LIMITED CURRENT AND UNDERWATER BIOLOGICAL SURVEY
AT THE POINT GABERT WASTEWATER OUTFALL
ON MOEN, TRUK

By

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Prepared for

ENVIRONMENTAL PROTECTION BOARD

TRUST TERRITORY OF THE PACIFIC ISLANDS

As per

TRUST TERRITORY CONTRACT NO. 175-62

University of Guam

The Marine Laboratory

Technical Report No. 20

May 1975

TABLE OF CONTENTS

INTRODUCTION

Background

At the Sixth Trust Territory Environmental Protection Board (TTEPB) meeting held on November 30 to December 4, 1974, on Moen, Truk, the Director of the University of Guam Marine Laboratory presented his findings (Tsuda et al., 1974) on a limited current and biological study in the Tuanmokot Channel in Ponape. Since other similar type studies were lacking on other islands of the Trust Territory, the Director presented a proposal to the Board in which the services of the Marine Laboratory would be extended to carry out current and biological studies at other island outfalls. Cost incurred by the Board would be only for transportation, excess baggage, per diem, expendable supplies, and publication. The field work would be undertaken by Marine Laboratory personnel with the aid of personnel from the Trust Territory Environmental Health Division. The reporting of results and recommendations would be the sole responsibility of the University group.

The present report carried out between March 25 and April 2, 1975, on Moen (Fig. 1) represents the first study undertaken under this agreement.

Description of Sewer Outfall

The secondary treatment plant (Fig. 2) is located at Gabert Point on the northwestern tip of Moen, the second largest island in the lagoon (9 sq. mi.) and the district center. The sewage line runs in a northwest direction where the effluent is released (Fig. 3) from three ports (the fourth port nearest shore is sealed) in 8.4 m (27 feet) of water about 185 m from the northwestern edge of the runway. The plant operating since December 1974 is releasing about 10,000 to 15,000 gallons of secondarily treated sewage a day and has the capacity to handle up to 750,000 gallons per day. The school, hospital, government building and the government staff housing are the only buildings hooked up to the sewer line.

In the past bacteriological monitoring and limited underwater surveys have indicated that the northern coastline of Moen is in a relatively pristine state. It is the Trust Territory Environmental Protection Board's policy that these water should maintain their existing quality.

Scope of Work

1. What effect, if any, the discharge of secondary effluent will have on the ecological condition of the lagoon adjacent to Moen Island.

2. The extent and magnitude of surface and subsurface currents at the diffuser site so that reliable predictions on outfall plume dispersion and dilution can be developed by the Board.

3. Baseline ecological conditions that can be utilized for future comparison and determination of potentially deleterious long-term effects.

Personnel

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ACKNOWLEDGMENTS

We acknowledge Mr. Nachsa Siren, Executive Officer of the Trust Territory Environmental Protection Board, and the board members for providing the funds to carry out this study; Mr. William A. Brewer, Environmental Specialist, for handling the logistics on Saipan and Truk, and his aid in obtaining the oxygen, temperature, salinity and coliform data for this study; Mr. Sikaret Lorin, Chief District Sanitarian of Truk District, for coordinating his employees who helped us in the long dreary 24-hour current study; Mr. Tawn Paul, Chief Conservation Officer of Truk District, and Truk's representative to the Trust Territory Environmental Protection Board, for the use of his SCUBA tanks and, at times, use of his boat; Mr. Joshua Simon, Sanitarian, for analyzing the coliform samples; Messrs. Risauo Alifios, Joshua Simon, Kawareta Job, Rokucho Esein, and Daniel Sephach for their help during the 24-hour current study; Mr. Dick Stolp, Air Mike Manager on Truk, for his aid in setting up our operation near the runway; Mr. Kimiuo Aisek, Proprietor of the Blue Lagoon Dive Shop, for providing additional SCUBA tanks and refilling our tanks; Dr. James A. Marsh, Jr. for analyzing the NO_3-N and PO_4-P samples; Dr. Masashi Yamaguchi for identifying the corals; and Dr. Lucius G. Eldredge for giving us the scientific names of certain invertebrates.

Our special appreciation is extended to Mr. Mitaro Danis, District Administrator of Truk, and the wonderful people of Truk who permitted us to carry out this study on Moen.

METHODOLOGY

Effluent Quality

Temperature, salinity and dissolved oxygen samples were taken at the mouth of Port 2 and at 1 m intervals from the port in the direction of the plume. Coliform, NO_3-N, and PO_4-P samples were also collected at the mouth of Port 2 and at 2 m intervals from the port. In addition, water samples were taken at 10 m intervals parallel and perpendicular to the pipeline as seen in Fig. 4. Only temperature, salinity, and dissolved oxygen were recorded for each sample (a-m).

All samples were collected in 500 ml polyethylene bottles by opening the tightly fitted caps at the desired sampling depth. The bottles were brought to the boat where temperature, dissolved oxygen and salinity were recorded with a YSI oxygen meter and a YSI S-C-T meter. Sample bottles for NO_3-N and PO_4-P were immediately placed in ice and taken to the reefer within an hour of sampling to be frozen for later analyses (Strickland and Parsons, 1968) on Guam.

Additional samples were also obtained for coliform analyses. These samples were processed the same day using the membrane filter method (A.P.H.A., 1971). Fecal coliforms were cultured on Difco M-FC medium at 44.5 ± 0.5°C; total coliforms were cultured on Difco M-Endo medium at 35.0 ± 0.5°C.

Water Circulation

A buoy was fastened by a rope to Port 4 which marked the site from which pairs of drogues, 1 m and 5 m deep, were released at one or two hour intervals for 24 hours (March 27-28, 1975). Positions of the drogues were recorded each hour. The direction and speed of the 19 drogue casts were then plotted and calculated. In addition, wind direction and speed were recorded each hour.

Transects

Three 100 m long transects were run (Fig. 5) perpendicular to the sewer line. Each transect extended 50 m to either side of the pipe.

Transect A was located about 100 m from shore in 6 m of water. The transect line ran through various types of substrate - sand, live *Acropora* thickets, dead *Acropora* thickets and *Porites*.

Transect B was located in sandy area about 185 m from shore in 8.4 m of water at the end of the sewer line.

Transect C was also located in a sandy area about 285 m from shore in 8.4-10 m of water.

Biota

Coral - The coral community was analyzed by using a point-center quarter technique (Cottam *et al*., 1953). For this technique a series of 10 points, 10 m apart, were selected along a 100 m transect line. The area around each point was divided into four equal quadrants. The coral nearest the transect point in each quadrant was located and its specific name, diameter or basal area, and the distance from the center of the corallum to the transect point was recorded. If no coral was observed within a maximum distance of 5 m from the transect point the collection point was recorded as no coral with a transect point to organism distance at 5 m and a diameter of zero.

From the above data total coral density, percentage of substratum coverage, and frequency of occurrence by living corals can be determined.

$$\text{Total Density of All Species} = \frac{\text{Unit Area}}{(\text{Mean point-to-point distance})^2}$$

$$\text{Percentage Coverage} = \text{Density of Species X Average Dominance Value for Species}$$

$$\text{Frequency of Occurrence} = \frac{\text{Number of points at which species occurs}}{\text{Total number of points sampled}}$$

By summing the relative values of each of these parameters an overall importance value is assigned to each transect species. A more detailed analysis of the overall species diversity was achieved by making a collection along the general area on both sides of the transect line.

Fish - A SCUBA-equipped diver swam the length of the transect, taking approximately 20 minutes to cover the 100 m distance, and all fish sighted within one meter to either side of the transect line were recorded.

Algae - Two sampling techniques were used in this study. At Transect A, the algal community was quantified by a modified point method utilizing a 25 cm X 25 cm quadrat placed on either side of the transect line at 5 m intervals. Thus, 40 samples were obtained. The quadrat frame was divided into a grid of 25 squares each 5 cm X 5 cm, providing 16 interior "points" where the grid line intersected. Each algal species was recorded at every "point" it occurred. If no alga was found under any of the "points" then whatever was present, e.g., sand, live coral, soft coral, dead coral, was recorded. From this data, relative abundance and frequency were calculated for each species.

