
C. vagabundus Linnaeus			X	
GOBIIDAE (Gobies)				
gobiid sp. 8	*			
LABRIDAE (Wrasses)				
Halichoeres margaritaceus (Cuvier & Valenciennes)		1(.01)	7(.035)	2(.02)
Stethojulis bandanensis (Bleeker)			X	
Thalassoma amblycephala (Bleeker)			X	X
T. janseni (Bleeker)			1(.005)	X
T. lutescens (Lay & Bennett)				X
T. quinquevittata (Lay & Bennett)				X
MUGILOIDIDAE (Sandperches)				
Parapercis cephalopunctata (Seale)			X	
POMACENTRIDAE (Damselfish)				
Abudefduf sordidus (Forsskal)		1(.01)		
Abudefduf sp.	X			
Glyphidodontops glaucus (Cuvier)	6(.03)	1(.01)	17(.085)	7(.07)
G. leucopomus (Lesson)			3(.015)	1(.01)

Table 23. Continued.

	TRANSECT			
	A[1]	A[2]	B[1]	B[2]
Total No. of Fish	7	8	29	11
Total Density/m^2	.035	.08	.145	.11
Total Species/Transect	3	4	5	4
Total Species/Zone	4	4	10	11
Total Species: 17				

* Gobiid sp. 8 was common in tidepools on transect A[1] but severe wave conditions did not allow accurate enumeration of this very small species.

Transects B^1 and B^2 both indicate that G. glaucus is the most abundant fish on the reef flat, followed in both cases by Halichoeres margaritaceus. While this is in agreement with general observations in the vicinity of the transects, it is felt that had wave conditions permitted another set of transects to be run nearer the reef margin, the transition to a G. leucopomus/Thalassoma dominated zone would have been witnessed.

The only major difference in the resident fish fauna between the existing and proposed sewer outfall sites, then, is the presence of small gobiid fishes throughout the intertidal zone off the septic tank and their absence in similar tidepools in the upper and mid-intertidal zone at the site of the existing sewer outfall pipes.

CONCLUSIONS AND RECOMMENDATIONS

YAP

Suitability of the Proposed Outfall Sites

The volume of domestic sewage which would be released at Balabat and Pelak had been estimated by Lyon Associates, Inc., to be .5 million gallons per day and .25 million gallons per day, respectively, over a 20-year period, i.e., until the year 1998. The Balabat site was included in this study because Hawaii Architects and Engineers (1968) had previously recommended this site over Donitsch Island. Previous water circulation studies indicated that effluent would move from the Donitsch outfall towards the Outer Islanders' village and Chamorro Bay during certain times of year (Austin, Smith and Associations, 1967; Lyon Associates, Inc., 1975; Amesbury et al., 1976; and Chernin, 1978).

Balabat - The results of current studies presented in this report indicate that effluent released at the proposed diffuser site would be carried out the channel on ebb tides and would be carried back onto the reef flat, northwest of the diffuser site, on flood tides. The impact of untreated effluent on the reef flat could be minimized if the diffuser was centrally located on the channel floor (28 m deep). If the effluent is to be treated, then the diffuser could be located at a 5-m depth to allow for sufficient dispersion of the unconsolidated sewage. Because of the relatively rapid rates of tidal flushing, we feel that the proposed Balabat site is adequate for a sewer outfall.

Pelak - Current studies for the proposed diffuser site (North Station) at Pelak indicate a flow reversal with tide change; however, our findings also indicate relatively low flushing rates. This implies that water in the wide channel area never completely flushes and therefore would develop similar conditions to that of Chamorro Bay and adjacent areas in regards to fecal coliform counts (Amesbury et al., 1976).

The alternate site (South Station) at Pelak appears to be more adequate for a sewer outfall. A flow reversal with tide change is apparent and the flushing rate is three times faster than at the north station. At both stations, effluent would be carried onto the western reef flat; this will occur throughout the tide cycle at the proposed site and only during rising tides at the alternate site.

