A CANDIDATE MARINE ENVIRONMENTAL IMPACT SURVEY FOR THE POTENTIAL DEVELOPMENT OF THE URUNO POINT REEF AREA ON GUAM, MARIANA ISLANDS

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UNIVERSITY OF GUAM MARINE LABORATORY

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By

Richard E. Dickinson and Roy T. Tsuda

A CONTRACT REPORT

Prepared for

AUSTIN, SMITH AND ASSOCIATES, INC.

As per

MEMORANDUM OF UNDERSTANDING AND AGREEMENT

SIGNED ON MARCH 14, 1975

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TABLE OF CONTENTS

INTRODUCTION

Background

The Uruno Point area is at present a beautiful, completely unspoiled and relatively inaccessible coastline (ca. 2 mi. long) located on the northwest side of Guam (Fig. 1). Within the last two years, there has been much discussion for the development of a beach resort in this area. It has also been proposed that monies in excess of $50 million will be spent in the proposed Uruno Beach Resort Development for construction of hotels, restaurants, marina, aquarium, and a botanical garden.

A letter dated August 31, 1973 from Mr. William A. McAlister (President, T. J. Davis, Inc.) to Dr. William V. Vitarelli (Vice President of Research and Special Projects, University of Guam) provides a glimpse into the proposed development.

> "It is the intent of the developers to retain and add to the natural beauty in order that the complex will present a unique, tropical, natural resort area with particular emphasis on the Chamorro culture, native flora and fauna, and the marine life in the waters adjacent to the beach area."

Although the University of Guam Marine Laboratory has been participating in discussion on the environmental aspects of the proposed Uruno Resort Development since August 31, 1973, the final affirmative step of the Marine Laboratory's participation in this study was negotiated on March 14, 1975 in a Memorandum of Understanding and Agreement between Austin, Smith, and Associates, Inc., and the University of Guam.

The fact that Marine Laboratory personnel were involved in the marine survey does not constitute an endorsement of the proposed Uruno Beach Resort Development Project by the authors, the Marine Laboratory, or the University of Guam. We felt the study was necessary and have approached all aspects in an unbiased manner. All opinions expressed herein are those of the authors.

Scope of Work

The Marine Laboratory was given a month to both complete the following studies and submit its findings and recommendations.

1. Prepare a biological survey for the development including:
   - A. Construction of three swimming pools on the reef flat.
   - B. Construction of a marina.
   - C. Construction of sewage outfall for discharge of secondary treated effluent at -60 feet.
2. Perform current studies (two 24-hour studies).

Personnel

Since time was limited, a large work force comprised of graduate students, undergraduate students, and marine technicians was mobilized to undertake the field work. Roy T. Tsuda, Ph.D., Director of the Marine Laboratory, served as Principal Investigator and Richard E. Dickinson, M.S. candidate in Biology, Marine Laboratory, served as the Student Project Leader. The actual report writing fell on these two individuals.

The students who contributed to the study were as follows: Gerald A. Heslinga, Visiting Undergraduate from Harvard University; William J. Zolan, James E. Doty, Ronald D. Strong, Daniel S. Wooster, and William J. Tobias, all M.S. candidates in Biology, University of Guam Marine Laboratory. Ronald D. Strong, in addition to participating in the field work, provided the excellent photographs used in this report.

Marine technicians Frank Cushing and Pat Beeman, Marine Laboratory, also contributed their experience in the offshore current studies.

During certain stages of the project, specialists were asked to provide names to the multitude of reef organisms found in the study area. Dr. Steven S. Amesbury, Agricultural Experiment Station, University of Guam, provided us a checklist of fishes found on the reef flat; Dr. Frank Rowe, Australian Museum, provided us a checklist and quantitative information on the holothurians (sea cucumbers) present on the reef flat; and Dr. Masashi Yamaguchi, Marine Laboratory, University of Guam, identified the scleractinian corals collected from the area.

GENERAL DESCRIPTION OF REEF ZONES

Shoreline

The beach from Achae Point to just south of Falcona Beach is roughly 10-15 m wide, extending from the dense vegetation zone down a 30° slope to the ocean. The beach is composed mostly of unconsolidated bioclastic deposits of mollusc shells, Foraminifera tests, and coral sand, similar to that described by Jones and Randall (1973) for an unconsolidated beach. The shoreline is interrupted by two small rocky headlands between Uruno Point and Falcona Beach. Remnant patches of raised limestone are also scattered along the shore.

Inner Reef Flat

The inner reef flat is roughly 10-15 m wide and consists of bioclastic beach deposits, mostly *Acropora* rubble, mollusc shells, Foraminifera, and coral sand. The moat system is shallow, between 1-1.5 m deep and poorly developed. There are numerous small freshwater rivulets, especially noticeable at low tide, running from the shore and rocky headlands into the moat and there is an apparent layer of freshwater on the surface in many places.

Outer Reef Flat

The outer reef flat varies from 50 m to 160 m wide and has numerous scattered patches of exposed limestone. In deeper areas the substrate is covered by the staghorn coral, *Acropora hebes*. This coral forms dense, flat-topped thickets which grow upward to the low tide line and comprise the principal structure on the outer reef flat. Additionally, massive *Porites* microatolls can be found in the deeper pools and are scattered along the reef flat. There are large deposits of broken *Acropora* branches and other coral debris creating small patches of sand-rubble substrate.

Randall and Holloman (1974) provides a general description of the reef flat and offshore zones.

> "A narrow cuesta-type of algal ridge forms an elevated hummocky region at the reef margin. This ridge is solid and massive and is cut by short shallow surge channels. There is no room-and-pillar development at the reef margin and reef front zones comparable to that found on the southeast side of Ritidian Channel. The reef front is cut by a groove-and-spur system along most of the section, although at some locations considerable development of coral-algal knobs and bosses is

taking place on the upper surfaces of spurs. The reef front appears to be somewhat in equilibrium as far as outward growth and erosion are concerned. The 55-foot submarine terrace is present along most of the section, but it is narrow and irregular. At some places there seem to be relic features such as grooves and channels at the seaward margin of the terrace which resemble a sunken reef-margin system.

The outer part of the reef front, submarine terrace, and seaward slope zone was heavily infested by Acanthaster planci in 1969 along this entire sector. Most of the reef-building corals were killed in all three fringing reef zones as a result of predation by these starfish. Wave and surf action prevented intensive starfish damage in the reef margin and inner part of the reef front zones. Rich coral growth is more or less restricted to this narrow wave-assaulted region at the present time. Recent surveys show that recolonization of the dead coralla surface by calcareous red algae in the reef front zone has maintained the structural integrity of the colonies. New coral growth from planula settlement and small patches which survived the initial starfish predation was also evident in the affected zones during this survey."

METHODOLOGY

Water Circulation Studies

In an effort to obtain a general idea of the water movements over the reef flat and the current patterns off-shore, dye and drogue studies were conducted in the study area. Fluorescein dye was released over the inner and outer reef flat zones along each of the four reef flat transects (Fig. 2) during periods of high tide (April 5) and low tide (April 10). The water was flooding from 1.5 to 1.0 feet during the high tide study and ebbing from about .9 to .5 feet during the low tide study. The velocity of the water movement was obtained by measuring the dye patch movement per unit time (m/sec.) and the direction relative to shore was recorded. The speed and direction of the wind during each drop was also recorded.

The original proposal for the off-shore current studies was to carry out 24-hour drogue studies at two sites - one station north of Uruno Point and the other station south of the Point. However, we were forced to resort to an alternative plan of only conducting studies during the daylight hours on two days, April 11 (0830-1700) and 12 (0930-1700). The uncompleted status of our negotiations (March 7-8) with the contractors, heavy seas (April 4-5), and the lack of a larger boat for overnight studies (April 11-12) forced us to carry out the alternative plan.

Thus, on April 11-12, pairs of drogues (1 m and 5 m) were cast at each of two stations both marked by buoys. Station 1 was located north of Uruno Point about 130 m from the reef margin, while Station 2 was located south of the Point about 170 m from the reef margin. Both stations were located in water over 60 feet deep. The direction and the distance traveled by the drogues were recorded each hour. In most cases, the pair of drogues were left to drift for two hours and then recast at their respective stations. Wind speed and direction were also recorded.

Biological Studies

Transects (Fig. 2) were established along the reef flat and off-shore to facilitate quantitative study of corals, algae, and holothurians and to provide a metered line for bottom profiles (Figs. 3-4).

The reef flat transects (1-4) were located perpendicular to shore and extended 70-80 m toward the reef margin. The selection of the transect sites was based on a desire to assess the reef flat at potential marine and swimming areas; therefore, obstructed zones and rocky headlands were deliberately avoided.

The offshore transects, 5 & 6, were located perpendicular to the 60 foot terrace edge and extending 100 m toward the margin. The sites were chosen to provide data from both the more exposed windward reef north of Uruno Point and the more protected reef south of the point.

In addition the transect was used as a guide for the bottom profiles (Fig. 5).

Algae

The macroalgal community was quantified by a modified point method (Tsuda, 1972) utilizing a 25 cm x 25 cm quadrat randomly tossed 10 times in the inner reef flat, the outer reef flat and the reef margin. These tosses were made along Transects 1-4. The reef margin, however, was only sampled on Transects 1 and 2. Twenty-two tosses were made along the reef terrace, two per every 10 m distance.

The quadrat frame was divided into a grid of 25 squares, each 5 cm x 5 cm, providing 16 interior "points" where the grid lines 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, dead coral, was recorded. From this data, relative abundance and frequency were calculated for each species in their respective zones and transects. The percent algal cover in relationship to the amount of sand, live coral and dead coral, was calculated by considering every item recorded for all "points."

$$\text{Relative Abundance} = \frac{\text{No. of Points per Species}}{\text{No. of Points all Species}} \times 100$$

$$\text{Frequency} = \frac{\text{No. of Tosses a Particular Species Occurred}}{\text{Total No. of Tosses}} \times 100$$

All algal species seen in the various zones, i.e., inner reef flat, outer reef flat, reef margin, reef front, reef terrace and reef slope, were recorded.

Corals

Ten random tosses utilizing a 50 cm x 50 cm quadrat were made in the inner reef flat and the outer reef flat on all four reef flat transects. The modified point methods, similar to that used in the algal study, was used to obtain relative abundance, frequency, and percent coverage. This method differs from that used for quantifying the reef terrace corals because corals are more widely distributed on the reef flat and the point quarter method would not be practical.

The point quarter method (Cottam et al., 1953) was used in quantifying the corals on Transects 5 & 6 on the reef terrace. A series of points, 10 m apart, were selected from the transect line and 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 or generic name, diameter, and the distance from the center of the corallum to the transect point was recorded. Total coral density, frequency, and relative density were then determined from the above data.

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

$$\text{Relative Density} = \frac{\text{Individuals of a Species}}{\text{Total Individuals of all Species}} \times 100$$

$$\text{Frequency} = \frac{\text{Number of Points at which Species Occurs}}{\text{Total Number of Points Sampled}} \times 100$$

In addition, a general collection of corals was made from the zones in the study area.

Fishes

Fishes were surveyed at three areas along the reef flat (Transects 1, 2, and 4). Two environmental zones, the inner reef flat with a substrate made up of sand with scattered limestone boulders and the outer reef flat with a substrate of limestone pavement and Acropora beds, were separately inventoried. Surveys were made by snorkeling in a meandering pattern for about 15 minutes through the zone under investigation.

RESULTS AND DISCUSSION

Water Circulation Studies

Reef Flat Water Movement

The dye studies carried out during high tide showed a northeasterly movement, parallel to shore (Figs. 6-9) at all transects. The inner reef flat zones showed stronger movement at Transects 1, 2, and 4. Water movement over the inner and outer reef flats at Transect 3 was relatively similar, with movement over the outer reef flat slightly faster. The dye at Transect 4 moved northeasterly and then exited at a rocky headland approximately 200 m northeast of the drop site. This outcrop diverts the water and is hazardous, especially during high tide, when volume transport is greatest.

The dye studies on April 5 were conducted during high surf (5-7 feet) causing high turbulence which, in turn, increased the rate of water movement. In general, the dye studies indicate strong along shore movement, especially during high tides and heavy surf, creating hazardous swimming conditions as close as 30 feet from shore.

The low tide dye studies (Figs. 10-13) showed considerably less movement than during high tides. There was no movement of water at Transect 1 and the dye was visible for over one hour. With the exception of the dye patch dropped at Transect 2, water moved in a northeasterly direction parallel to shore. At Transect 2, the water moved in a southerly direction towards shore. The slow movement is primarily caused by the minimal drainage during low tides when extensive sections of the reef are exposed.

Offshore Currents

Drogue studies were conducted 1, 3, and 5 miles north of Ritidian Point by the Navy Oceanographic Office (Huddell et al., 1974) on February 24, 1971 and August 26, 1971. They state that "During February surface currents appeared to be relatively weaker; no movement at all was observed 5 miles (8 km) north of the point. Currents within a mile of Ritidian Point showed a more easterly component during both winter and summer than the currents further from shore. Surface currents north of Ritidian Point flowed against the prevailing winds and opposite to the North Equatorial Current as shown in both the current meter data and drogue tracking."

Our offshore current studied (Figs. 14 and 15) indicate a general southwesterly flow except for the morning drogues which moved north from both stations on the two days. Most drogues in our study were affected by the wind. The more protected location of Station 2 (south of Uruno Point) probably accounts for the slower movement of these drogues as opposed to the northern drogues which moved in excess of 1 knot in one instance. None of the drogues ran aground on the reef, however, those from Station 1 traveled closely parallel to the reef margin.