Since Transects B and C were run on sandy substratum primarily dominated by *Halimeda cylindracea*, density was obtained for this algal species by counting the number of individual thalli per 25 cm X 25 cm quadrat. This value was then multiplied by 16 to arrive at a density per m^2. A density value was also obtained from Transect A in the sandy area.

Plankton - Six plankton tows were made in the area of the Gabert Sewer Outfall (Fig. 6). Three of these were made with a 28 cm diameter coarse mesh net (1.0 mm mesh opening) and three were made with a 45 cm diameter double-mesh net (.20 and .075 mesh opening; samples from both nets of the double net were combined). The six tows were made immediately below the surface and covered a distance of 360 to 550 meters.

CHARACTERISTICS OF EFFLUENT

As seen in Table 1, temperature was relatively constant varying from 28.1 to 28.6°C. Salinity was lowest (28.2 and 28.9°/oo) at the mouth of the port but quickly mixed to 32.3 and 32.9°/oo one meter away from the port.

Dissolved oxygen levels were slightly lower (4.8-5.0 ppm) at the mouth but were close to saturation (6.2 ppm) just three meters away from the port. These dissolved oxygen values may be questionable since the technique of displacing air with water causes bubbling, which in turn will increase the dissolved oxygen content in the sample bottles. A Van Dorn sampler should have been used and will be used in future studies.

As expected, fecal coliform was highest (60/100 ml) at the mouth of the port but quickly decreased to 5/100 ml two meters away. This value is still recognized as signifying unpolluted conditions. Total coliform, on the other hand, was high (770/100 ml) at the source but quickly decreased to 40/100 ml just one meter away and was 0/100 ml two meters away.

NO_3-N and PO_4-P levels were high at 0.98 ug-at/l and 2.02 ug-at/l, respectively, at the mouth but were at "normal" levels just one meter away.

The values in Table 2 show that the effluent has no influence on the water quality around the outfall at substrate level. The only evidence of freshwater is at Station d (27.3°/oo) obtained from the port.

WATER CIRCULATION

The distance traveled and speed of the 19 pairs (1-m and 5-m drogues) of drift drogues for March 27-28, 1975 is presented in Fig. 7. As can be seen on the tide graph, the 24-hr. current study was conducted during neap tide when the difference of high and low tides was only one foot. Thus, very little flushing was taking place during the study.

The results of the 24-hr. current study (Figs. 8 and 9) indicate that water movement is predominantly away from shore. The only exception was the pair of drift drogues (No. 11) which headed southeast about 100 m parallel to the reef margin. The direction of the wind had almost no influence on the drift drogues.

If the drogues are listed in relation to the time of ebb, slack, and flood tides, a pattern can be seen - ebb, 3-7, 12-15; slack, 8 and 9; and flood, 1 and 2, 10 and 11, 16-19. All of the 5-m drogues (Fig. 9) released during ebb or slack tides moved in a northerly, northwesterly, or westerly direction; those drogues released during flood tide moved in a southerly or southwesterly direction. The movement of water in that direction during flood tides was most likely influenced by the incoming water from Northeast Pass.

BIOTA

Corals

Table 3 lists the species of corals collected or observed at the three transects studied at the Gabert Sewer Outfall study area. See Fig. 5 for locations of transects. Table 4 presents the relative density, frequency, percentage coverage, and importance value for each transect coral studied.

Porites lutea was by far the most abundant coral occurring at Transects A, B and C comprising 60, 80, 68 percent of the total coral coverage, respectively. Of the total 42 coral species collected or observed at the Gabert Sewer Outfall only three species occurred at all three transects - *Favia speciosa*, *Pocillopora damicornis* and *Porites lutea*.

Species diversity, density, and percentage of living coral coverage are considerably greater at Transect A, than at Transects B and C. A dominant coral species occurring at Transect A was *Acropora formosa* where colonies form extensive thickets.

Total coral densities at Transects B and C were $<.077/m^2$ and $<.067/m^2$, respectively. Both areas consisted predominantly of sand and *Halimeda* substrate. The extremely low coral density is reflective of the broad sand substratum.

Most coral observed at Transect C were more or less confined to submarine mounds in the general area. Here coral density and diversity are much greater than that of the broad sandy areas.

Numerous small colonies of *Pocillopora damicornis* on the average of 8-10 mm in diameter have begun to settle and colonize the relatively recent installation of the Gabert Sewer Outfall pipe. This is reflective of coral colonization potential and sexual reproduction.

Fishes

Fish were not abundant in the area of the Gabert Sewer Outfall (Table 5). Most of the fishes observed were associated with areas of relatively high, or complex, substrate relief (coral outcrops and the sewer pipe itself), and the low observed fish abundance reflects the wide-spread occurrence of relatively featureless silt and sand substrate.

Of the thirty-one species observed, only three (the pomacentrids *Abudefduf leucopomus* and *Pomacentrus pavo* and the labrid *Halichoeres marginatus*) were seen on all three transects (Table 5). These are small fishes and were among the most abundant species observed. They tended to occur in clusters around coral outcrops and were probably permanent residents of these outcrops. Many of the other, larger species (acanthurids, balistids, chaetodontids, mullids, *Scarus sordidus*, *Epinephelus merra*, and *Zanclus cornutus*) probably move from area to area and might be expected to occur from time to time at all the transects.

The low abundance of fishes at the Gabert Sewer Outfall seems to be the result of limitations imposed by the infrequent occurrence of appropriate substrate. Natural levels of nitrates and phosphates (Table 1) indicate that the water is potentially productive, and the abundance of plankton (Table 7) bears this out. The high abundance and diversity of fishes associated with enhanced substrate topography provided by sunken ships in the Truk lagoon emphasize the importance of this environmental factor on fish communities. This suggests that the increased levels of nutrient enrichment, which are expected to occur as the use of the Gabert Sewer Outfall expands, will not result in any increase in fish biomass or diversity. On the contrary, any factors which would tend to decrease the amount of appropriate fish substrate, such as extensive siltation, can be expected to cause a decrease in fish abundance in this area.

Algae

Table 6 presents a checklist of marine algae found at the three transects. Algal cover at all three transects was low at 7%, 2%, and 3% respectively. *Halimeda cylindracea* was by far the most dominant alga at all three transects: Transect A-42/m^2, Transect B-34/m^2, and Transect C-46/m^2.

All of the algal species, except *H. cylindracea* and *H. macroloba*, at Transect A were found on the dead *Acropora* thickets. Only the four sand dwelling species (*H. cylindracea*, *H. macroloba*, *Avrainvillea obscura*, and *Udotea argentea*) characterized by their massive holdfasts were found on Transect B. In the case of Transect C, all species other than the four sand inhabiting species were found on dead *Porites* in an 2 m^2 area, Aside from the algae found on the dead *Porites*, the same four species found in Transect B occur here.

The paucity of benthic algal species simply reflects the lack of suitable substrates and not the influence of the sewer effluent.

Plankton

The coarse mesh net collected only the largest plankters. Few of these were taken, but the most abundant were larvaceans and chaetognaths (Table 7). The finer mesh double net collected many more smaller plankters. Most abundant in these collections were copepods, mollusks, larvaceans, dinoflagellates, and crustacean larvae (Table 7), The proportions of different plankters were very similar from tow to tow and are combined to give an overview of the plankton in this area.

The abundance of plankton and the relative strong current in the area of the Gabert Sewer Outfall indicate that there is an abundance of food available for plankton-feeding fishes. Large numbers of larvaceans were observed by divers in the water (the small larvacean is made visible by the relatively large - ca. 2 cm diameter - gelatinous "house" that each animal secretes around itself). Schooling fishes of the genus Caesio were seen feeding avidly on these larvaceans. Larvaceans feed on very minute suspended material (<30 μ; Nicol, 1967) and may serve as an important energy pathway channeling primary productivity to planktivorous fishes. It is of interest that Caesio sp., which feed on these larvaceans, were used extensively as baitfish by the pre-war Japanese tuna fishery in Truk (Wilson, MS).