Regardless of the site, effluent waters would have to be treated here to minimize the impact to the reef flat. The proposed site is 5 m deep and the alternate site is 9 m deep, and these depths would not allow for adequate dispersion of untreated effluent material.

Impact of Outfall Construction

The construction of any facility on the reef flats of Balabat or Pelak will generate silt which will have some effect on the reef community downstream. Siltation is reported to be the most common type of pollution on islands (Johannes, 1975). In the case of the Balabat and Pelak sites, the main components on the reef flat are seagrasses and algae which should be able to tolerate a moderate degree of siltation.

Based on the fluorescein dye studies and the predominant wind vectors during the year, the movement of silt over the shallow seagrass beds will be towards the southwest at Balabat and at Pelak. Movement in shallow waters seems to be highly dependent on wind speed and direction. None of the reef organisms found at these two sites can be considered as threatened or endangered. In addition, the lagoon hole just east of the proposed sewer route at Balabat should be free from the influence of silt. These holes must be preserved in their natural state since they are the areas where large food fish congregate (Amesbury, 1978) and where coral diversity is the highest (Neudecker, 1978).

A logical way to discuss the possible effects of construction on the reef flat is to describe the damage done on a similar type habitat, such as at Donitsch Island. An examination of the Donitsch site during our recent visit in March 1978 showed the damaged area along the sewer line route to be about 20 m wide. At the channel margin, the damaged area was slightly wider, i.e., about 25 m wide. The 20-m wide strip along the sewer line is now inhabited by the algae *Padina tenuis*, *Caulerpa racemosa*, *Dictyota bartayresii*, and the low-lying seagrass *Halophila ovalis*. The original seagrass assemblage of *Thalassia hemprichii* and *Enhalus acoroides* have not repopulated the damaged area because the substratum has changed from a sand to a consolidated substratum. The consolidated substratum, consisting primarily of reef rocks, was placed here to anchor the sewer pipe.

The overall damage of the Donitsch reef flat is not significant. If the same care is taken during construction of the other proposed sites, damage will be minimal. The use of a silt screen during construction is always good practice, but in this case the cost of using such an expensive device may not be feasible since drastic damage from siltation is not anticipated.

Impact of Treated and Untreated Effluent

The degree of environmental deterioration affected by the introduction of sewer effluent depends largely upon the type and extent of treatment before its release. When untreated sewage is discharged into a coastal aquatic environment, one can generally expect rather wide-ranging effects. The biochemical oxygen demand (BOD) of untreated sewage is characteristically high, thus a reduction in the available oxygen in the affected waters is likely. A value for oxygen content of 4 ppm or less is often considered unsuitable for the survival of fishes (Willrich and Smith, 1970). Untreated effluent would also contain a substantial load of suspended solids. The most obvious detrimental effect of this material is to the aesthetic value of the site. It would also, however, increase the turbidity of the water column, thus reducing the light available for primary production.

The use of an Imhoff tank for the digestion of settleable solids would reduce the suspended load greatly and also reduce to some degree the BOD of the discharged sewage. Dissolved organics, inorganic nutrients and chlorine would still be present in the treated effluent. Elevated concentrations of inorganic nutrients may tend to stimulate plant growth in the area. Chlorination would effectively reduce the level of coliforms and other pathogenic organisms in the water. Chlorine, however, is toxic to many marine organisms. The use of chlorine does not rule out the enteroviruses in the water. Since both treated and untreated sewage would be transported by freshwater, the density of the effluent would be lower than the lagoonal waters into which it is discharged and it would tend to rise to the surface. The diffusion of materials during this ascent is an important factor in the design of any sewage diffuser pipe; the greater the distance the effluent rises the more effectively it is diffused. See Officer and Ryther (1977) for a critical assessment of secondary sewage treatment versus ocean outfalls.

FALALOP, ULITHI ATOLL

General Sewer Scheme

The small quantity of sewage released on the reefs off the Outer Islands High School does not seem to affect the reef biota. It does contain disease bearing microorganisms which one of our team members unpleasantly experienced. The presence of large waves during the major part of the year on these shores aid immensely in dispersing the sewage exiting the outfall pipes, as well as the fecal matter deposited on shore during low tides. This same heavy surf, however, can prove disasterous to sewer lines which are not anchored on the reef flat, as seen during past typhoons which destroyed the sewer lines.