The prevalent southwesterly trend follows the theory (Emery, 1962) that the North Equatorial Current splits northeast of Guam and continues south along the eastern and western sides to converge southwest of Guam. However, the Navy's study at Ritidian seems to contradict this.

In trying to correlate the peculiar northerly drifts with the tidal cycle (since the drogues were moving against the prevailing wind), it appears that this northerly current exists approximately four hours out-of-phase with the tidal cycle. Our study included the hours when the tide was at its lowest point (Fig. 16). Further current studies should be made to include the hours when the tide is at its peak to see if a northerly current develops.

Water Movement At 50 Feet Depth

Dye was released in 50 feet of water at both Stations 5 and 6. The dye patch on Transect 5 moved seaward and diffused down the reef slope, while the dye patch on Transect 6 moved inshore toward the reef margin.

Biological Studies

Table 1 lists the 56 species of marine benthic algae, thus far, collected or observed in the six reef zones at the Uruno Point study area. This listing must be considered preliminary since collections and observations were carried out on only four days. Table 2 presents the relative abundance, frequency, and algal cover of the predominant algae in four - inner reef flat, outer reef flat, reef margin, and reef terrace-of the six reef zones.

The dominant algae on the inner reef flat are Cladophoropsis membranacea, Jania capillacea, Gelidiella acerosa, and Jania capillacea; the dominant algae on the outer reef flat are Microdictvon okamurai, Boodlea composita, and Polysiphonia sp. Turbinaria ornata is the obvious algae on the reef margin which is comprised predominantly of Porolithon onkodes. In those areas of the reef which possesses a distinctly raised reef margin, a golden-colored species of Gelidium is dominant.

The reef front is dominated by the larger algae, e.g., Halymenia durvillaei, Galaxaura oblongata, and Galaxaura marginata. Tolypiocladia glomerulata is the dominant alga on the reef terrace along both Transects 5 and 6. Halimeda discoidea is distributed sparsely on the reef slope which is covered with coralline algae.

When the benthic algae are considered as a whole, the turf community is by far the most dominant and seem to be in ample abundance to serve as food for the herbivorous fish population on the reef terrace.

Corals

Table 3 lists the species of corals collected or observed in three reef zones at the Uruno Point study area. The list is not complete since only three of the six reef zones were sampled. Table 4 shows the relative abundance, frequency and percent coverage for the inner and outer reef flat corals and Table 5 presents the relative density, frequency, and total density for the reef terrace corals.

Small branches of Acropora hebes and a few small Porites colonies comprise most of the living coral in the inner reef flat. This zone is mostly rubble and sand. The dominant coral on the outer reef flat is Acropora hebes where colonies form extensive thickets. The other more common species are Goniastrea retiformis, Pocillopora damicornis, and Psammocora contigua. The flat elevated limestone areas were devoid of coral and are mostly a sand-algal cover.

The reef terrace is sparsely populated with live coral. The predominant coral is an encrusting Montipora conicula. Another encrusting form, Montipora tuberculosa is also common. These two corals form broad encrusting patches on the substrata and are vividly colored blue and red in their natural state. Other common corals are Favia pallida, Platygyra rustica, Porites lichen, and Pocillopora sp.

The reef terrace experienced heavy Acanthaster planci predation (Chesher 1969, Tsuda, 1971) and numerous dead coral colonies are evident.

Fishes

The reef flat area of Uruno Point contains a varied assemblage of typical tropical reef fish species (Table 6). Tourist-oriented development in this area should take advantage of this very accessible "natural aquarium" by preserving it for the enjoyment of snorkelers and divers. The opportunity to observe such colorful fishes as the butterflyfishes (Chaetodontidae), damselfishes (Pomacentridae), surgeonfishes (Acanthuridae) and triggerfishes (Rhinecanthus rectangularis, the well-known "humuhumu-nukunuku-a-pua'a" of Hawaii) in their natural setting could develop into a considerable tourist attraction.

Holothurians

Table 7 includes a list of the holothurians found in the study area. Holothuria (Halodeima) atra is the dominant holothurian of the inner reef flat. It is typically found on, but not restricted to, sandy areas. The second most visually dominant holothurian is Stichopus chloronotus, which seems to be more abundant here than on other reef flats. S. chloronotus is restricted to solid substrates and is generally more abundant in the outer reef flat.

The relatively inconspicuous Holothuria (Platyperona) difficilis was found associated with thickets of dead Acropora hebes in the outer reef flat of Transect 3. In these areas it is the most numerous holothurian - reaching estimated concentrations of over 75 individuals per 10 m^2. Precise counts were not possible at the time of the survey, however, these holothurians are quite interesting in that their distribution seemed very distinct (Figs. 17 and 18). This may indicate narrow habitat requirements for this organism.

Bohadschia bivittata and B. argus are present in moderate numbers in the sandy areas. These species are notable for their irritability and habit of releasing sticky cuvierian organs at the slightest disturbance. This has been known to cause annoyance to swimmers and waders. Actinopyga echinites and the large Holothuria (Microthele) nobilis are also present in moderate numbers.

Finally, one specimen each of Holothuria (Semperothuria) cinerascens and Holothuria (Thymiosycia) hilla were collected. Notably, no synaptids were seen. These are common on reefs elsewhere on Guam.

Other Macroinvertebrates

A checklist of the other common macroinvertebrates can be found in Table 7.

CONCLUSIONS

The reef flat of the study area does not have an extensive moat system nor did we notice any exceptionally deep areas. The deepest water is within 35 meters of shore and averages 4-5 feet at MHHW. Dye studies indicate strong reef flat currents during high tides and especially when influenced by high surf. At such times, swimming would be hazardous.

The outer reef flat is not particularly rich in coral growth and snorkeling would be possible only at high tide when conditions are hazardous. Additionally, no broad sandy areas were noted and the substrate has much coral debris, thus requiring footwear for snorkelers or reef walking.

There are no natural coves in the study area and a marina is not feasible without extensive dredging of the reef flat and construction of a retaining wall for added protection.

The offshore current studies showed a consistent west southwest drift with the notable exception of a northerly drift for morning drogues. Drogues from Station 1 moved faster probably due to their more exposed location and were greatly influenced by the wind.

The water directly off Uruno Point is considerably rougher than north toward Achae Point or south to Falcona Beach. We believe currents sweeping down from the north are forced offshore at Uruno Point.

The reef structure between areas north and south of Uruno Point are markedly different. The northern (Transect 5) reef terrace is considerably narrower than that of the south and the reef front is characterized mostly by a groove and spur development. The southern reef terrace (Transect 6) is broad and has numerous wide surge channels and is pocketed with holes and steep pinnacles providing beautiful SCUBA diving. Underwater trails would be ideal here.

Dye patches released at 50 foot depth on the terrace of both stations also differed. Station 1 dye patch moved seaward and diffused down the reef slope while dye from Station 2 moved directly shoreward.

The Uruno Point study area includes the most extensive stretch of undisturbed beach on Guam. Because the area has been inaccessible in the past it retains a virtually undisturbed environment and any alteration must be carefully evaluated to ensure minimal changes to its natural beauty.

RECOMMENDATIONS

A candidate environmental impact survey of the marine environment conducted within a 30-day period is obviously piecemeal since it does not consider the seasonal variation of the organisms and the variable current patterns during a yearly cycle. Thus, the following recommendations which are the results of discussions among project participants must be accepted with caution.

1. If swimming holes must be dredged, they should be located in the deeper moat areas of the inner reef flat within 30 to 40 m from shore. Although the dye studies on the inner reef of the southern side of Uruno Point show greater water movement, these swimming holes should be situated on this more protected side. When the exact locations of the swimming holes are pinpointed, further dye studies should be carried out at each site.

2. It is not feasible to construct a marina on the reef flat. The construction of an inland marina connected by a channel through the reef flat is the better alternative. This again should be located south of Uruno Point as tentatively planned.

3. Based on the limited offshore current studies, the most suitable location to release the sewage effluent seems to be directly off Uruno Point. We further recommend that the effluent be released through multiple diffusers on the reef slope which lies in about 60 feet of water. Engineering studies will no doubt cite this depth as too excessive if the sewerage is to be secondarily treated. However, a safety measure must be included in case the treatment plant malfunctions, thus, bypassing raw sewage into the nearshore waters. Further drogue studies must be carried out over the reef slope directly off Uruno Point at different times of year.

4. Rigorous control over exploitation of reef resources, e.g., fishes, lobsters, and shells, must be established to preserve the natural environment since easy access to this once relatively inaccessible area will be provided if this Resort Development becomes a reality. These controls should not be enforced on those traditional fishermen who have always fished in this area.

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Table 1. Checklist of marine algae recorded from the Uruno Point study area.

Species	Inner Reef Flat	Outer Reef Flat	Reef Margin	Reef Front	Reef Terrace	Reef Slope
CYANOPHYTA (blue-green algae) - 3 spp.						
Microcoleus lyngbyaceus (Kutz.) Crouan		X		X	X	X
Schizothrix calcicola (Ag.) Gomont	X	X	X	X	X	X
Schizothrix mexicana Gomont		X	X		X	
CHLOROPHYTA (green algae) - 20 spp.						
Boergesenia forbesii (Harv.) Feldmann	X	X				
Boodlea composita (Harv.) Brand	X	X				
Caulerpa antoensis Yamada	X	X		X	X	
Caulerpa racemosa (Forskal) J. Ag.		X		X		
Caulerpa serrulata (Forskal) J. Ag.	X	X	X			
Chlorodesmis fastigiata (C. Ag.) Ducker		X	X	X		
Cladophoropsis membranacea (Ag.) Boerg.	X	X				
Dictyosphaeria cavernosa (Forskal) Boerg.	X	X		X	X	
Dictyosphaeria versluysii W. v. Bosse	X				X	
Enteromorpha clathrata (Roth) Ag.	X					
Halimeda copiosa Goreau & Graham						X
Halimeda discoidea Decaisne			X	X	X	X
Halimeda incrassata (Ellis) Lamx.						X
Halimeda opuntia (L.) Lamx.	X	X	X		X	X
Microdictyon okamurai Setch.	X	X	X			
Neomeris annulata Dickie		X		X	X	
Neomeris vanbosseae Howe	X	X		X	X	
Valonia aegagropila C. Ag.	X	X				
Valonia ventricosa J. Ag.		X		X	X	
Valoniopsis pachynema (Martens) Boerg.		X				
PHAEOPHYTA (brown algae) - 10 spp.						
Dictyota bartayresii Lamx.		X				
Dictyota friabilis Setch.				X	X	
Feldmannia indica (Sonder) Womers. & Bailey		X			X	

Table 1. (continued)

Species	Inner Reef Flat	Outer Reef Flat	Reef Margin	Reef Front	Reef Terrace	Reef Slope
Lobophora variegata (Lamx.) Womers.	X	X	X	X	X	X
Padina jonesii Tsuda				X	X	X
Padina minor Yamada	X	X				
Ralfsia pangoensis Setch.	X					
Sargassum cristaefolium C. Ag.		X	X			
Sphacelaria tribuloides Meneghini		X		X	X	
Turbinaria ornata (Turner) J. Ag.	X	X	X	X		
RHODOPHYTA (red algae) - 23 spp.						
Actinotrichia fragilis (Forskal) Boerg.				X		
Amphiroa fragilissima (L.) Lamx.	X			X	X	
Champia parvula (C. Ag.) Harvey		X				
Chondria sp.					X	
Dasyphila plumarioides Yendo				X		
Desmia hornemanni Lyngbye				X		
Galaxaura filamentosa Chou		X				
Galaxaura marginata Lamx.	X	X		X		
Galaxaura oblongata (E. & S.) Lamx.		X		X		
Gelidiella acerosa (Forskal) Feldm. & Hamel	X	X	X			
Gelidiopsis intricata (Ag.) Vickers		X	X			
Gelidium pusillum (Stackh.) Le Jolis	X	X			X	X
Gelidium sp.			X			
Halymenia durvillaei Bory				X		
Hypnea cervicornis J. Ag.	X	X		X	X	
Jania capillacea Harvey	X	X	X	X	X	
Leveillea jungermannioides Harvey		X	X			
Liagora sp.				X		
Polysiphonia sp.	X	X	X	X	X	

Table 1. (continued)

Species	Inner Reef Flat	Outer Reef Flat	Reef Margin	Reef Front	Reef Terrace	Reef Slope
Porolithon onkodes Foslie	X	X	X	X	X	X
Rhodymenia sp.				X		
Trichogloea sp.		X				
Tolypiocladia glomerulata (Ag.) Schmitz & Hauptfleisch				X	X	
Total Number of Species Per Zone	25	38	17	29	24	10

Table 2. Relative abundance (RA) and frequency (F) of the benthic algae quantified on the inner reef flat, outer reef flat, reef margin, and reef terrace based on six transects at the Uruno Point study area. See Fig. 2 for locations of Transects 1 - 6.