CONCLUSIONS

The low quantity of effluent (10,000-15,000 gallons per day) is not affecting the surrounding environment as evidenced by the rapid dispersion of nutrients and coliform within three meters from the ports. There is no sign of nutrient enrichment and coliform in the surface water. The water circulation study conducted over a 24-hr. period shows that the water movement is predominately away from shore.

At the present time, the effluent does not effect the biota in the vicinity of the outfall. The low species number of algae (17), corals (42), and fishes (31) is due to the lack of adequate habitats in this area. The area surrounding the diffusers is characterized by sand and silt.

As long as the sewage treatment plant functions properly, the waters in the vicinity of the outfall should remain in a pristine state.

RECOMMENDATIONS

1. Personnel from Truk's Environmental Health Division should continue to monitor the waters for changes in salinity and coliform at the outfall site when the volume of effluent released increases. These two parameters are good indicators of degrees in mixing.
2. The sewage treatment plant must be given a high priority in terms of electrical power usage to insure the proper functioning of the plant. In addition, the second blower, which is now inoperable, should be repaired.

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Table 1. Characteristics of secondarily treated effluent sampled at 1-m or 2-m intervals from source (port) at Point Gabert outfall. March 31, 1975, 1100. Values in parentheses taken two days earlier (March 29, 1975, 1100) from same site. See Fig. 4 for location of sample stations.

Station	Temp. (°C)	Salinity (‰)	D.O. (ppm)	Fecal Coliform (per 100 ml)	Total Coliform (per 100 ml)	NO_3-N (ug-at/l)	PO_4-P (ug-at/l)
1 (Port)	28.6(28.5)	28.9(27.2)	4.8(5.0)	60	770	0.98	2.02
2	28.5(28.5)	32.9(32.3)	5.5(5.0)	60	40	-	-
3	28.5(28.5)	33.0(32.5)	5.9(5.0)	5	0	0.26	0.23
4	28.2(28.5)	33.0(32.5)	6.2(5.2)	5	0	-	-
5	28.1	33.4	6.1	0	0	0.29	0.22
6	28.1	33.5	6.1	0	0	-	-
7	28.2	33.5	6.1	0	0	0.25	0.25
8	28.5	33.8	6.1	0	0	-	-
9	-	-	-	-	-	0.26	0.23
10 (Surface)	28.5(28.5)	32.2(32.5)	6.2(6.0)	0	0	-	-
*11 (Control)	-	-	-	-	-	0.29	0.22

*Sample taken about 3 km off harbor entrance away from outfall site.

Table 2. Temperature, salinity, and dissolved oxygen values obtained from samples taken at 10 m intervals from port 4. See Fig. 4 for location of sample stations.

Station	Depth (m)	Temp. (°C)	Salinity (‰)	D.O. (ppm)
a	7.2	28.5	32.0	5.5
b	7.9	28.5	32.0	5.4
c	7.9	28.5	32.3	5.8
d	9.4	28.9	27.3	6.2
e	9.4	28.4	31.4	5.4
f	9.7	28.0	30.9	5.4
g	11.0	28.5	30.6	6.2
h	9.4	28.1	31.9	6.0
i	9.4	28.1	32.0	6.0
j	9.4	28.0	32.3	5.9
k	9.4	28.0	32.3	5.9
l	9.4	28.0	32.3	5.4
m	9.4	28.0	33.0	5.8

Table 3. Checklist of corals occurring on or in the vicinity of Transects A, B, and C. See Fig. 5 for location of transects.

Species	Transects A	B	C
Acropora delicatula (Brook)	X		
Acropora echinata (Dana)	X		
Acropora formosa (Dana)	X		
Acropora hyacinthus (Dana)	X		X
Acropora hystrix (Dana)	X		X
Acropora nobilis (Dana)	X		
Astreopora profunda Verrill			X
Euphyllia fimbriata (Spengler)			X
Favia favus (Forskal)	X	X	
Favia speciosa (Dana)	X	X	X
Favites abdita (Ellis & Solander)	X		X
Fungia echinata (Pallus)	X		
Fungia fungites (Linnaeus)	X		
Goniastrea pectinata (Ehrenberg)	X		X
Goniopora sp. 1	X		
Goniopora sp. 2	X		
Hydno phora mayori Hoffmeister	X		
Leptastrea purpurea (Dana)	X		
Lobophyllia corymbosa (Dana)	X		
Lobophyllia costata (Dana)		X	
Millepora platyphylla Hemprich & Ehrenberg	X		
Millepora tenera Boschma	X		
Montipora erythraea Marenzeller	X		
Montipora minuta Bernard			X
Montipora socialis Bernard			X
Montipora tuberculosa (Lamarck)			X
Montipora verracosa (Lamarck)			X
Pachyseris rugosa (Lamarck)			X
Pachyseris speciosa (Dana)	X		
Pectinia laciniata (Milne-Edwards & Haime)	X		X
Platygyra lamellina (Ehrenberg)	X	X	
Platygyra rustica (Dana)	X		
Plesiastrea versipora (Lamarck)	X		
Pocillopora damicornis (Linnaeus)	X	X	X
Polyphyllia talpina (Lamarck)	X	X	
Porites andrewsi Vaughan		X	
Porites (*Synaraea*) *hawaiiensis* Vaughan			X
Porites (*Synaraea*) *iwayamaensis* Eguchi			X
Porites lobata Dana	X		
Porites lutea Milne-Edwards & Haime	X	X	X
Seriatopora angulata Klunzinger	X	X	
Symphyllia nobilis (Dana)	X	X	
Total No. of Species	31	10	17

Table 4. Living Coral density, percent of substratum coverage, frequency of occurrence, and importance value. Corals are arranged in order of their importance value. See Fig. 5 for location of transects.

Species	Density/m²	Rel. Density	Percent Coverage	Rel. Percent Coverage	Freq. of Occurr.	Rel. Freq. of Occurr.	Importance Value
				TRANSECT A			
Porites lutea	.73	50.00	20.91	59.81	.80	33.30	143.11
Acropora formosa	.18	12.50	6.98	19.96	.20	8.33	40.79
Favia speciosa	.11	7.50	1.12	3.20	.20	8.33	19.03
Lobophyllia corymbosa	.07	5.00	1.46	4.17	.20	8.33	17.50
Fungia echinata	.07	5.00	.86	2.46	.20	8.33	15.79
Symphyllia nobilis	.07	5.00	.51	1.46	.20	8.33	14.79
Pocillopora damicornis	.07	5.00	.44	1.25	.20	8.33	14.58
Goniopora sp.	.04	2.50	1.80	5.15	.10	4.16	11.81
Flatygyra lamellina	.04	2.50	.36	1.03	.10	4.16	7.69
Montipora tuberculosa	.04	2.50	.29	.83	.10	4.16	7.49
Favites abdita	.04	2.50	.23	.66	.10	4.16	7.32
Total Species	11						
Total Genera	11						
Overall Density	1.45/m²						
Overall Coverage	35.96%						
				TRANSECT B			
Porites lutea	.018	22.50	.41	80.87	.50	45.45	148.82
Favia speciosa	.006	7.50	.05	9.16	.30	27.27	43.93
Platygyra lamellina	.002	2.50	.03	5.57	.10	9.10	17.17
Symphyllia nobilis	.002	2.50	.01	2.79	.10	9.10	14.39
Favia favus	.002	2.50	.01	1.60	.10	9.10	13.20
Total Species	5						
Total Genera	4						
Overall Density	< .077						
Overall Coverage	.502%						

Table 4. (Continued)

TRANSECT C

Species	Density/m^2	Rel. Density	Percent Coverage	Rel. Percent Coverage	Freq. of Occurr.	Rel. Freq. of Occurr.	Importance Value
Porites lutea	.010	15.00	.29	67.92	.40	36.36	119.28
Acropora hyacinthus	.002	2.50	.03	7.92	.10	9.10	19.52
Polyphyllia talpina	.002	2.50	.03	7.92	.10	9.10	19.52
Pocillopora damicornis	.002	2.50	.03	7.54	.10	9.10	19.14
Symphyllia nobilis	.002	2.50	.02	3.96	.10	9.10	15.56
Montipora socialis	.002	2.50	.02	3.53	.10	9.10	15.13
Favia speciosa	.002	2.50	.01	1.18	.10	9.10	12.78

Total Species	7
Total Genera	7
Overall Density	<.067
Overall Coverage	.43%

Table 5. Fishes observed at the Gabert sewer outfall, March 1975.