Since these reefs are poorly represented in terms of reef organisms which in turn is caused by their exposure during low tide, the effect of construction and its resulting siltation is not the major concern. What is important is the lengthening of one of the existing outfall pipes over the reef margin so that the sewage can be released away from the shoreline. The ideal outfall to lengthen is the one on the east side. Here, the reef flat and reef margin is lower, and the site is further away from the channel. Water flows toward the reef margin here because of its lower terrain as seen in the dye studies. The presence of an extensive submarine terrace (ca. 6 m deep) off the northern side of Falalop Island provides no alternative than to construct the outfall on the terrace. The design of such an outfall must be able to withstand future typhoons. If such an outfall can be designed and constructed, the sewage can then be pumped through the pipe and released in 6 m of water. The outfall should extend beyond the wave-breaker zone so that the effluent is not carried back to shore.

The effluent will rise slowly if carried by brackish water and will have more time to mix with the seawater. Based on the results of the current studies, the effluent should then move toward the channel and enter the lagoon. The effluent, however, should be well mixed by the time it reaches the channel entrance. Contrary to our water circulation results, several individuals who are familiar with the waters of the channel have told us that reversals in water movement are common, i.e., the water moves out of the channel during ebb tides. Additional current studies must be conducted at other times of year, especially during the calmer months, to quantify water movements off the eastern sewer outfall.

Primary treatment of the sewage before release is preferable, however, secondary treatment seems ridiculous for the amount of sewage generated by a population of 300 students. If sewage dispersion across the submarine terrace proves adequate, village hookup to the outfall system may be feasible at a future date. This suggestion may not be practical but can be explored by engineers who possess the expertise in such matters.

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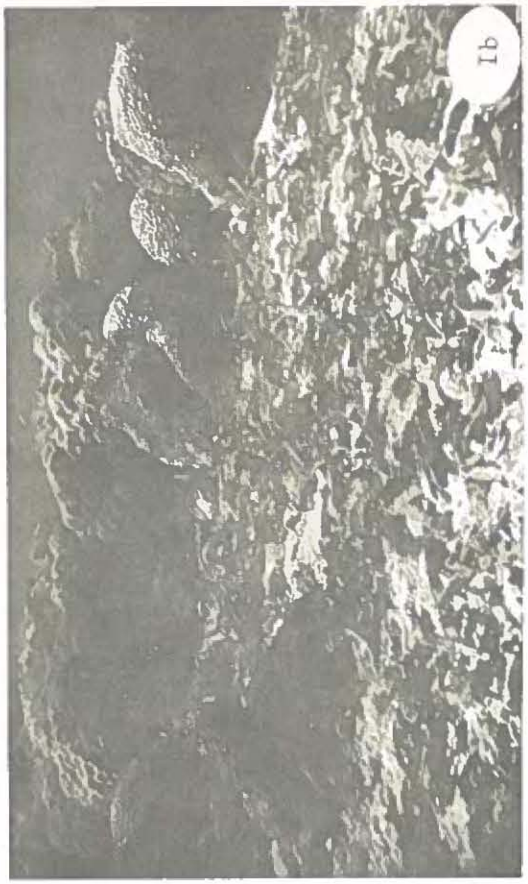
PLATE I

a. Stand of soft corals on channel margin at Balabat, Yap. (Photo by J. O. Stojkovich).

b. Massive *Porites lutea* mounds adjacent to channel margin at Balabat, Yap. The seagrass *Thalassia hemprichii* is shown in the foreground. (Photo by J. O. Stójkovich).

c. View of the silty bottom (5m deep) at the site of the proposed sewer outfall in Pelak Channel, showing the calcareous green alga *Halimeda macroloba* and the seagrass *Halophila minor* (low-lying on silt). (Photo by J. O. Stojkovich).