Species	Transects 1		2		3		4	
	RA	F	RA	F	RA	F	RA	F
INNER REEF FLAT								
CYANOPHYTA								
Schizothrix calcicola					5	20		
CHLOROPHYTA								
Boergesenia forbesii							23	70
Caulerpa antoensis					19	40	14	30
Caulerpa serrulata	10	30	5	20	5	10		
Cladophoropsis membranacea	20	20					5	20
Enteromorpha clathrata	6	10						
Halimeda opuntia	12	30	4	20			7	20
Microdictyon okamurai	4	20						
Neomeris vanbosseae					1	10		
Valonia aegagropila	8	40	1	10				
PHAEOPHYTA								
Lobophora variegata	4	20	16	60	1	10		
Padina minor							1	10
Ralfsia pangoensis							1	10
Turbinaria ornata	4	30			1	10		
RHODOPHYTA								
Galaxaura oblongata					1	10	10	30
Gelidiella acerosa			4	20	65	80		
Gelidium pusillum							3	20
Jania capillacea	14	50	61	60			30	60
Polysiphonia sp.	6	10	4	20	2	10		
Porolithon onkodes	12	60	6	40			6	30
Algal Cover (%)	48		53		63		80	

Table 2. (continued)

Species	Transects 1 RA	1 F	2 RA	2 F	3 RA	3 F	4 RA	4 F
				OUTER REEF FLAT				
CYANOPHYTA								
Schizothrix calcicola	1	10			9	30		
CHLOROPHYTA								
Boergesenia forbesii					1	10		
Boodlea composita					14	30		
Caulerpa antoensis	1	10			5	10	24	40
Caulerpa serrulata	7	30	6	20				
Cladophoropsis membranacea	8	40	3	20			23	20
Halimeda opuntia	6	40	2	20	12	40	4	10
Microdictyon okamurai	56	100	41				18	40
Neomeris vanbosseae					2	20		
Valonia aegagropila	4	30	3	40				
PHAEOPHYTA								
Padina minor							2	20
Turbinaria ornata	2	70	2	20				
RHODOPHYTA								
Gelidiella acerosa			22	60	20	30	9	20
Gelidium pusillum	2	20					6	10
Jania capillacea			19	50			10	20
Polysiphonia sp.					37	50		
Porolithon onkodes	3	30	2	30			4	30
Algal Cover (%)	63		81		69		73	

Table 2. (continued)

Species	Transects 1 RA	1 F	2 RA	2 F
	REEF MARGIN			
CYANOPHYTA				
Schizothrix calcicola	9	10		
Schizothrix mexicana			1	10
CHLOROPHYTA				
Caulerpa serrulata	3	20		
Halimeda opuntia			5	20
Microdictyon okamurai			19	60
PHAEOPHYTA				
Lobophora variegata			1	10
Turbinaria ornata	65	80	13	60
RHODOPHYTA				
Gelidiella acerosa			3	10
Gelidiopsis intricata			7	20
Jania capillacea	18	40	15	20
Polysiphonia sp.			33	40
Porolithon onkodes	5	30	2	20
Algal Cover (%)	71		61	

Table 2. (continued)

Species	Transects 5 RA	5 F	6 RA	6 F
REEF TERRACE				
CYANOPHYTA				
Microcoleus lyngbyaceus	6	32	12	41
Schizothrix calcicola	2	4	2	4
CHLOROPHYTA				
Caulerpa antoensis			2	9
Caulerpa racemosa			<1	4
Dictyosphaeria cavernosa	2	18	<1	4
Dictyosphaeria versluysii	1	9	2	4
Halimeda discoidea			1	9
Neomeris annulata			<1	4
Neomeris vanbosseae			1	4
PHAEOPHYTA				
Dictyota friabilis	5	36	5	23
Feldmannia indica			<1	4
Lobophora variegata	16	54	6	27
Padina jonesii	1	9	1	9
Sphacelaria tribuloides	6	18		
RHODOPHYTA				
Amphiroa fragilissima			<1	4
Chondria sp.	6	32		
Galaxaura marginata			2	14
Gelidium pusillum	6	18	11	23
Jania capillacea	6	36	2	9
Polysiphonia sp.	4	18	22	41
Porolithon onkodes	13	45		
Tolypiocladia glomerulata	26	50	26	45
"coralline"			4	4
Algal Cover (%)	83		72	

Table 3. Checklist of corals recorded from the Uruno Point study area.

Species	Inner Reef Flat	Outer Reef Flat	Reef Terrace
Acanthastrea echinata (Dana)			X
Acropora abrotenoides (Lamarck)			X
A. aspera (Dana)		X	
A. hebes (Dana)	X	X	
A. humilus (Dana)			X
A. tubicinaria (Dana)		X	
Astreopora listeri (Bernard)			X
A. myriopthalma (Lamarck)			X
Coscinarea columna (Dana)			X
Cyphastrea chalcidicum (Forskaal)			X
C. serailia (Forskaal)			X
Favia pallida (Dana)			X
F. stelligera (Dana)			X
Favites virens (Dana)		X	
Fungia fungites var. incisa Doederlein			X
Goniastrea pectinata (Lamarck)			X
G. retiformis (Lamarck)	X	X	X
Heliopora coerulea (Pallas)			X
Leptastrea purpurea (Dana)			X
Leptoria phrygea Ellis & Solander			X
L. sp.		X	
Millepora dichotoma Forskaal		X	
M. exaesa Forskaal			X
M. platyphylla Hemprich & Ehrenberg			X
Montipora conicula Wells			X
M. floweri Wells			X
M. tuberculosa (Lamarck)			X
M. verrucosa (Lamarck)			X
Oulophyllia crispa (Lamarck)			X
Pavona clavus (Dana)			X
P. varians (Verril)		X	
Platygyra rustica (Dana)			X
Pocillopora damicornis (Linnaeus)	X	X	
P. verrucosa (Ellis & Solander)			X
P. sp.			X
Porites lichen (Dana)			X
P. lutea Milne Edwards & Haime	X	X	X
Psammocora contigua (Esper)	X	X	
Stylophora mordax (Dana)			X

Table 4. Relative abundance (RA), frequency (F) and percent coverage for the reef flat corals quantified on the inner and outer reef flat based on four transects at the Uruno Point study area. See Fig. 2 for locations of Transects 1-4.

SPECIES	TRANSECTS 1 RA	1 F	2 RA	2 F	3 RA	3 F	4 RA	4 F
				INNER REEF FLAT				
Acropora hebes			40	10	100	20	50	10
Goniastrea retiformis	8	10	2	10				
Pocillopora damicornis			20	10				
Porites lutea	54	20					50	10
Psammorora contigua	38	10	20	10				
Per Cent Coverage (%)	18		12		13		13	
				OUTER REEF FLAT				
Acropora aspera					4	10		
A. hebes	79	70	52	50	78	70	28	20
A. tubicinaria							4	10
Favites virens							9	10
Goniastrea retiformis	13	20	40	40			18	10
Leptoria sp.	3	10						
Millepora dichotoma							14	10
Pavona varians					2	10		
Pocillopora damicornis			3	10	8	20	9	20
Porites lutea	3				8	10	14	10
Psammocora contigua	2	10	5	10			4	10
Per Cent Coverage (%)	24		26		26		14	

Table 5. Relative density (RD), frequency (F) and total density for the reef terrace corals quantified on the reef terrace based on two transects at the Uruno Point study area. See Fig. 2 for locations of Transects 5 and 6.

SPECIES	TRANSECTS 5 RD	5 F	6 RD	6 F
Acanthastrea echinata	03	10	03	10
Acropora abrotenoides	05	20	03	10
A. humilis	03	10		
Astreopora listeri	02	10	03	10
A. myriopthalma	02	10		
Coscinarea columna			02	10
Favia palida	12	40	02	10
Goniastrea retiformis	08	30		
Heliopora coerulea			02	10
Leptastrea purpurea			13	50
Millepora exaesa	05	10	05	20
Montipora conicula	20	40	37	90
M. tuberculosa	07	30	05	20
M. verrucosa	05	20	10	30
Oulophyllia crispa	02	10		
Platygyra rustica	08	30	05	10
Pocillopora sp.	10	30		
Porites lichen	08	30	10	40
TOTAL DENSITY	$15/m^2$		$16/m^2$	

Table 6. Checklist of fishes recorded from the Uruno Point study area. Symbols: + - species present; * - species made up more than 10% of total number of fishes observed on one or more of the surveys in the indicated environmental zone.

Species	Inner Reef Flat	Outer Reef Flat
ACANTHURIDAE		
Acanthurus olivaceous Bloch and Schneider		+
A. lineatus (Linnaeus)		+
A. nigrofuscus Forskaal	+	+
A. triostegus (Linnaeus)	*	*
Naso literatus Bloch and Schneider	+	+
APOGONIDAE		
Cheilodipterus quinquelineata Cuvier and Valenciennes	+	
BALISTIDAE		
Rhinecanthus rectangularis (Bloch and Schneider)		+
BLENNIIDAE		
Cirripectus sp.	+	
BOTHIDAE		
unidentified bothid	+	
CANTHIGASTERIDAE		
Canthigaster solandri (Richardson)		+
CHAETODONTIDAE		
Chaetodon auriga Forskaal	+	+
C. citrinellus Cuvier	+	+
C. ephippium Cuvier		+
C. quadrimaculatus Gray		+
Megaprotodon strigangulus (Gmelin)		+

Table 6. (continued)

Species	Inner Reef Flat	Outer Reef Flat
CIRRHITIDAE		
Cirrhitus pinnulatus (Bloch and Schneider)	+	+
GOBIIDAE		
Eleotrides strigatus (Brovssonet)	+	
HOLOCENTRIDAE		
Adioryz sp.	+	
LABRIDAE		
Cirrhilabrus sp.	*	*
Gomphosus varius Lacepede		+
Halichoeres hortulanus (Lacepede)		+
H. marginatus Ruppell	+	+
H. trimaculatus (Quoy and Gaimard)	*	*
Hemigymnus fasciatus (Bloch)		+
H. melapterus (Bloch)		+
Labroides dimidiatus (Cuvier and Valenciennes)		+
Stethojulis axillaris (Quoy and Gaimard)	+	+
Thallasoma hardwickei (Bennett)	+	+
T. purpureum (Forskaal)		+
LUTJANIDAE		
Scolopsis cancellatus (Cuvier and Valenciennes)		+
MUGILOIDIDAE		
Parapercis cephalopunctatus (Seale)	+	
MULLIDAE		
Mulloidichthys auriflamma (Forskaal)		+
M. samoensis (Gunther)		+
Parupeneus pleurostigma (Bennett)		+

Table 6. (continued)

Species	Inner Reef Flat	Outer Reef Flat
POMACENTRIDAE		
Abudefduf amabilis (De vis)	*	*
A. dicki (Lienard)		+
A. glaucus (Cuvier and Valenciennes)	*	*
A. leucopomus (Lesson)	*	*
A. leucozona (Bleeker)		+
A. septemfasciatus (Cuvier and Valenciennes)	+	+
A. sordidus (Forskaal)	+	*
Chromis caeruleus (Cuvier and Valenciennes)	*	*
Dascyllus aruanus (Linnaeus)	+	*
Pomacentrus amboinensis Bleeker	+	
P. nigricans (Lacepede)	+	+
P. vaiuli (Jordan and Seale)	+	
SCARIDAE		
Xanothon margaritus (Cartier)		+
juvenile scarids		+
unidentified scarid	+	
TETRAODONTIDAE		
Arothron hispidus (Lacepede)		+
Number of species	28	41

Total number of species observed=50

Table 7. Checklist of the conspicuous macroinvertebrates in the Uruno Point study area.

PORIFERA
- *Cinachyra australiensis* (Carter)

MOLLUSCA
- Bivalvia
  - *Tridacna maxima* (Roding)
- Gastropoda
  - *Conus chaldaeus* Roding
  - *C. ebraeus* Linnaeus
  - *C. miles* Linnaeus
  - *C. miliaris* Hwass
  - *C. sponsalis* Hwass
  - *Cymatium pileare* Linnaeus
  - *Cypraea moneta* Linnaeus
  - *C. tigris* Linnaeus
  - *Drupa ricinus* (Linnaeus)
  - *Lambis* sp.
  - *Latirus* sp.
  - *Thais tuberosa* Roding
  - *Nerita plicata* Linnaeus
  - *Trochus niloticus* Linnaeus
  - *Turbo argyrostoma* Linnaeus
  - *Vasum ceramicum* (Linnaeus)
  - *V. turbinellus* (Linnaeus)

ECHINODERMATA
- Asteroidea
  - *Choriaster granulatus* Lutken
  - *Culcita novaeguineae* Muller & Troschel
  - *Linckia laevigata* (Linnaeus)
  - *Linckia pacifica* Gray
- Echinoidea
  - *Echinometra mathaei* (de Blainville)
  - *Echinostrephus* sp.
  - *Echinothrix diadema* (Linnaeus)
- Holothuroidea
  - *Actinopyga echinites* (Jaeger)
  - *Bohadschia argus* (Jaeger)
  - *B. bivittata* (Mitsukuri)
  - *Holothuria (Halodeima) atra* Jaeger
  - *H. (Semperothuria) cinerascens* (Brandt)
  - *H. (Platyperona) difficilis* Semper
  - *H. (Thymiosycia) hilla* Lesson
  - *H. (Microthele) nobilis* (Selenka)
  - *Stichopus chloronotus* Brandt

CRUSTACEA
- Diogenidae (hermit crabs)
  - *Calcinus gaimardi* (H. Milne Edwards)
  - *Dardanus guttatus* (Olivier)