Species	TRANSECT A	B	C
Acanthuridae			
Acanthurus nigrofuscus Forskal	1	-	-
A. olivaceous Bloch & Schneider	-	-	4
Ctenochaetus striatus (Quoy & Gaimard)	17	2	-
Apogonidae			
Paramia quinquelinata Cuvier & Valenciennes	-	-	1
Balistidae			
Melichthys vidua Solander	-	2	-
Sufflamen chrysoptera (Bloch & Schneider)	1	-	-
Blenniidae			
Meiacanthus atrodorsalis (Gunther)	5	-	-
Unidentified blenniid 1	-	3	-
Unidentified blenniid 2	2	-	-
Canthigasteridae			
Canthigaster solandri (Richardson)	-	2	-
Chaetodontidae			
Chaetodon auriga Forskal	-	1	-
C. kleinii Bloch	5	4	-
Gobiidae			
Amblygobius albimaculatus (Ruppell)	-	7	1
Unidentified gobiids	-	6	3
Holocentridae			
Flammeo samarra (Forskal)	1	-	-

Table 5. (Continued)

Species	TRANSECT A	B	C
Labridae			
Halichoeres margaritaceous (Cuvier & Valenciennes)	1	-	-
H. marginatus Ruppell	30	9	2
Labroides dimidiatus (Cuvier & Valenciennes)	2	-	-
Thallasoma quinquevittata (Lay & Bennett)	-	-	1
Mullidae			
Mulloidichthys auriflamma (Forskal)	-	-	1
Parupeneus barberinus (Lacepede)	-	1	-
P. pleurostigma (Bennett)	4	-	-
Pomacentridae			
Abudefduf lacrymatus (Quoy & Gaimard)	6	-	1
A. leucopomus (Lesson)	1	2	28
A. septemfasciatus (Cuvier & Valenciennes)	12	-	-
Dascyllus aruanus (Linnaeus)	-	-	26
Pomacentrus albofasciatus (Schlegel & Muller)	-	18	1
P. pavo (Bloch)	15	88	26
Scaridae			
Scarus sordidus Forskal	7	-	-
Serranidae			
Epinephelus merra Bloch	-	1	-
Zanclidae			
Zanclus cornutus (Linnaeus)	3	-	-
Total Number of Individuals	113	146	95
Total Number of Species	17	14	12

Table 6. Checklist of marine algae recorded from the vicinity of Transects A, B, and C. Relative abundance and frequency (in parenthesis) values recorded for algae on Transect A.

Species	Transects A	B	C
CYANOPHYTA (blue-greens)			
Microcoleus lyngbyaceus (Kutz.) Crouan			X
CHLOROPHYTA (greens)			
Avrainvillea obscura J. Ag.		X	X
Caulerpa filicoides Yamada			X
Caulerpa racemosa (Forskal) J. Ag.			X
Halimeda cylindracea Decaisne	2% (21%)	X	X
Halimeda macroloba Decaisne		X	X
Halimeda macrophysa Askenasy			X
Halimeda micronesica Yamada	X		
Halimeda opuntia (L.) Lamx.	2% (6%)		
Rhipilia orientalis A. & E. S. Gepp			X
Udotea argentea Zanardini		X	X
PHAEOPHYTA (browns)			
Dictyota bartayresii Lamx.	X		
Dictyota patens J. Ag.	X		X
Lobophora variegata (Lamx.) Womersley	<1% (3%)		X
RHODOPHYTA (reds)			
Gelidiopsis intricata (Ag.) Vickers			X
Jania capillacea Harvey	X		
Polysiphonia sp.	<1% (3%)		
Algal Cover (%)	7	2	3
Number of Species	9	4	12

Table 7. Relative abundance of plankton collected in three double-net tows (based on 400 organisms counted) and in three coarse net tows (based on all 44 counted) at the outfall site. See Fig. 6 for direction and distance of each tow.

Plankton	Relative Abundance (%) Coarse Net (Tows 1-3)	Fine Double Net (Tows 4-6)
Copepods	-	45
Mollusk larvae	-	18
Tunicate larvae	41	16
Dinoflagellates	-	10
Other Crustacean larvae	-	7
Chaetognaths	48	2
Tintinnids	2	<1
Polychaete larvae	-	<1
Diatoms	-	<1
Juvenile decapods	5	-
Heteropods	2	-
Medusae	2	-

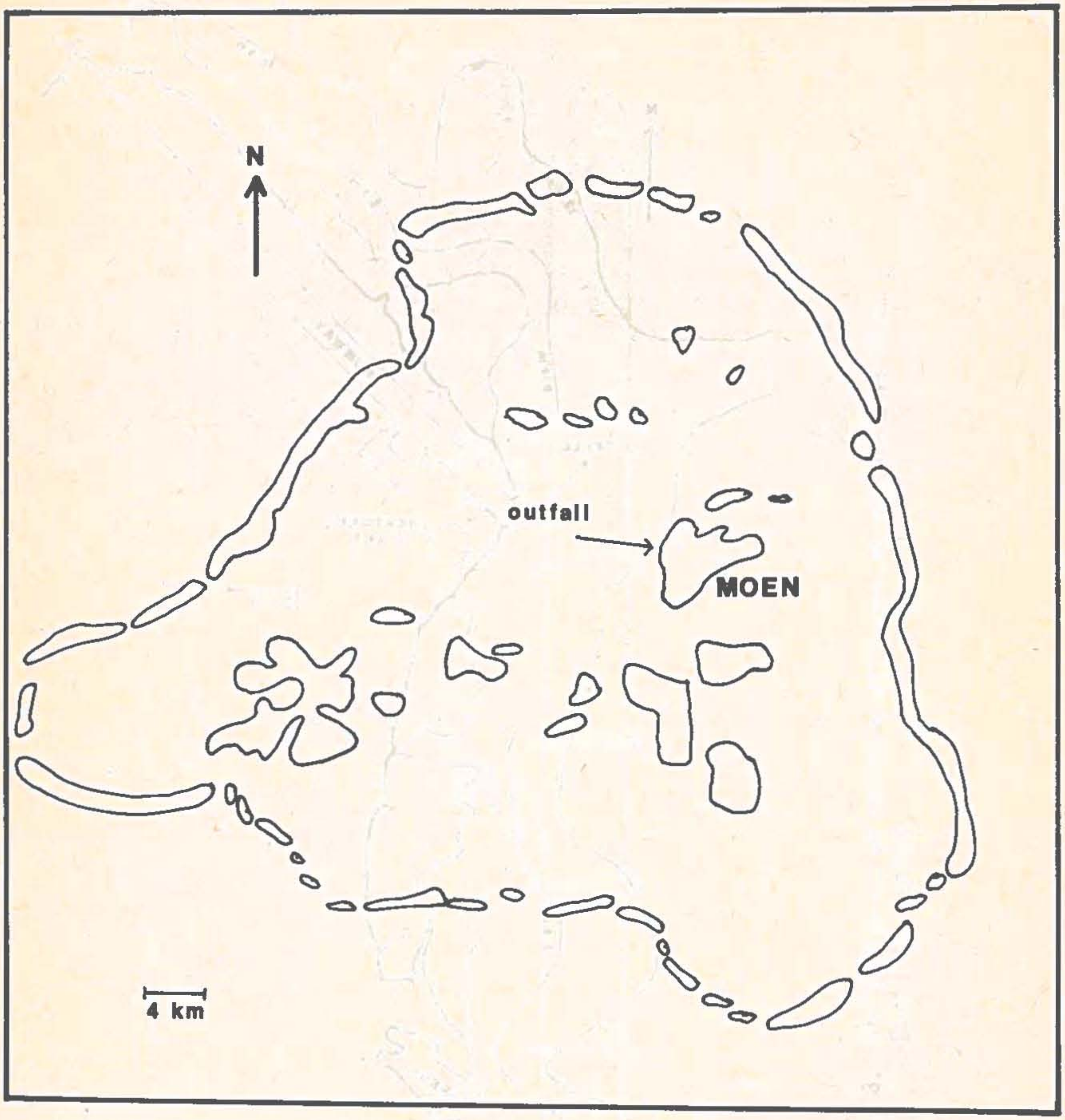


Fig. 1. Map of Truk showing location of Moen and outfall.