Ia


Ib


Ic

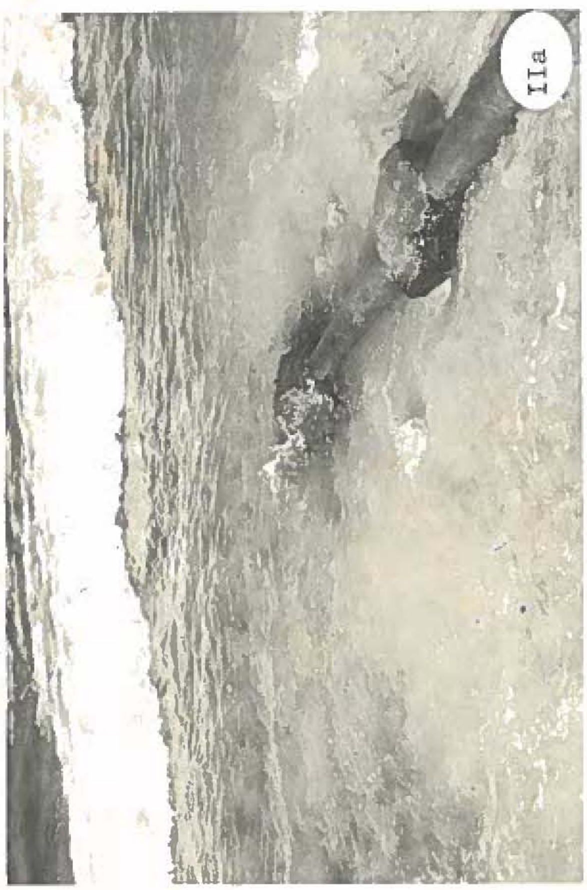
PLATE II

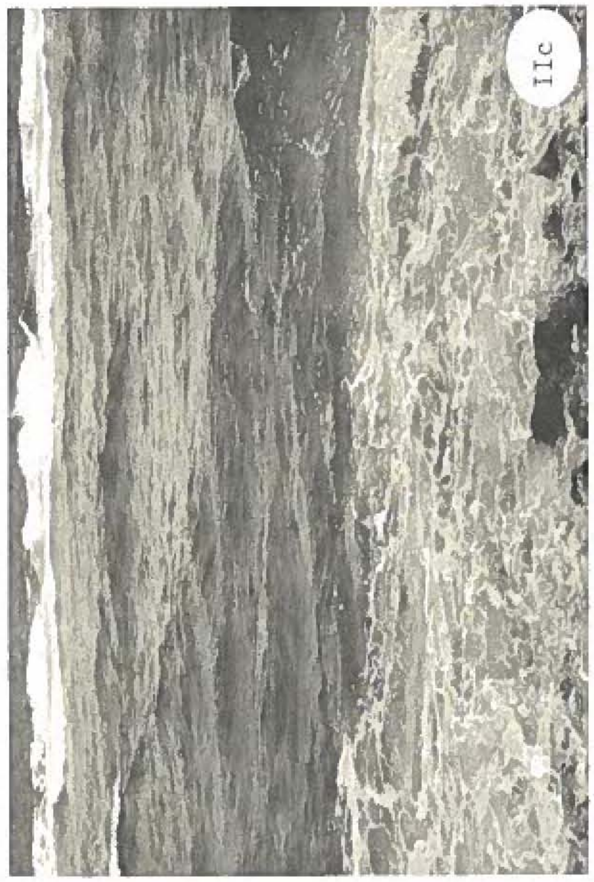
a. The western sewer outfall located in the lower intertidal zone off the Outer Islands High School, Falalop Island, Ulithi Atoll. (Photo by R. T. Tsuda).

b. The eastern sewer outfall located in the upper intertidal zone off the Outer Islands High School, Falalop Island, Ulithi Atoll. (Photo by R. T. Tsuda).

c. The reef area at high tide off the septic tank, Outer Islands High School, Falalop Island, Ulithi Atoll. (Photo by R. T. Tsuda).


IIb


IIa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