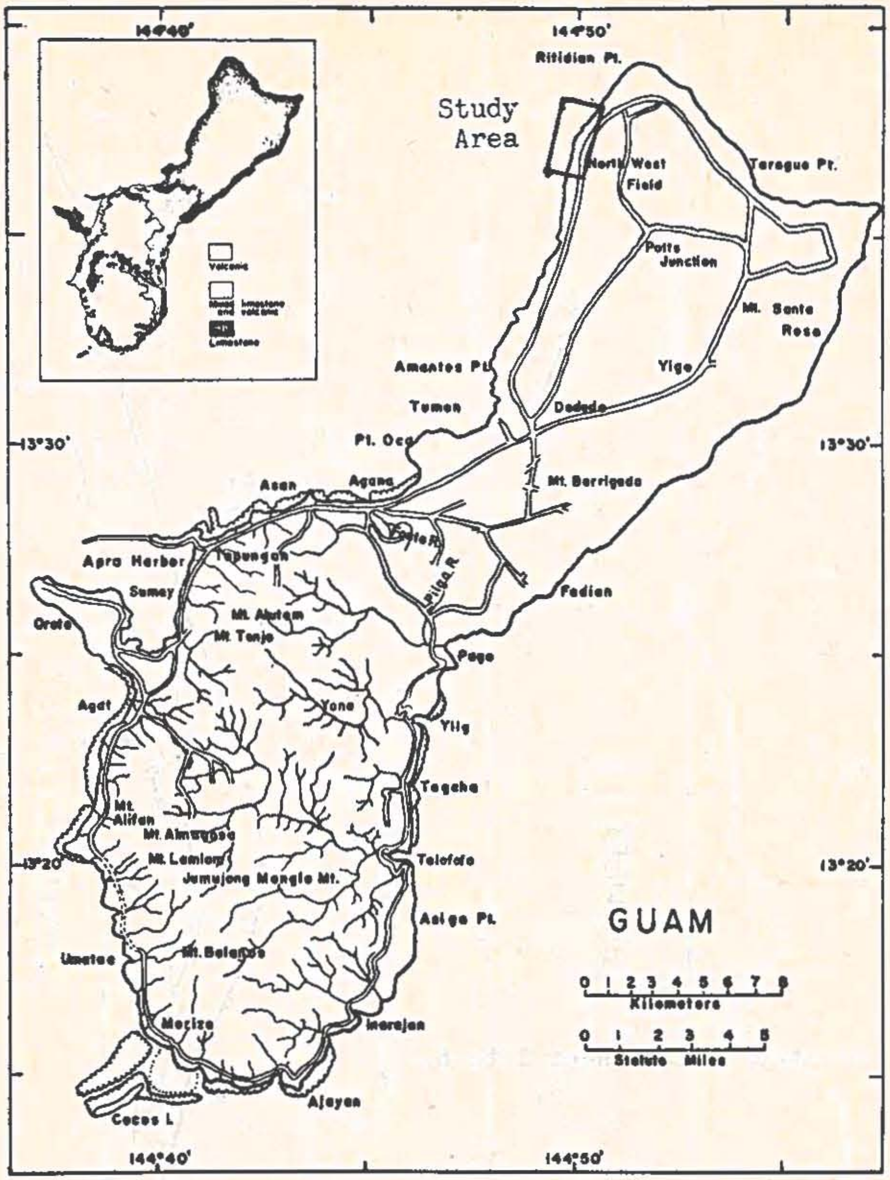

Fig. 1. Map of Guam showing the Uruno Point study area.

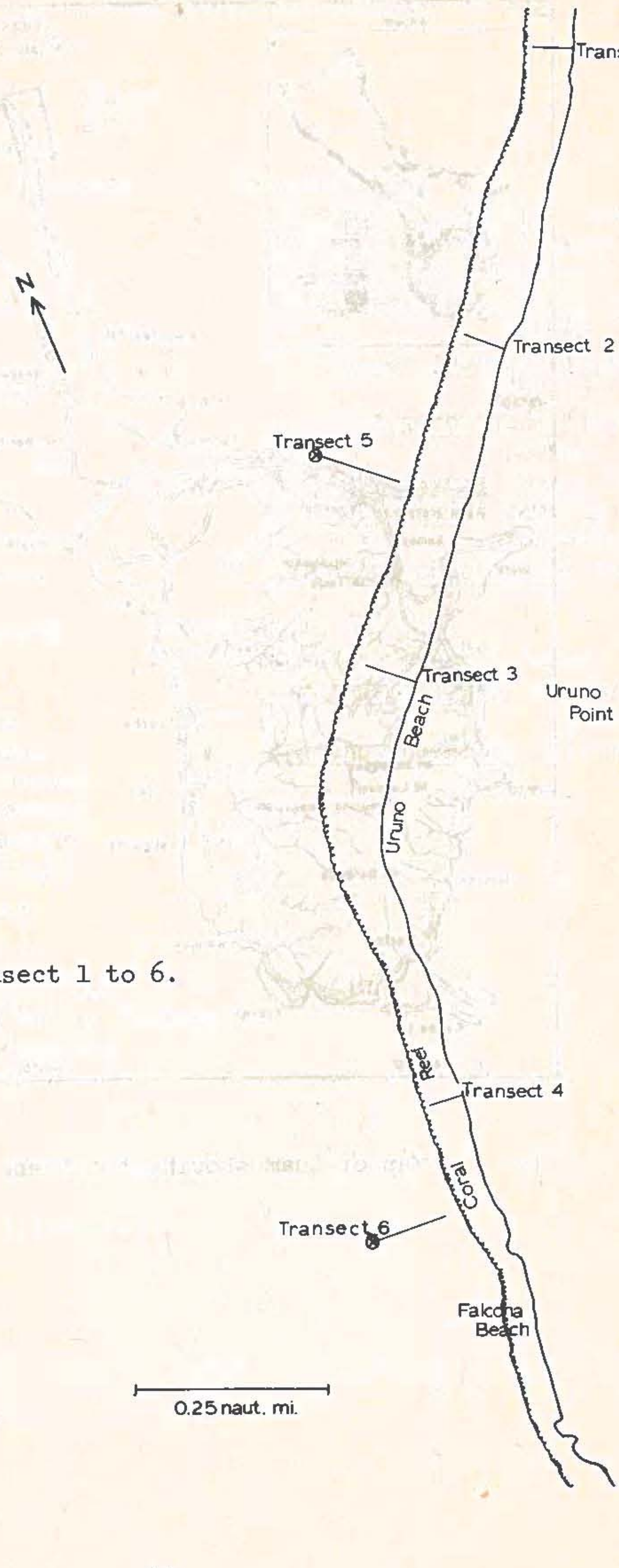

Fig. 2. Location of Transect 1 to 6.

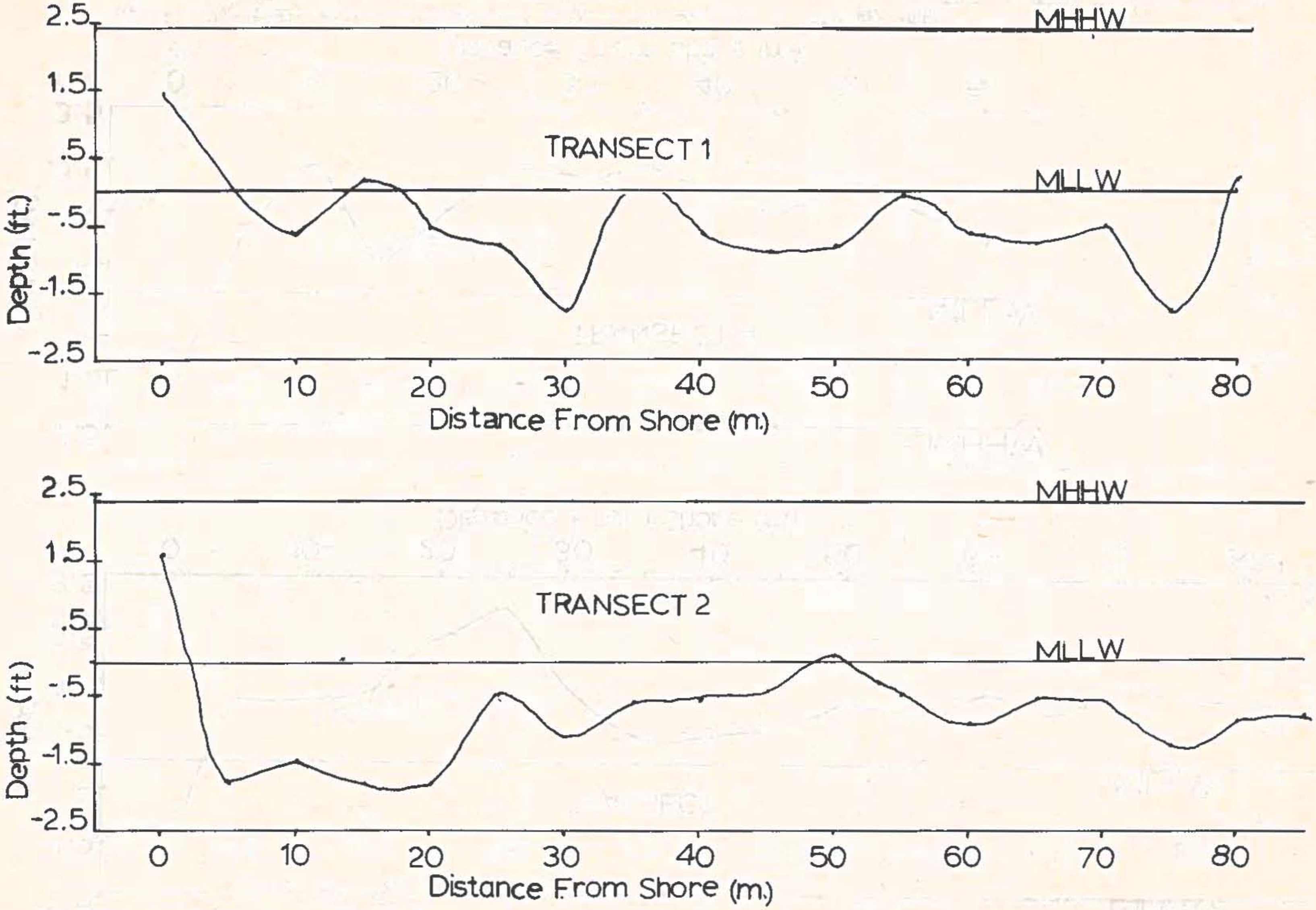

Fig. 3. Vertical profile of Transects 1 and 2 in relation to MLLW and MHHW.

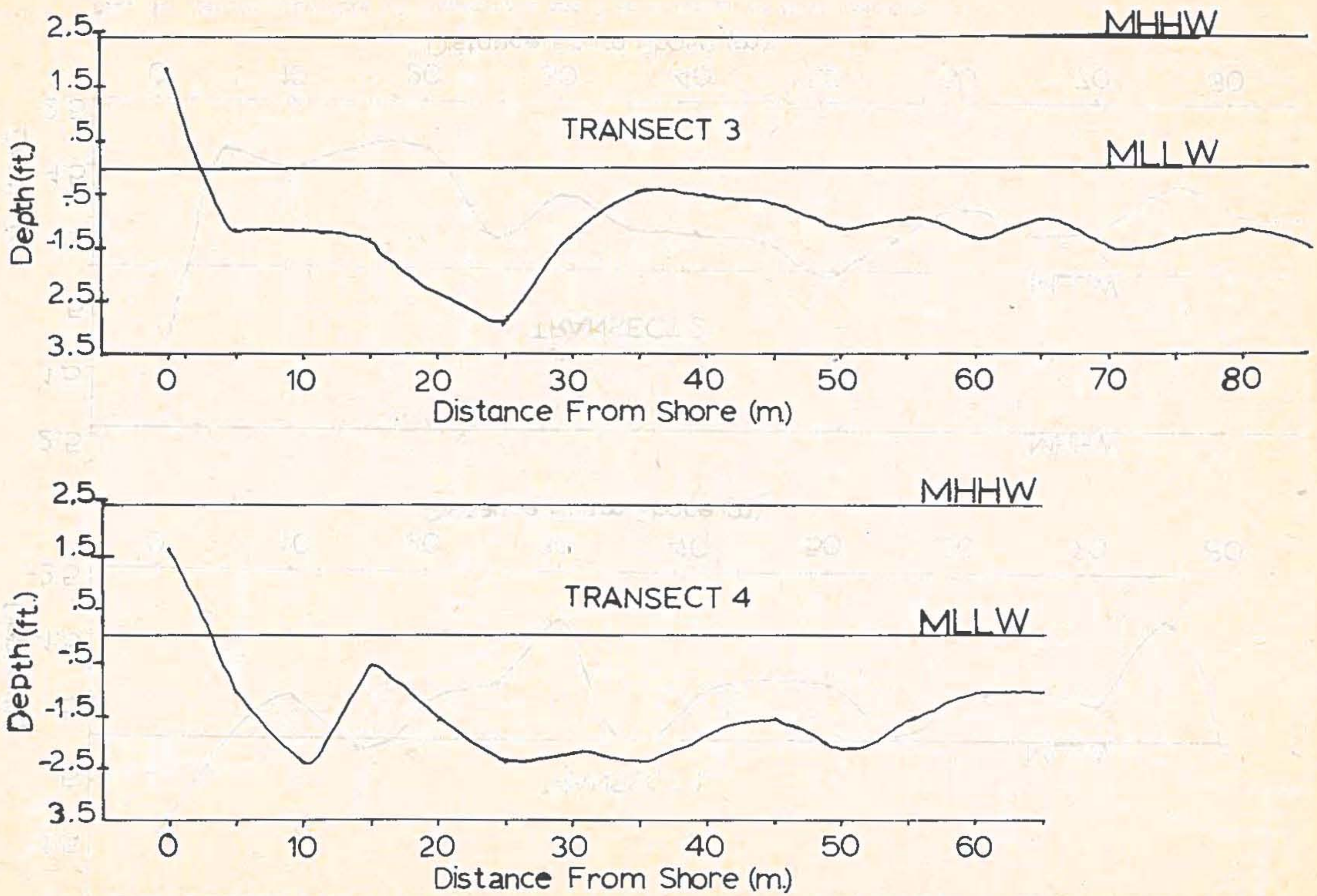

Fig. 4. Vertical profile of Transects 3 and 4 in relation to MLLW and MHHW.