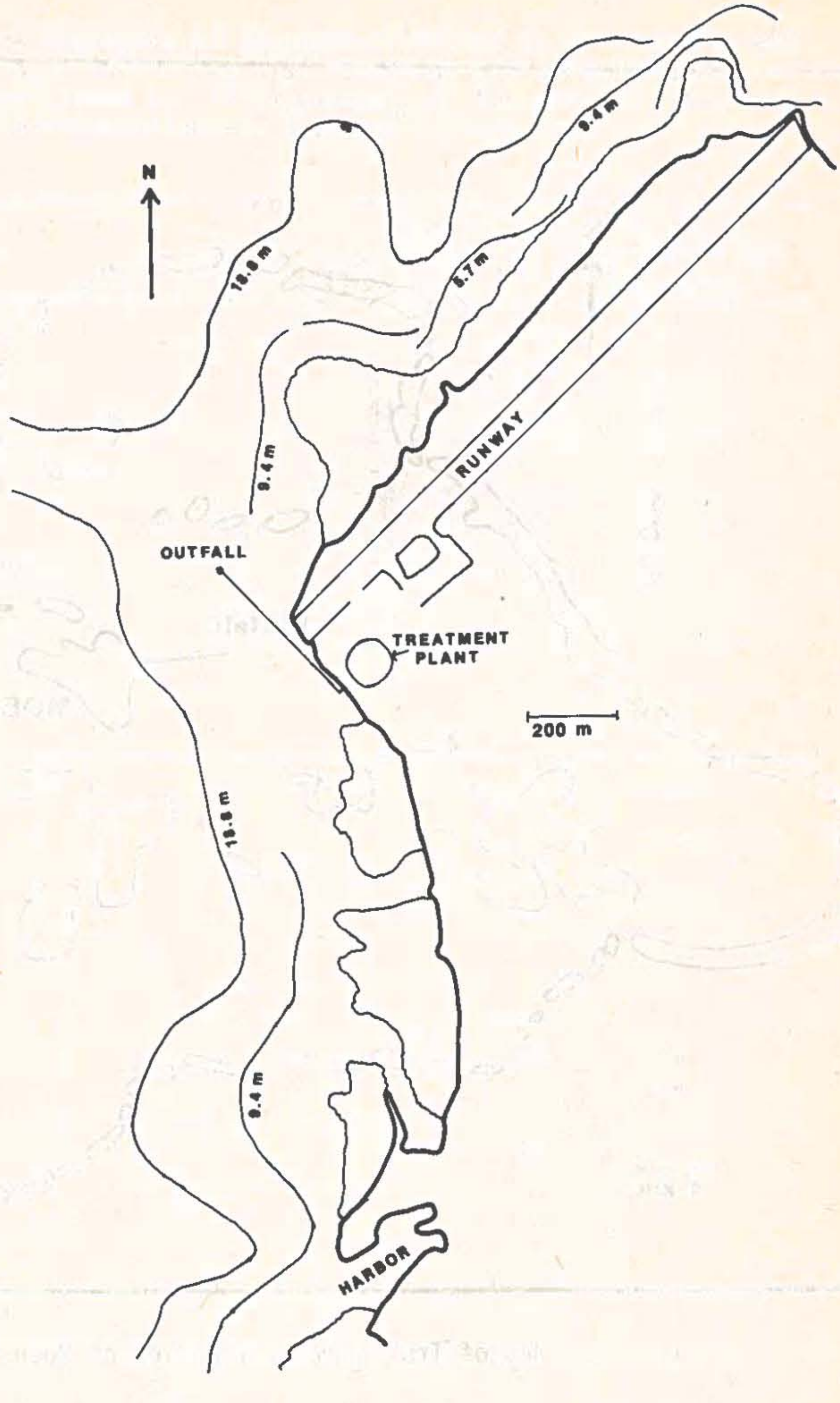


Fig. 2, Map of treatment plant, outfall, and depth contours.

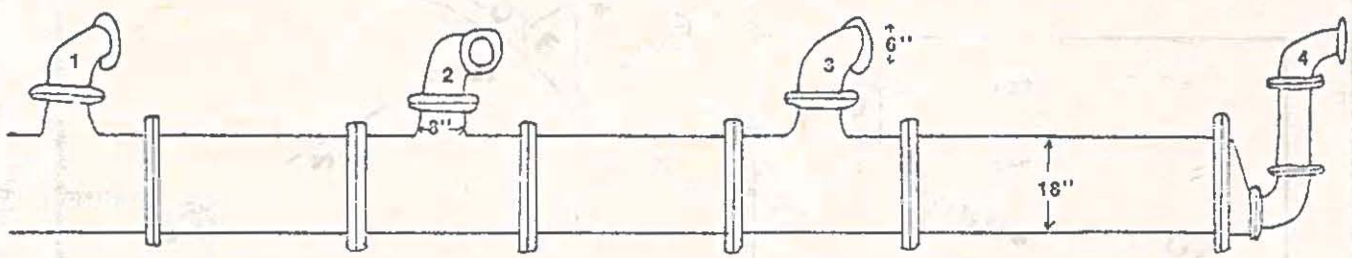


Fig. 3. Scale drawing of multiple diffusers at end of sewer line.
Port 1 is sealed.