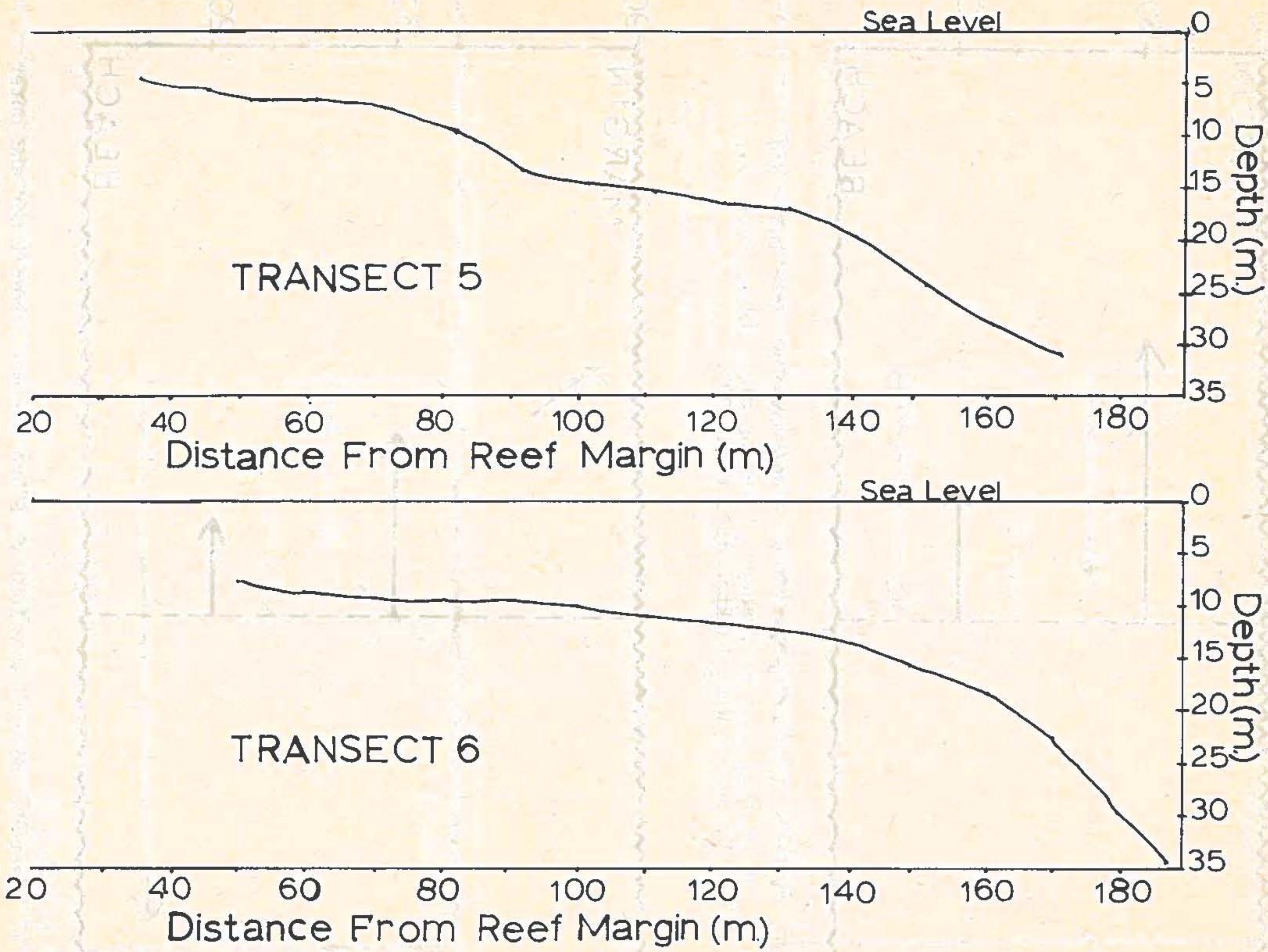

Fig. 5. Vertical profile of Transects 5 and 6 in relation to MLLW and MHHW.

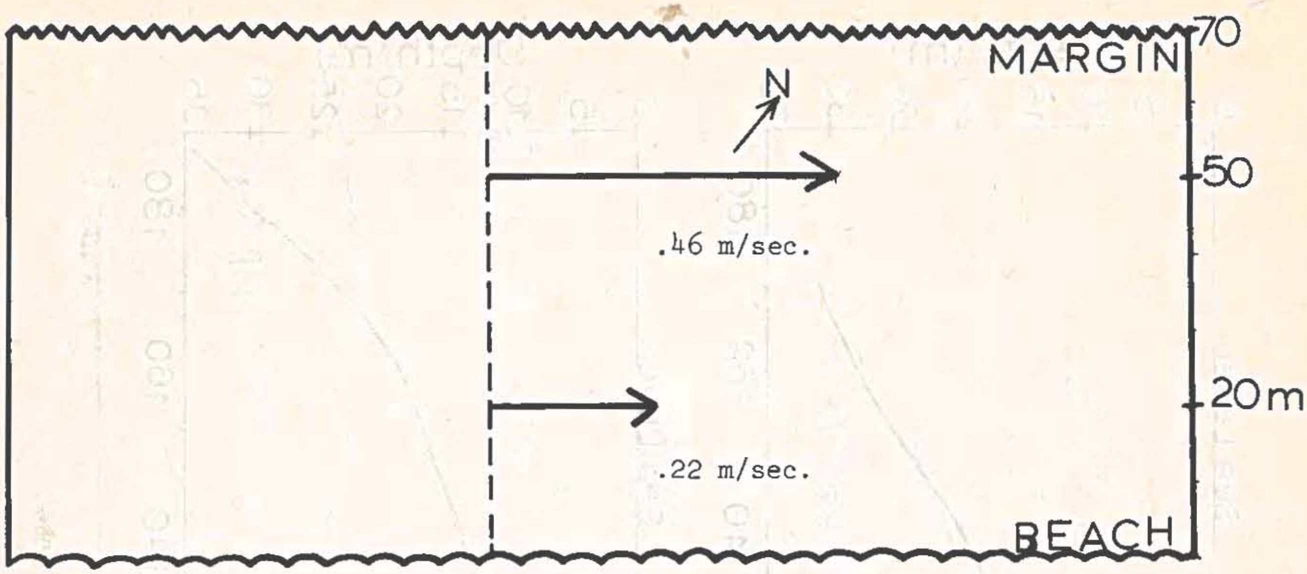

Fig. 6. Vectors indicating velocity of dye movement over inner and outer reef flat at Transect 1 during high tide. April 5, 1975; 0940. Wind 13 kts., direction 090°.

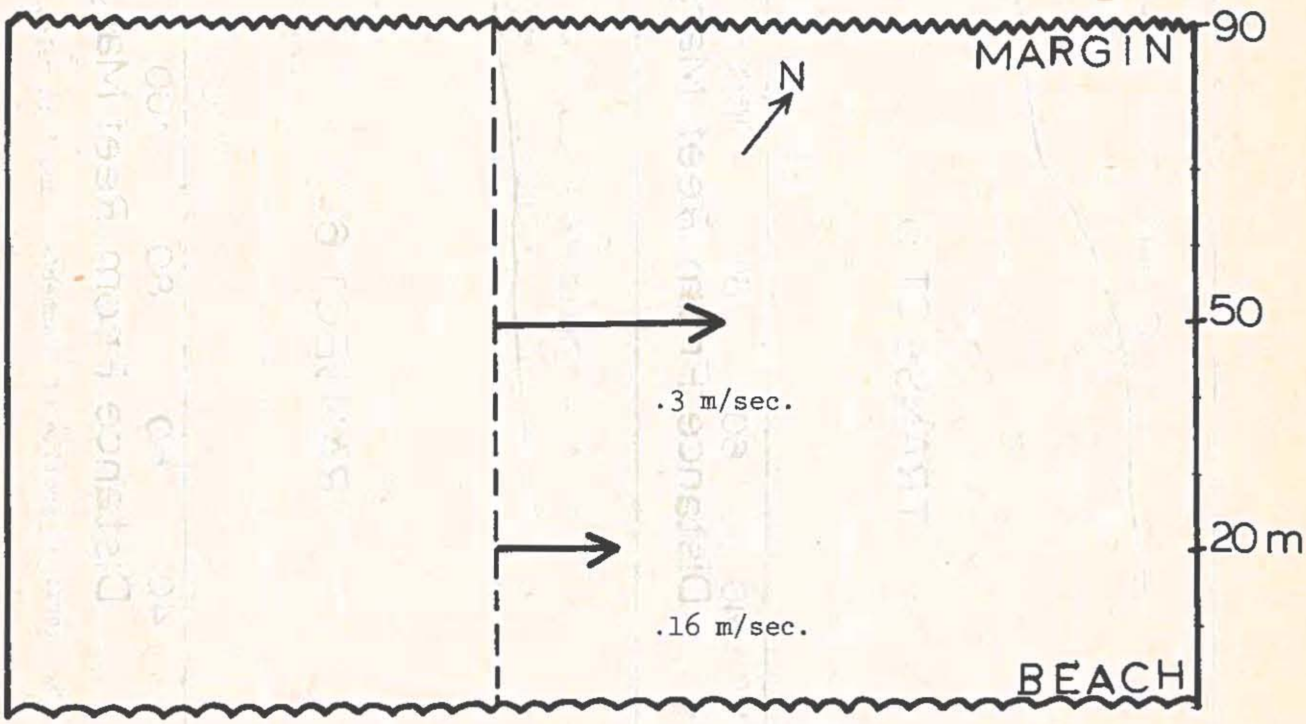

Fig. 7. Vectors indicating velocity of dye movement over inner and outer reef flat at Transect 2 during high tide. April 5, 1975; 1100. Wind 11 kts., direction 090°.

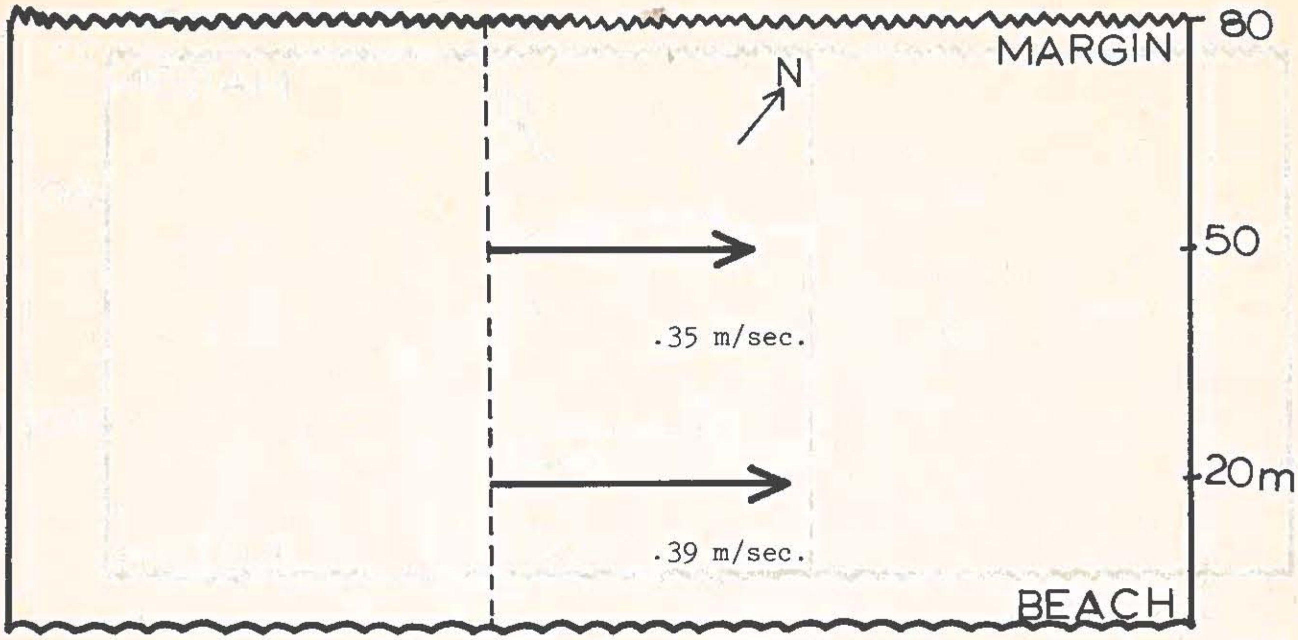

Fig. 8. Vectors indicating velocity of dye movement over inner and outer reef flat at Transect 3 during high tide. April 5, 1975; 1030. Wind 14 kts.,direction 090°.