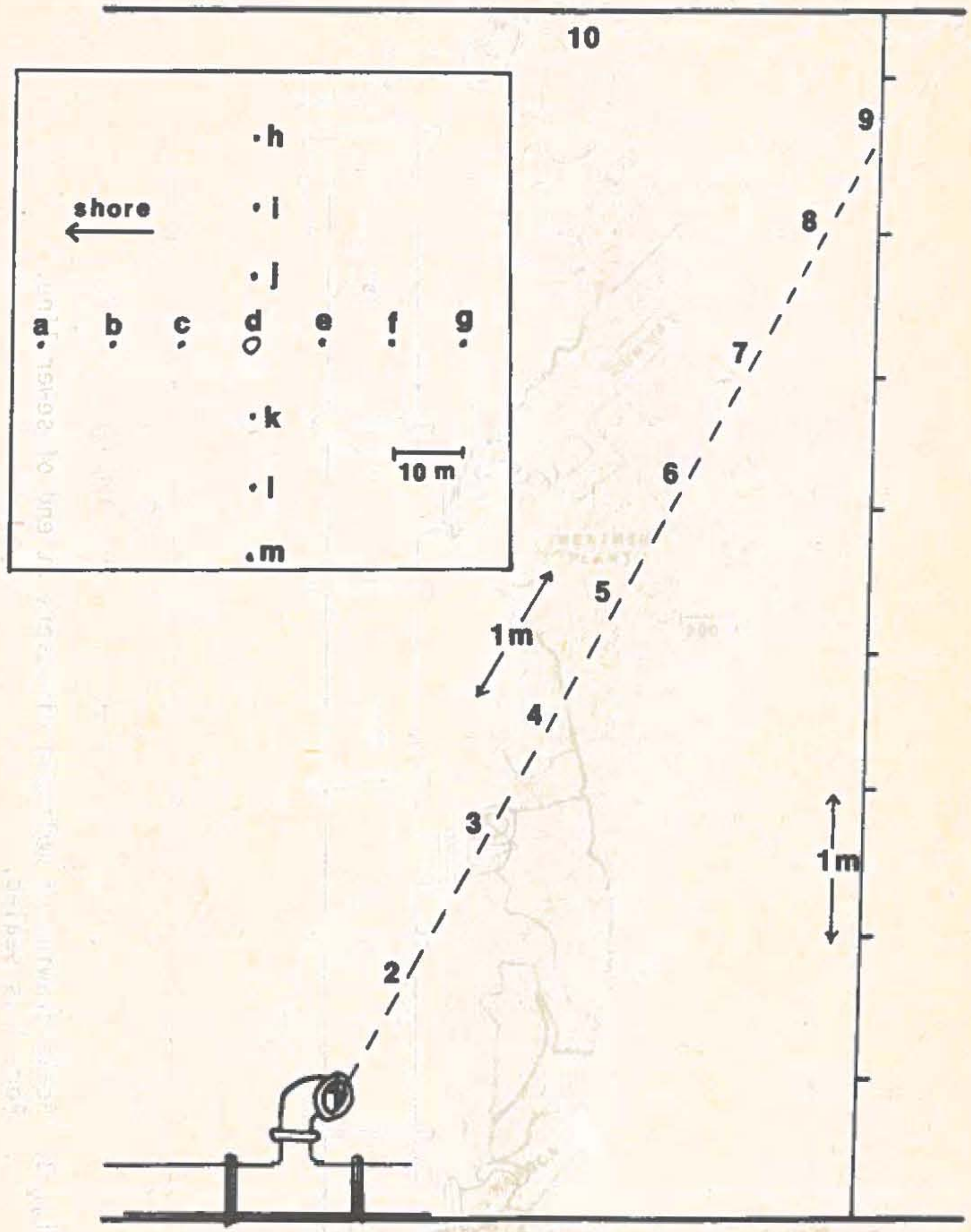


Fig. 4. Vertical sampling stations (1-10) where temperature, salinity, dissolved oxygen, coliforms, NO_3-N, and PO_4-P were sampled in relation to Port 2. Insert - Bottom sampling stations(a-m)where temperature, salinity, and dissolved oxygen samples were taken in reference to Port 4.

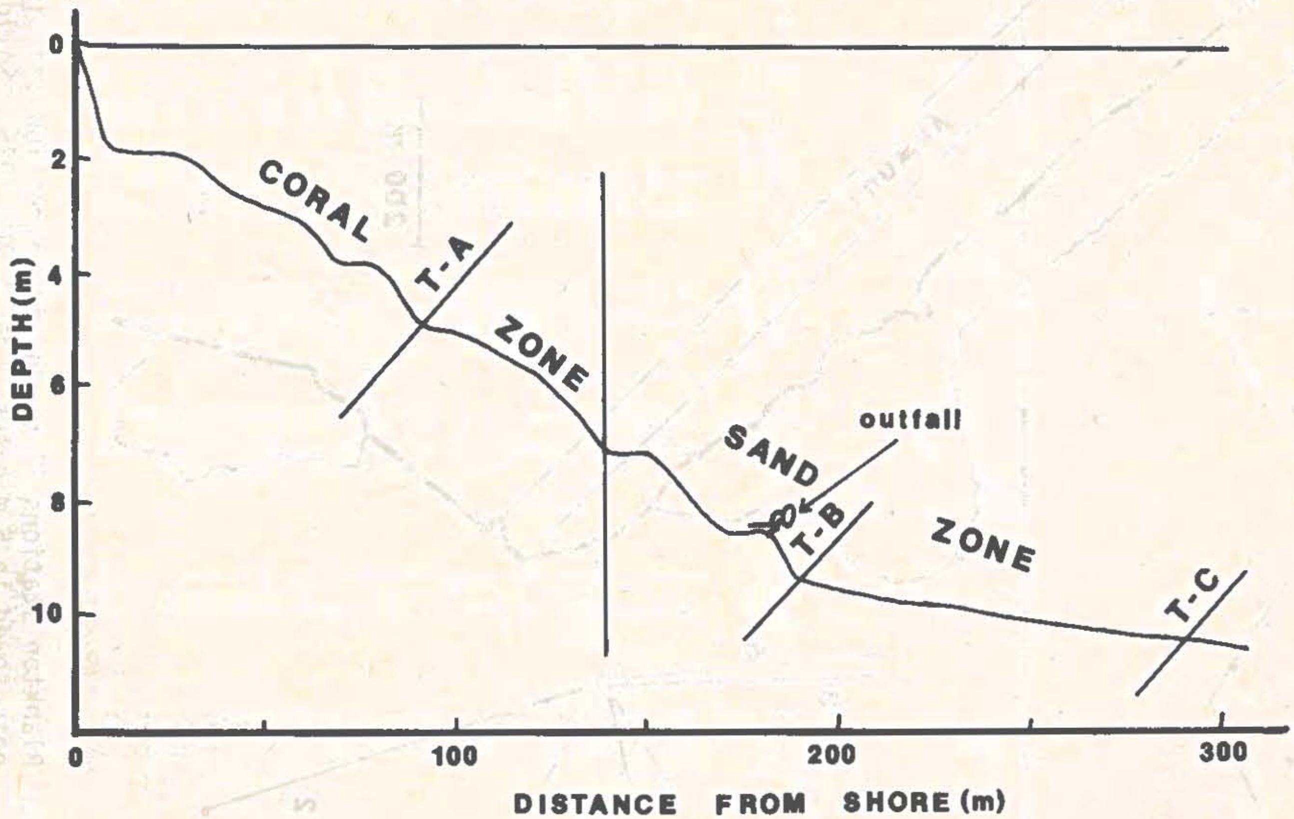


Fig. 5. Vertical profile showing route of sewer line from shore to 10-meter depth.

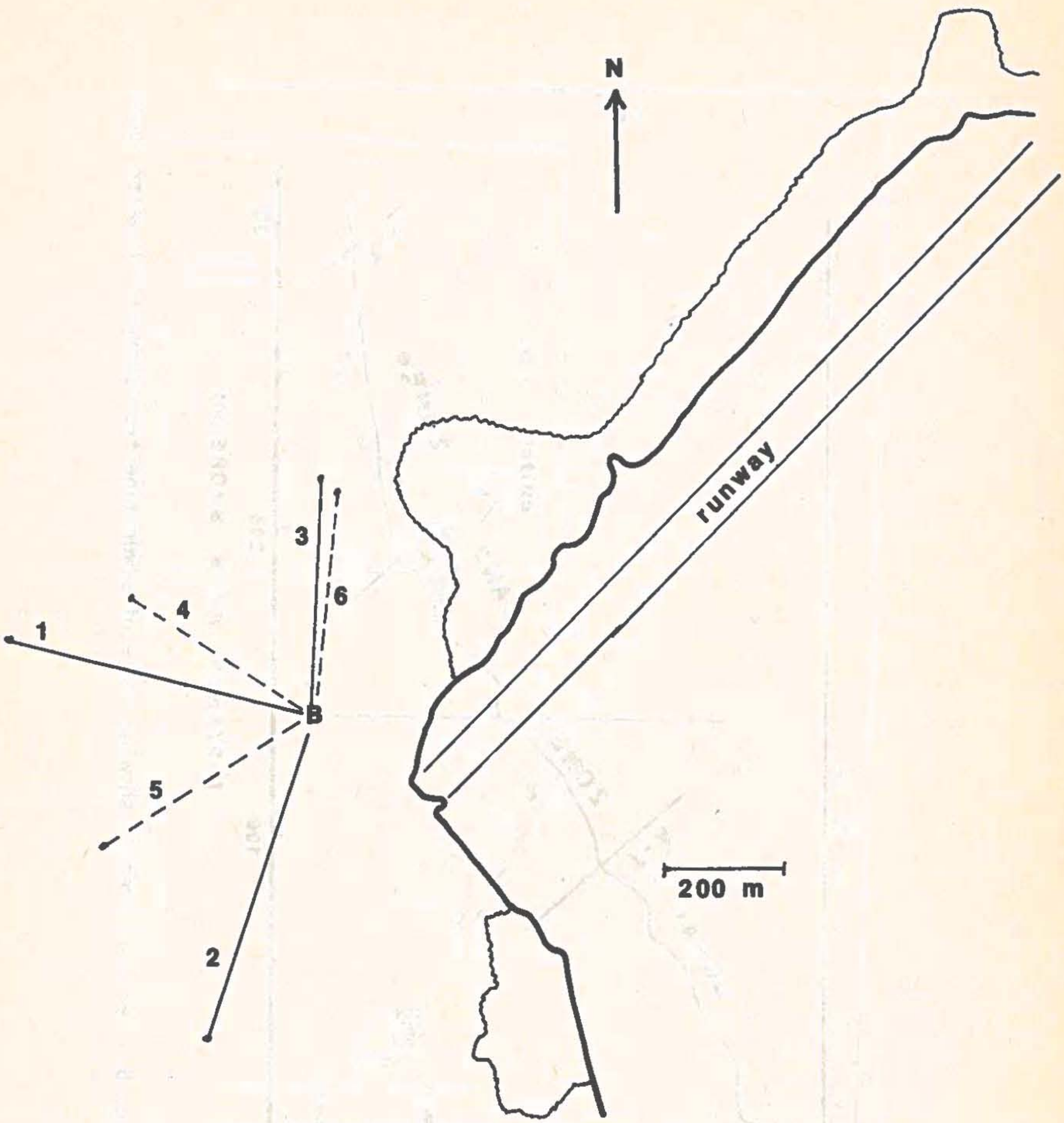
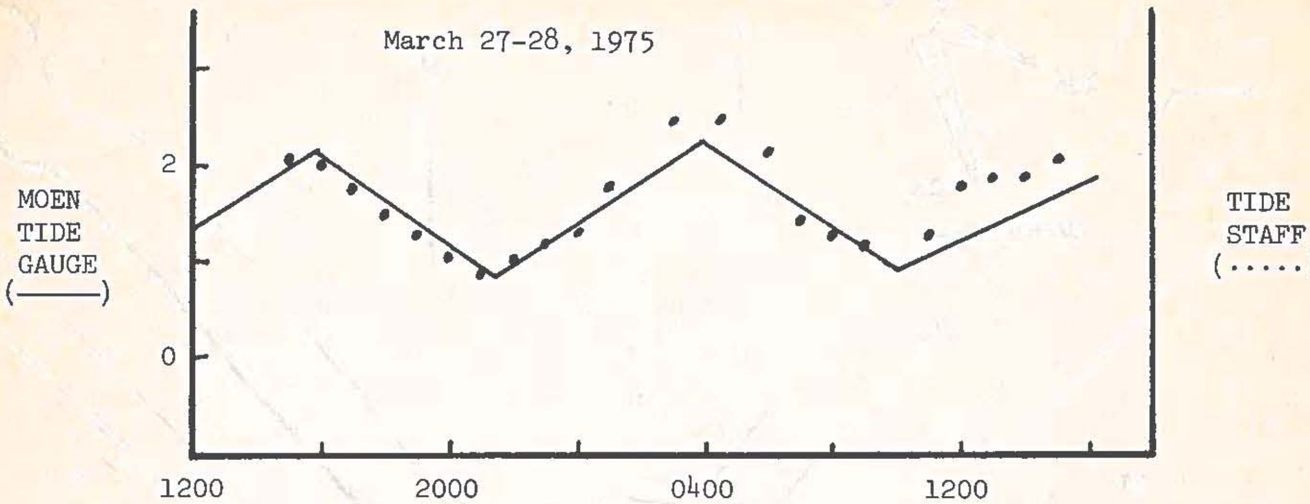


Fig. 6. Plankton stations (1-6) showing direction and distance nets towed in 5 minutes. March 30, 1975. Solid lines represent coarse net mesh and broken lines represent fine net mesh.



Drift	Start	ΔT (hr.)	1 m Dist. (NM)	1 m Speed (knots)	5 m Dist. (NM)	5 m Speed (knots)	Wind Dir.	Wind Knots
1	1400	1.00	3.6	3.6	1.9	1.9	045	18.3
2	1500	1.00	3.5	3.5	1.3	1.3	045	16.6
3	1600	1.00	2.4	2.4	0.7	0.7	045	17.6
4	1700	1.00	1.9	1.9	0.8	0.8	040	12.6
5	1800	1.00	2.0	2.0	1.5	1.5	045	16.6
6	1900	1.00	1.5	1.5	1.6	1.6	045	9.7
7	2000	1.00	1.9	1.9	1.5	1.5	060	15.5
8	2100	1.00	2.9	2.9	3.1	3.1	044	14.4
9	2200	1.00	1.6	1.6	1.1	1.1	045	1.8
10	2300	2.00	2.9	1.5	2.2	1.1	067	11.5
11	0120	3.17	3.5	1.1	3.0	0.9	065	3.6
12	0430	1.50	2.6	1.7	2.4	1.6	048	10.1
13	0600	1.00	2.5	2.5	1.6	1.6	095	13.7
14	0700	2.00	3.7	1.8	2.6	1.3	054	14.0
15	0900	2.00	2.6	1.3	1.7	0.8	065	14.4
16	1100	1.00	3.1	3.1	1.5	1.5	042	18.3
17	1200	2.00	5.1	2.6	3.1	1.6	052	18.3
18	1400	1.00	3.1	3.1	1.5	1.5	058	22.0
19	1500	1.00	2.9	2.9	1.0	1.0	045	16.6

Fig. 7. Tide profile and drift drogue data, March 27-28, 1975.

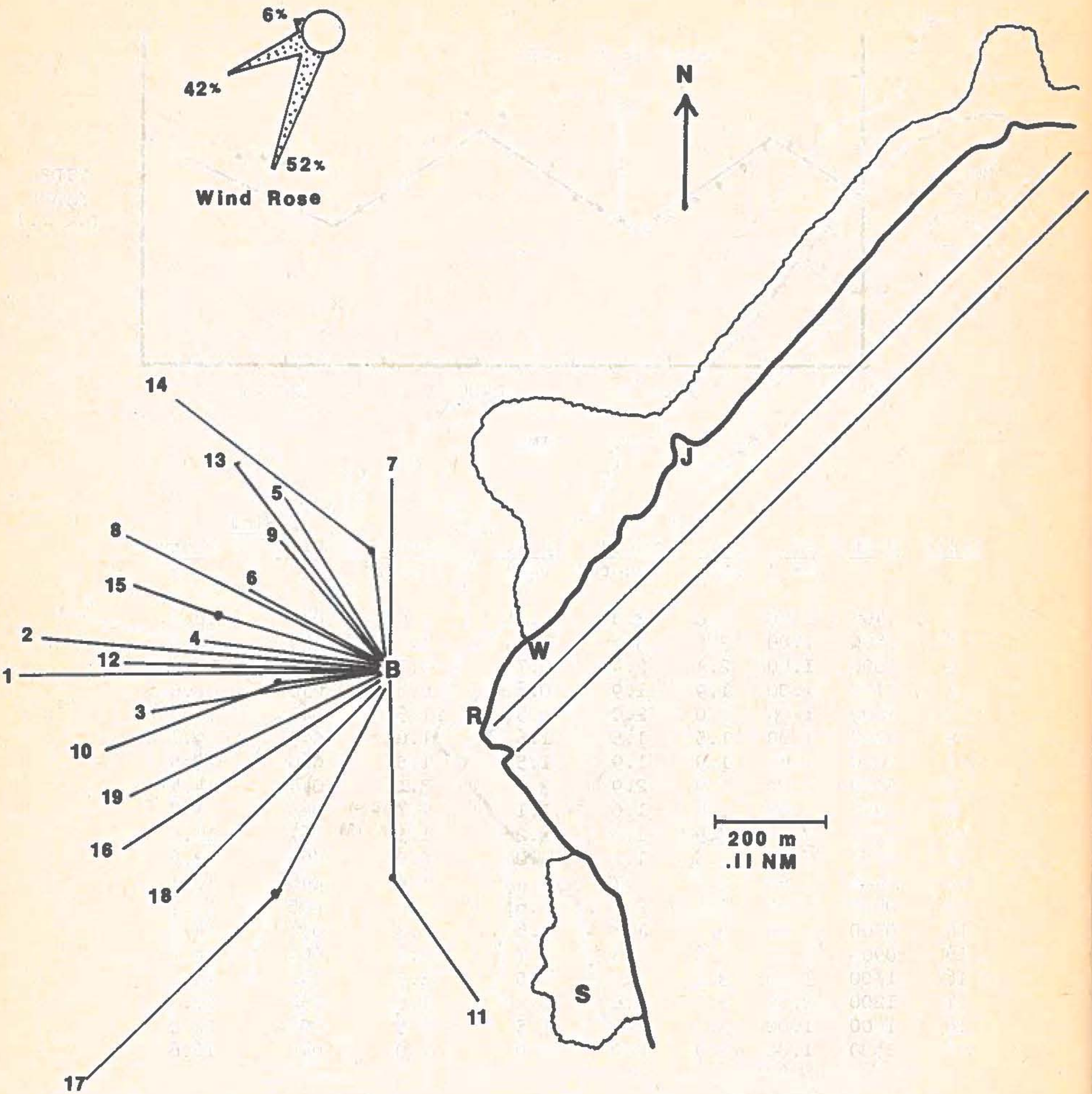


Fig. 8. 1-meter drogues, March 27-28, 1975.