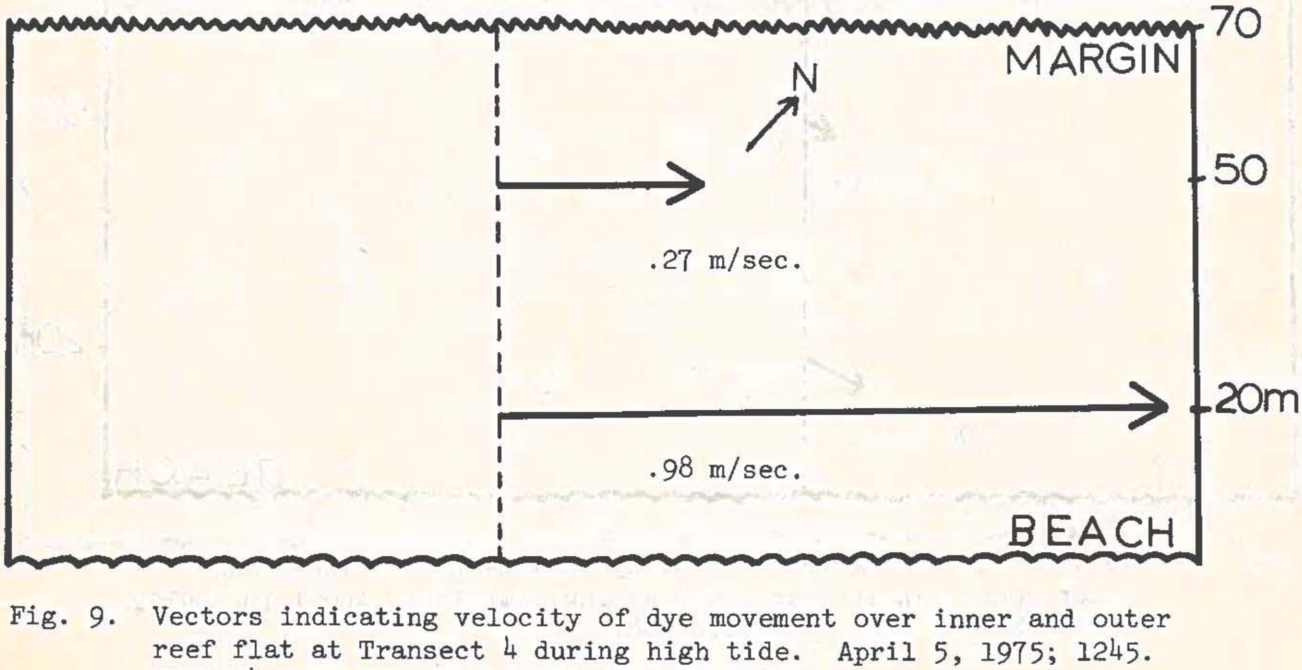

Fig. 9. Vectors indicating velocity of dye movement over inner and outer reef flat at Transect 4 during high tide. April 5, 1975; 1245. Wind 14 kts.,direction 090°.

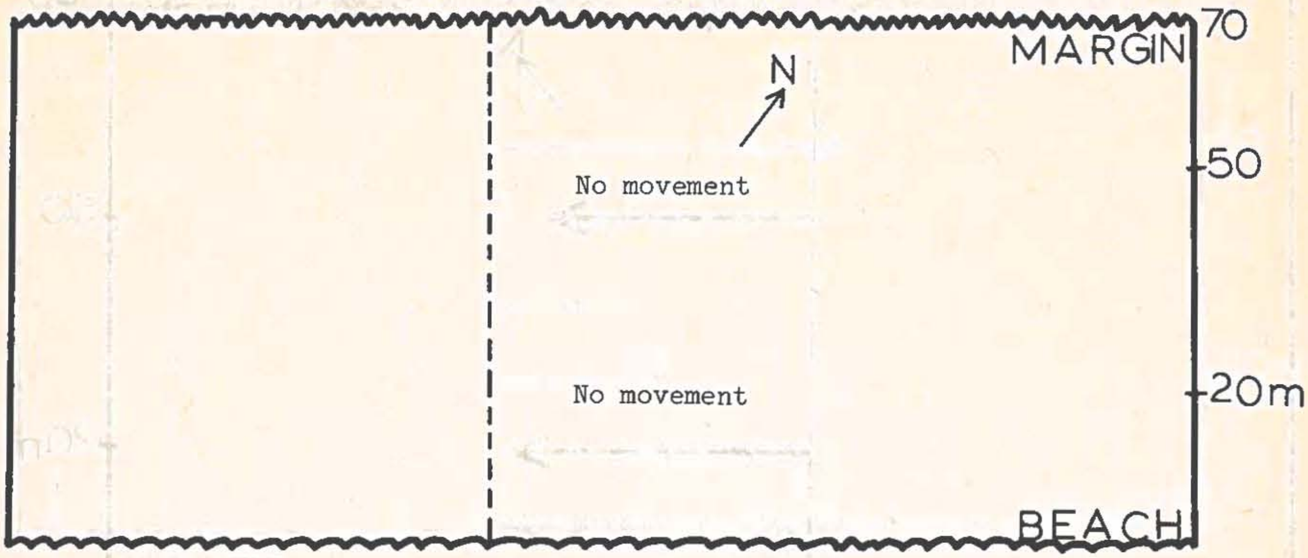

Fig. 10. No movement of dye over inner and outer reef flat at Transect 1 during low tide. April 10, 1975; 1300. Wind 9 kts., direction 087°.

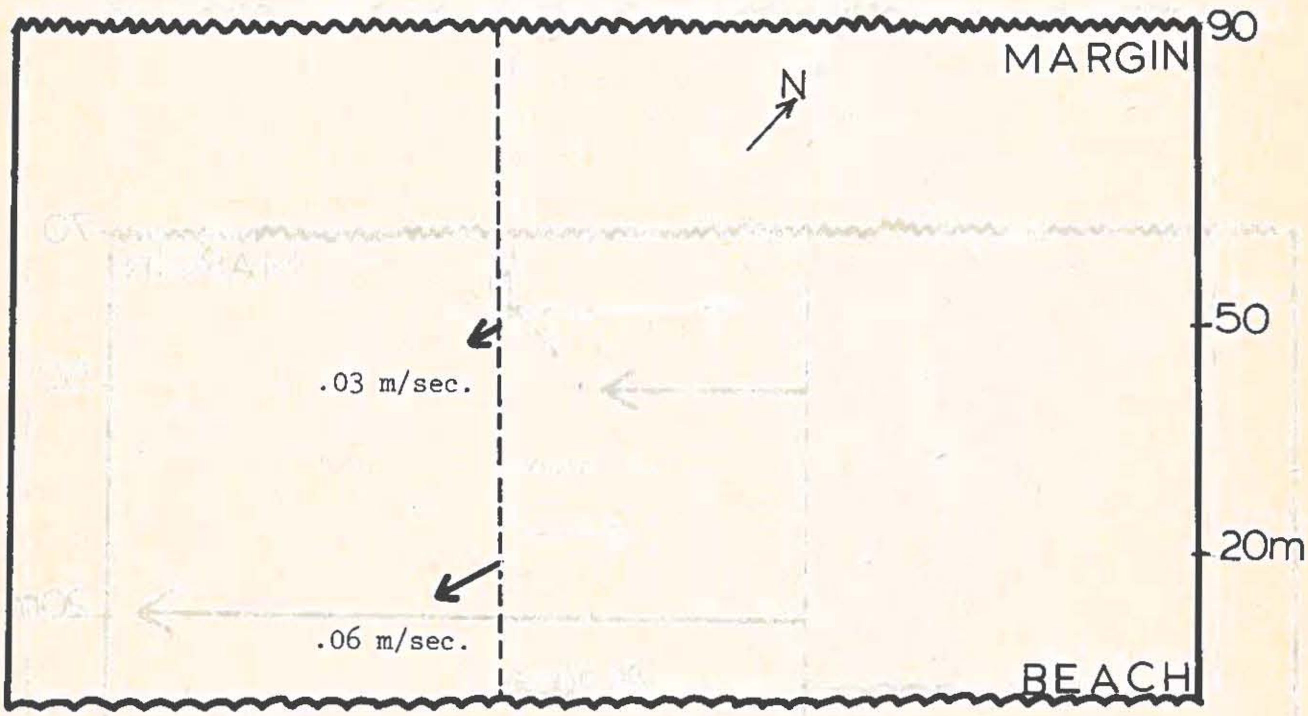

Fig. 11. Vectors indicating velocity of dye movement over inner and outer reef flat at Transect 2 during low tide. April 10, 1975; 1440. Wind 9 kts., direction 087°.

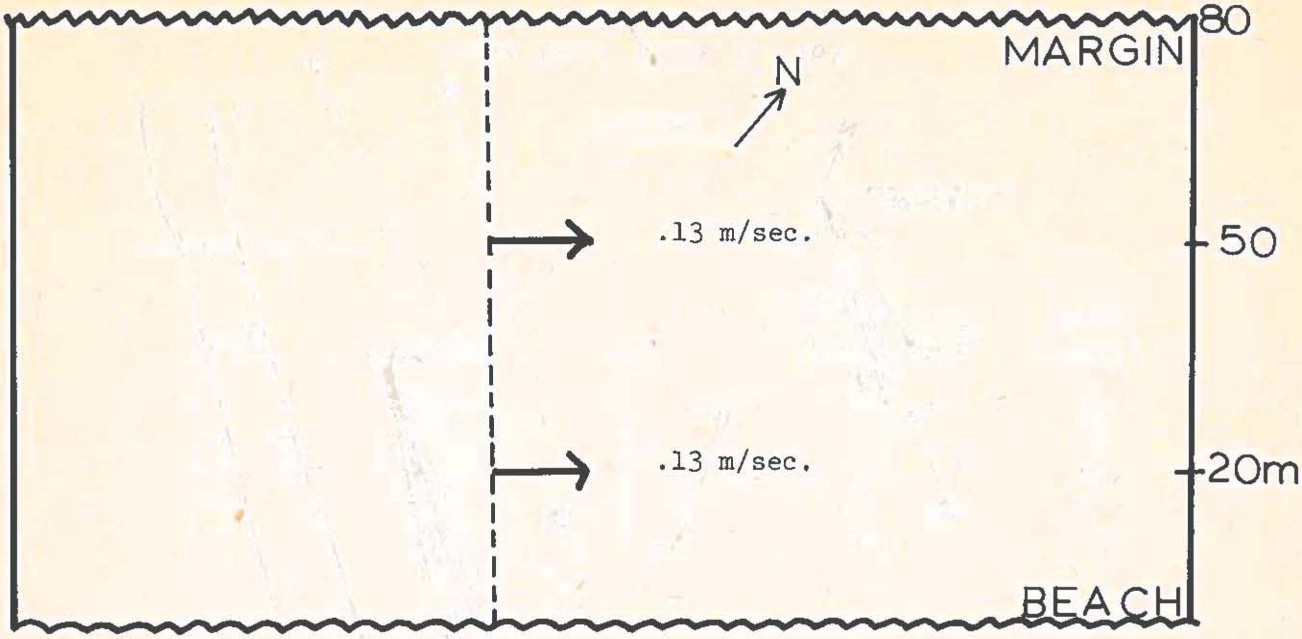

Fig. 12. Vectors indicating velocity of dye movement over inner and outer reef flat at Transect 3 during low tide. April 10, 1975; 1400. Wind 10 kts., direction 087°.

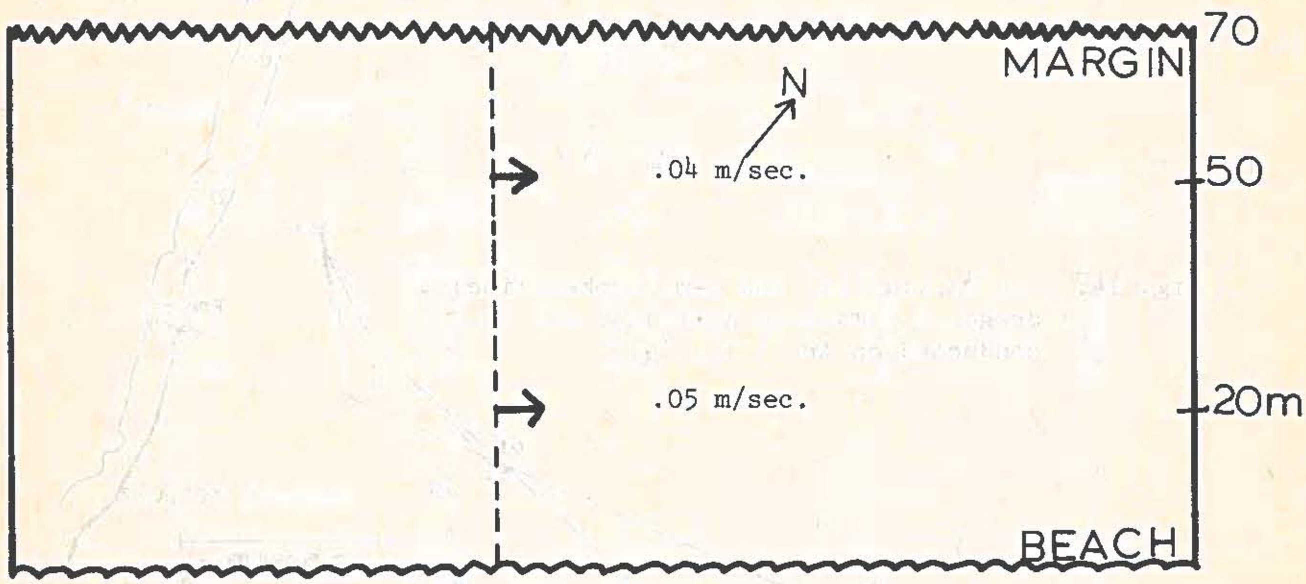

Fig. 13. Vectors indicating velocity of dye movement over inner and outer reef flat at Transect 4 during low tide. April 10, 1975; 1335. Wind 9 kts., direction 087°.

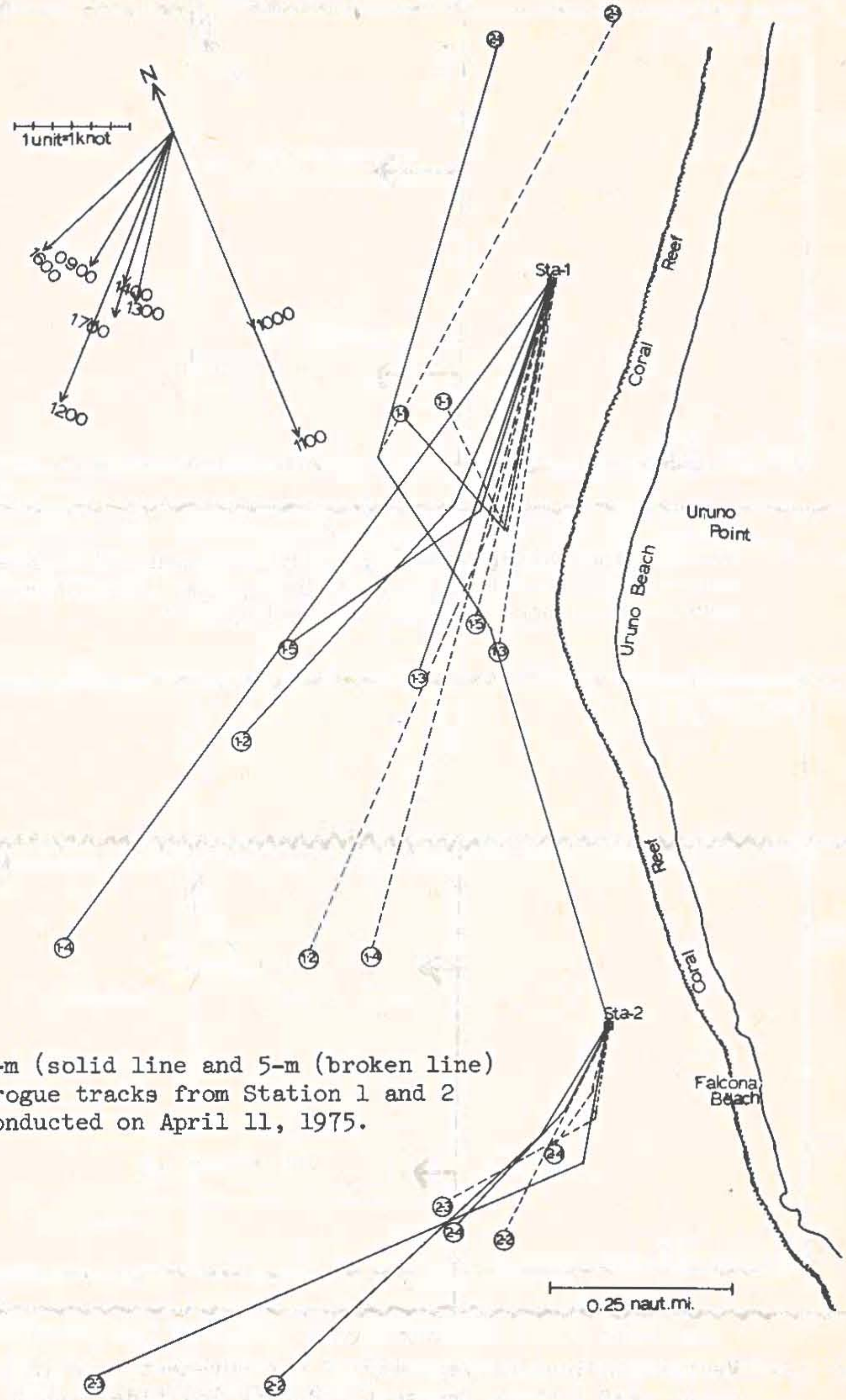

Fig. 14. 1-m (solid line and 5-m (broken line) drogue tracks from Station 1 and 2 conducted on April 11, 1975.

DRIFT DATA, APRIL 11, 1975

Station 1

1-meter Drogues

Drift	Start	ΔT	Distance (Naut. Mi.)	Speed (Knots)
1-1	0900	2	.55	.28
1-2	1100	2	.76	.38
1-3	1300	1	.56	.56
1-4	1400	1	1.1	1.1
1-5	1500	2	.64	.32

5-meter Drogues

Drift	Start	ΔT	Distance (Naut. Mi.)	Speed (Knots)
1-1	0900	2	.53	.27
1-2	1100	2	.95	.48
1-3	1300	1	.5	.5
1-4	1400	1	.94	.94
1-5	1500	2	.47	.23

Station 2

1-meter Drogues

Drift	Start	ΔT	Distance (Naut. Mi.)	Speed (Knots)
2-1	0840	2.3	1.4	.6
2-2	1100	2	.66	.33
2-3	1300	2.5	.97	.39
2-4	1530	1.5	.34	.23

5-meter Drogues

Drift	Start	ΔT	Distance (Naut. Mi.)	Speed (Knots)
2-1	0840	2.3	1.5	.64
2-2	1100	2	.32	.16
2-3	1300	2.5	.36	.14
2-4	1530	1.5	.19	.12

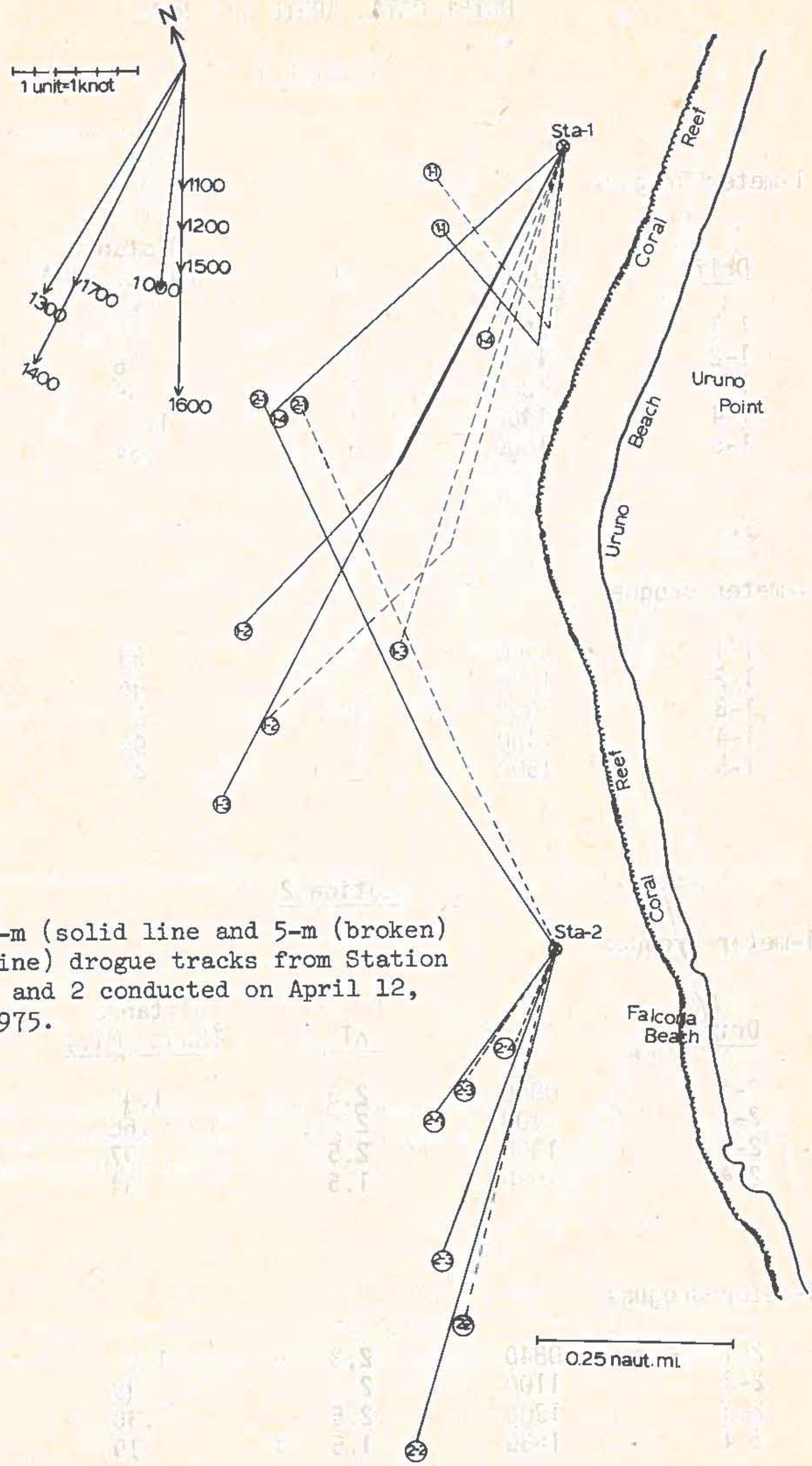

Fig. 15. 1-m (solid line and 5-m (broken) line) drogue tracks from Station 1 and 2 conducted on April 12, 1975.

DRIFT DATA, APRIL 12, 1975

Station 1

1-meter Drogues

Drift	Start	ΔT	Distance (Naut. Mi.)	Speed (Knots)
1-1	0930	2	.44	.22
1-2	1130	2	.73	.36
1-3	1400	1.25	.92	.74
1-4	1530	1.5	.52	.36

5-meter Drogues

Drift	Start	ΔT	Distance (Naut. Mi.)	Speed (Knots)
1-1	0930	2	.47	.24
1-2	1130	2	.84	.42
1-3	1400	1.25	.66	.52
1-4	1530	1.5	.25	.17

Station 2

1-meter Drogues

Drift	Start	ΔT	Distance (Naut. Mi.)	Speed (Knots)
2-1	0930	2	.80	.40
2-2	1130	2.5	.64	.26
2-3	1400	1.5	.40	.27
2-4	1530	1.5	.26	.18

5-meter Drogues

Drift	Start	ΔT	Distance (Naut. Mi.)	Speed (Knots)
2-1	0930	2	.76	.38
2-2	1130	2.5	.48	.20
2-3	1400	1.5	.21	.14
2-4	1530	1.5	.13	.09

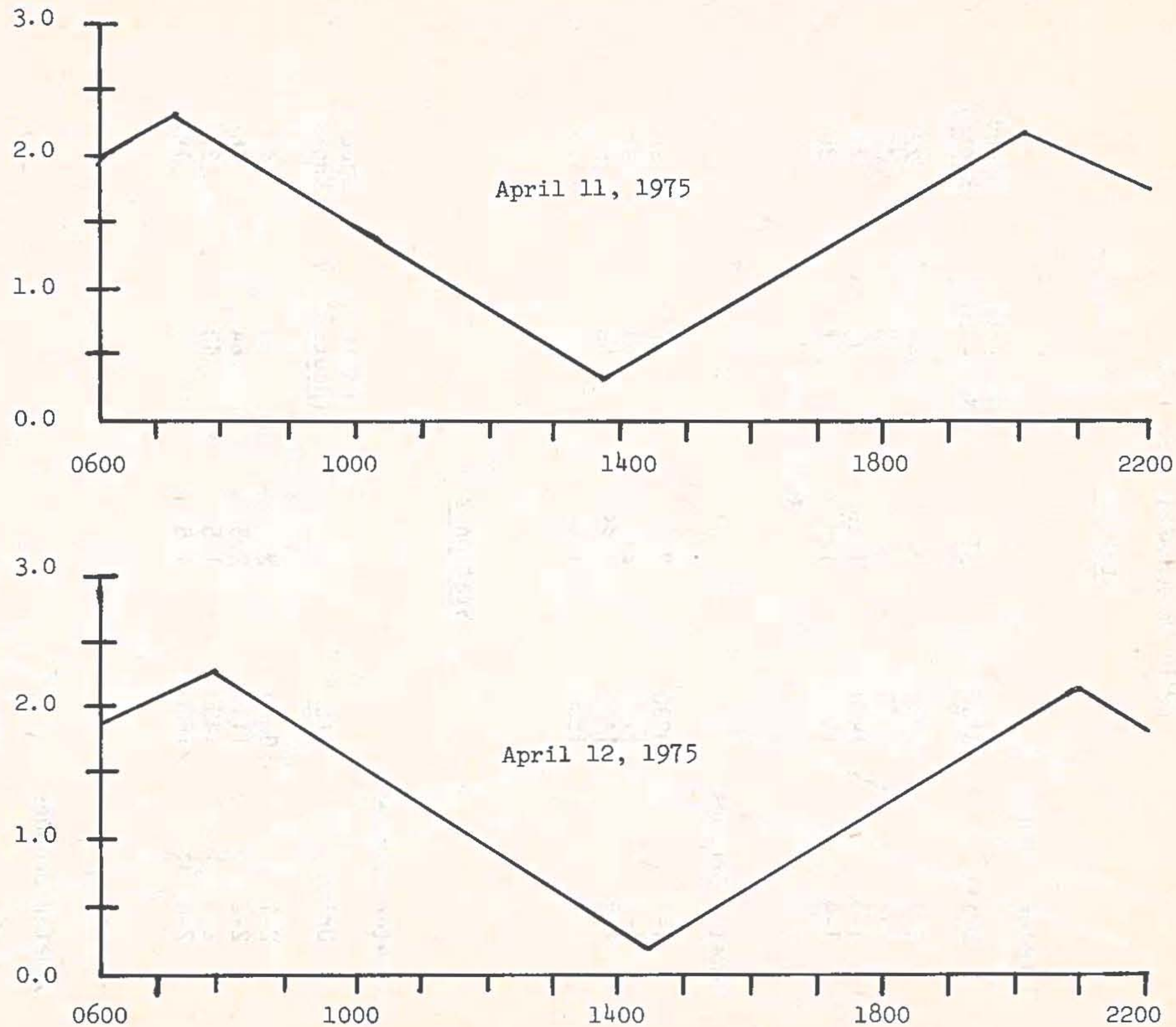

Fig. 16. Predicted tide changes between 0600 and 2200, April 11 and 12, 1975.