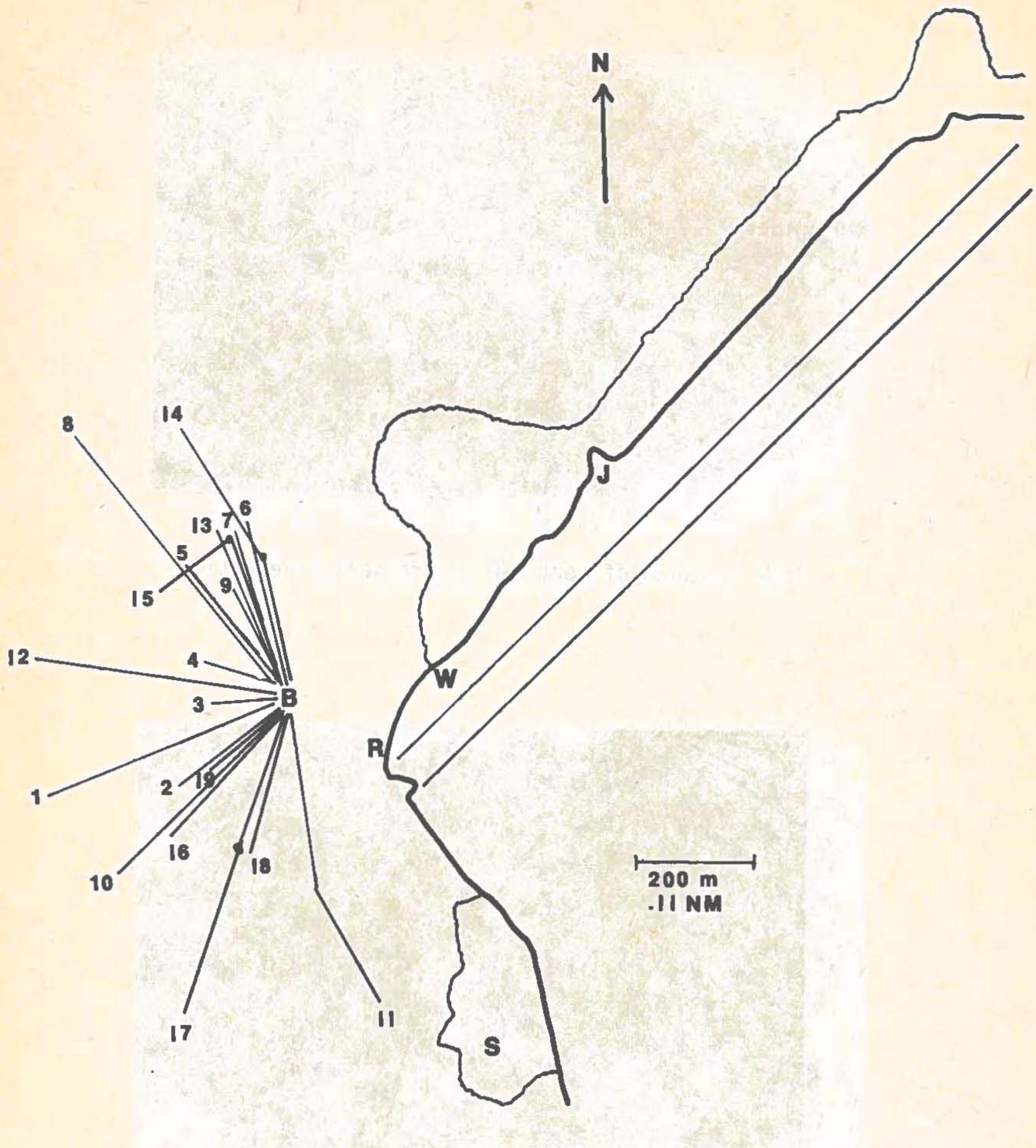


Fig. 9. 5-meter drogues, March 27-28, 1975.

PLATE I

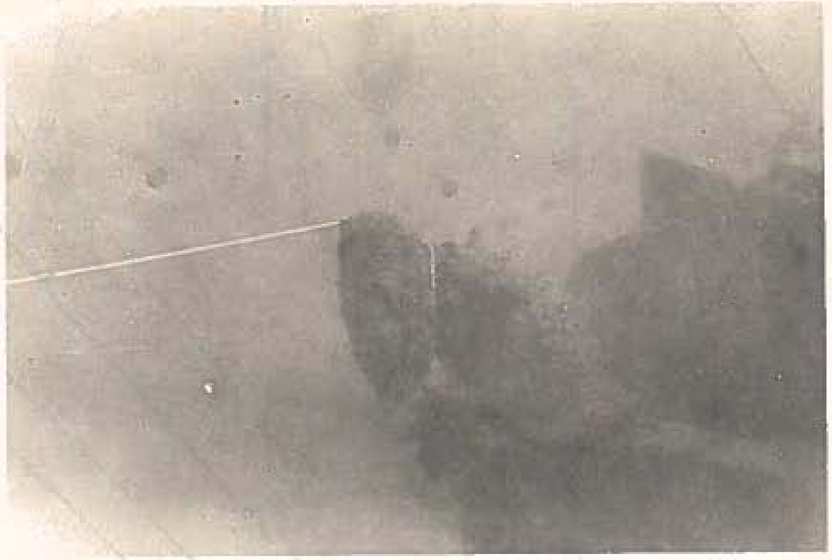


Fig. 1. View of port 4 with transect line attached.

Fig. 2. Collecting water sample along transect line.

PLATE II

Fig. 1. Live Acropora formosa on Transect A.

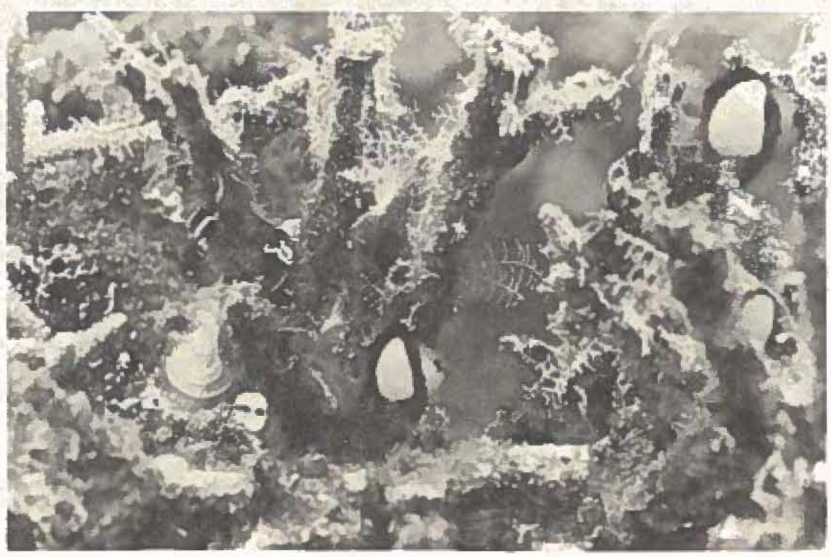


Fig. 2. Dead Acropora formosa covered with algae and hydroids on Transect A.

PLATE III

Fig. 1. Didemnum ternatanum colonies on concrete block which braces sewer line near Transect A.

Fig. 2. Tridacna squamosa near Transect A.

PLATE IV

Fig. 1. Halimeda cylindracea on sandy substratum on Transect B.

Fig. 2. Thalassia hemprichii on patch reef 500 m NE of outfall.