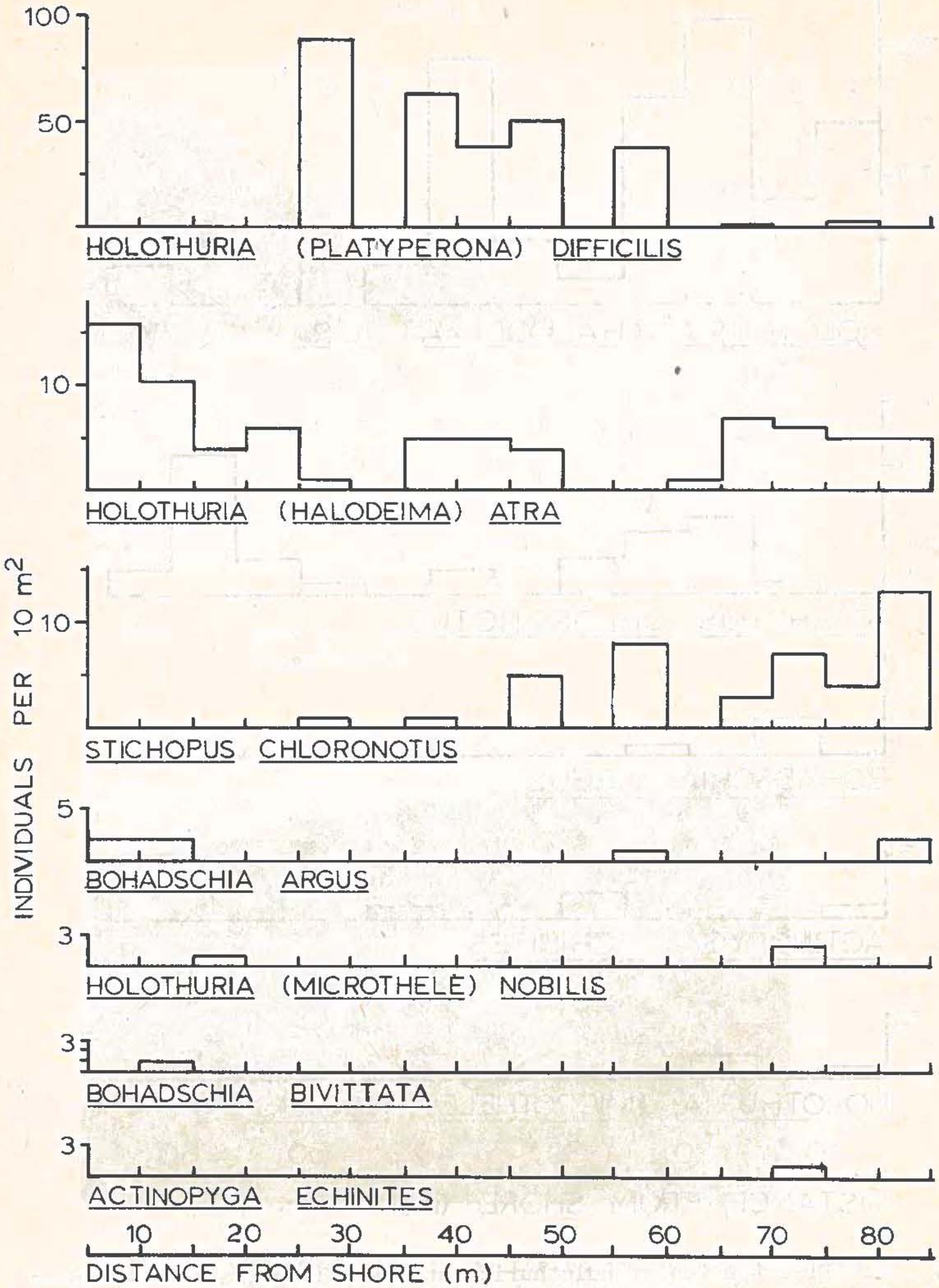

Fig. 17. Distribution of holothurian species along Transect 3. Data are numbers of individuals per 2 m x 5 m quadrat oriented with the long axis parallel to the transect. The numbers of *Holothuria (Platyperona) difficilis* are approximations.

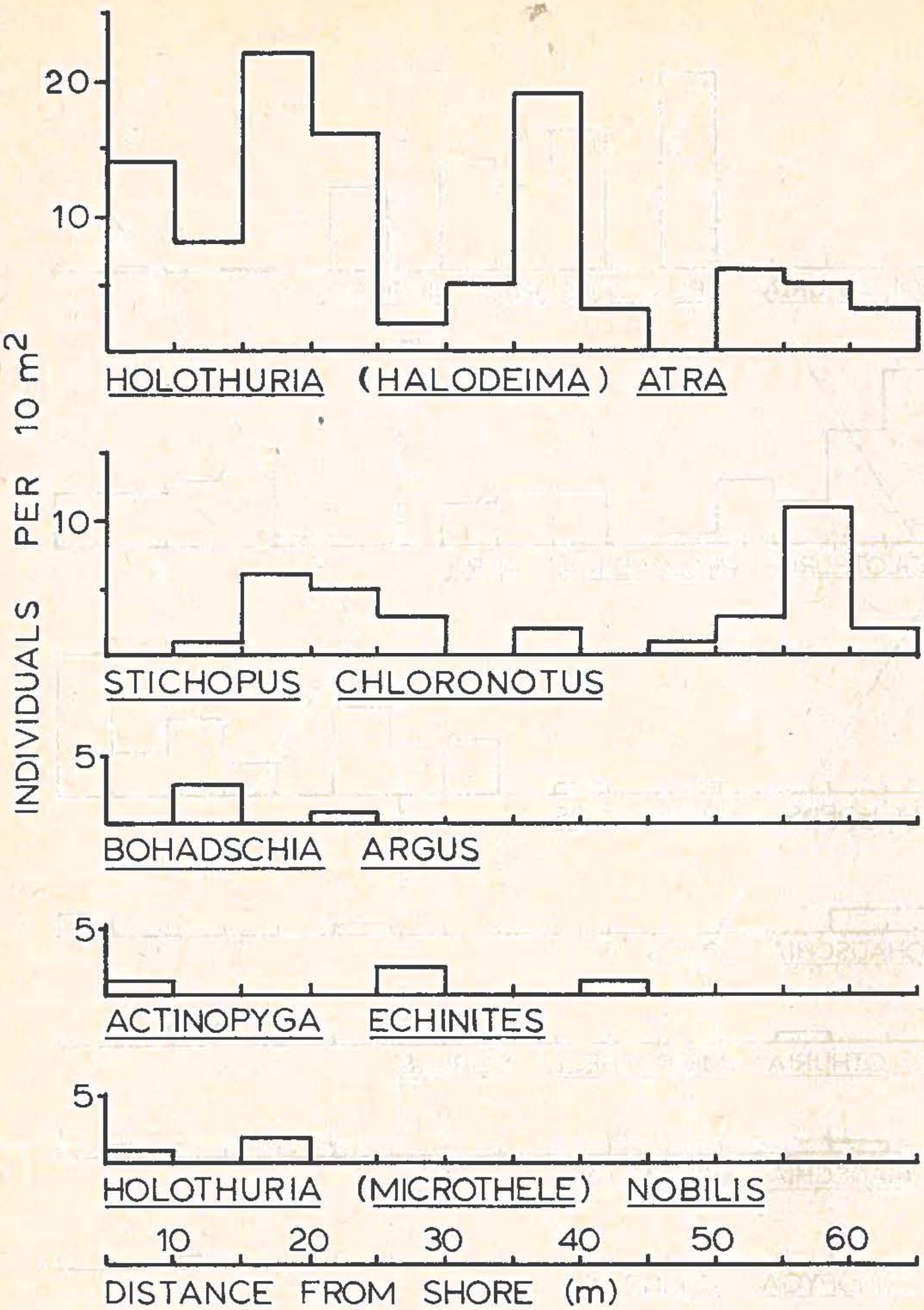

Fig. 18. Distribution of holothurian species along Transect 4. Data are numbers of individuals per 2 m x 5 m quadrat oriented with the long axis parallel to the transect. Also seen in this area were *Bohadschia bivittata*, *Holothuria (Semperothuria) cinerascens*, and *Holothuria (Thymosycia) hilla*.

PLATE I

Fig. 1. View of shoreline facing south toward Uruno Point.

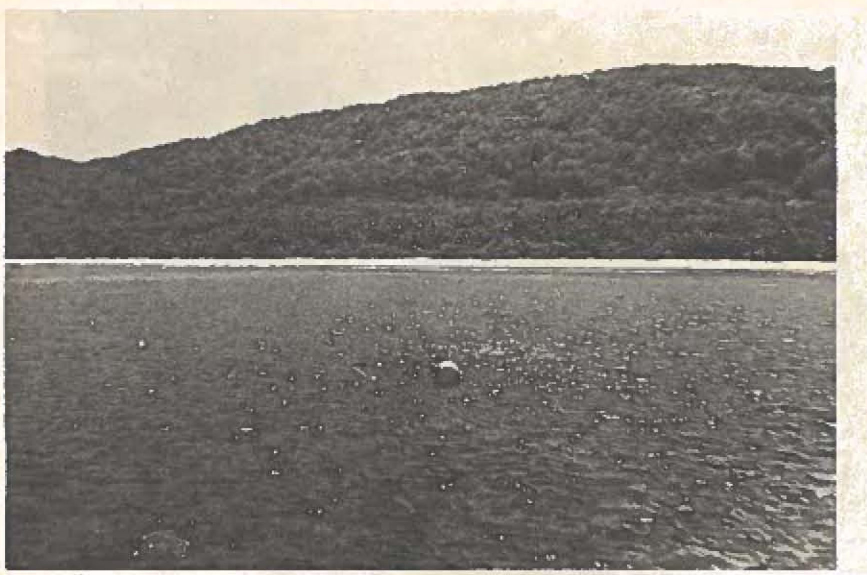

Fig. 2. View of terrain on the southern side of Uruno Point. Buoy marks Station 2 where drogues were cast as well as the area where Transect 6 was run.

PLATE II

Fig. 1. Technique used in measuring and timing the dye movement over the outer reef flat.

Fig. 2. Release of fluorescein dye in 50 feet of water. The general movement of the dye was then observed.

PLATE III

Fig. 1. A massive colony of Porites in 3 ft. of water on the outer reef flat.

Fig. 2. Porites and Acropora colonies in 3 ft. of water on outer reef as seen during high tide.

PLATE IV

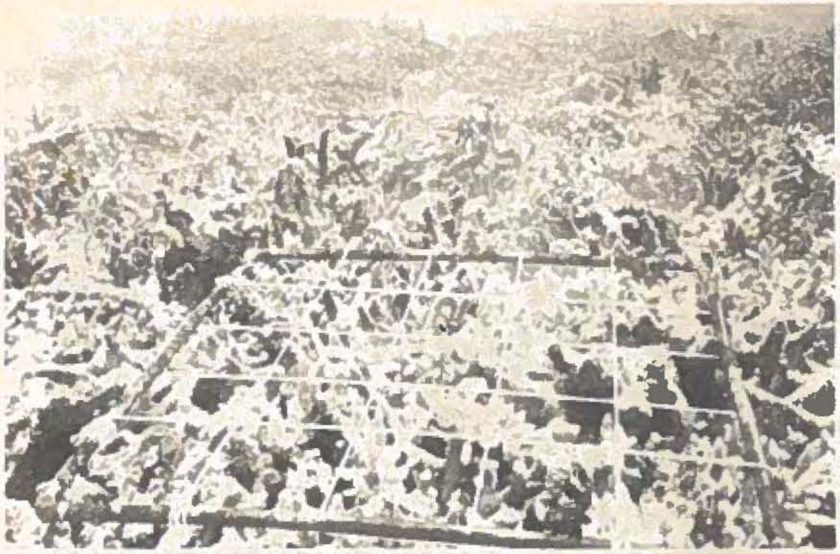

Fig. 1. Quadrat (50 cm x 50 cm) with 16 interior points, used to quantify corals, on portions of an Acropora thicket on the outer reef flat.

Fig. 2. View of the corals Porites and Acropora, as well as the brown alga Turbinaria and the sea cucumber Stichopus, on the outer reef flat near the reef margin.

PLATE V

Fig. 1. Reeling out the 100 m transect line on the reef terrace.

Fig. 2. Applying the point-quarter method in quantifying corals on the reef terrace.

PLAT : VI

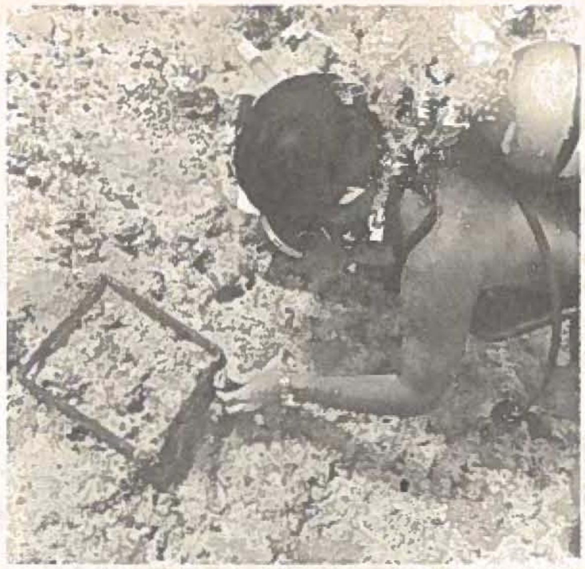

Fig. 1. Quantifying marine algae on the reef terrace.

Fig. 2. View taken from 100 ft. looking up at the reef slope. Gorgonians and surgeonfishes can be seen in the background.