A CANDIDATE MARINE ENVIRONMENTAL IMPACT SURVEY FOR POTENTIAL U. S. MILITARY PROJECTS ON TINIAN ISLAND, MARIANA ISLANDS

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By

ROBERT S. JONES, RICHARD H. RANDALL, AND ROY T. TSUDA

Co-Investigators

University of Guam

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INTRODUCTION

Background

Tinian Island (Figs. 1 and 2) lies within the Mariana Island group (San Jose Harbor is located at 14°58'N and 145°37'E) and is presently under the administrative jurisdiction of the U. S. Trust Territories of the Pacific Islands. The Island was captured from Japan during World War II and served primarily as heaquarters and base for the U. S. 20th Air Force. The extensive military base has, for the most part, been reclaimed by secondary jungle growth. The old B-29 runways at North Field, the runways at West Field, some of the primary roads, and San Jose Harbor are still pretty much intact and some of these facilities are used by Tinian's small community of 800 people. One strip of the West Field complex is used for commercial air traffic, and San Jose Harbor still serves as an excellent port for Trust Territory vessels.

The department of Defense with aid from the Department of State has expressed an interest in reestablishing an active military base on Tinian. It is proposed that it be a multiservice base involving several military organizations (Army, Navy, Marine Corps, and Air Force) but under overall Air Force Command.

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*This work and the opinions expressed herein are those of the authors and not necessarily those of the University of Guam, The Marine Laboratory, or Government of Guam.

At the writing of this report there was still much to be resolved with regards to the political questions between the U. S. Government, the governments of the Trust Territory and the Marianas District, and the people of Tinian. Hence, it was not yet feasible or possible for Air Force engineers to produce detailed plans at this stage. However, in order to comply with the National Environmental Policy Act, it was necessary to launch a preliminary or background environmental survey from which a more in-depth study might be planned, if and when political questions were resolved.

This study is the marine portion of the first of a three part series of required Environmental Impact Statements. The procedure is first to file a "Candidate EIS" which is highly preliminary. This is followed by a much more complex and detailed "Draft EIS" which is submitted to all Government agencies and other concerned parties for review. The last step is the "Final EIS", modified by comment from reviewers. Since planning is still far from complete, the present study falls into the category of "Candidate EIS" and should in no way be confused with the more in-depth studies required in future stages.

Personnel

Principal Investigator:

Robert S. Jones. Ph. D., Director, University of Guam Marine Laboratory (Ichthyology)

Co-Investigators:

Richard H. Randall, M. S., University of Guam Marine Laboratory (Coral Biology)

Roy T. Tsuda, Ph. D., University of Guam Marine Laboratory (Phycology)

Marine Technician:

T. L. Tansy

Student Assistants:

Michael J. Gawel

Ronald D. Strong

Daniel S. Wooster

The personnel for this study were selected because of their considerable past experience in coral reef biology in the Mariana Islands. Specialties of the authors include three of the Tinian marine environment's most important biotic components--reef building corals, reef fishes, and tropical benthic algae. All three students are graduate students in the University of Guam's Master of Science degree program in biology.

Proposed Construction

San Jose Harbor (Figs. 2 and 3)

This was designated Site I on the contract map. There is a proposal to improve and redredge the present harbor. It is presumed that the dimensions of the harbor will not change significantly but that existing breakwaters and wharfage would be repaired and perhaps strengthened (USAF engineer Gordon, personal communication). No depths were provided for harbor dredging and no information was available as to whether or not the channel through the reef would be widened. No data were provided as to the nature of ship traffic expected; type of harbor operations; or potential accidental, occasional, or long term discharge of materials into the harbor. It is therefore necessary to assume, for purposes of this report, that dredging of the harbor and channel to greater depths and repair of existing structures, with concurrent induced sedimentation will be the only sources of impact during harbor renovation. We are also assuming no discharge of any material into the harbor during normal harbor operations.

Lamanibot Bay (Figs. 2 and 4)

This was designated Site II on the contract map. It is our understanding (from personal communication with project engineers Gordon, Kajiwara, and Lau) that some part of this scenic bay will be considered for development as an alternate port site. It was not clear whether or not this would be in lieu of San Jose Harbor or supplemental to it. The major problem seems to center around the potential hazard of unloading explosives near San Jose Village, which lies directly adjacent to the existing harbor. Consideration is being given to moving San Jose Village to a more distant site. The matter is still under discussion in negotiations between the Marianas Political

Status Commission and the U. S. Government. Federal law requires a safety radius of a specific distance from places where ammunition ships are being unloaded. Should negotiations fail, we presume that Lamanibot Bay will be the site of either the entire port facility or at least a special ammunition handling facility. It seems most logical that the latter would be the case. We made this assumption and, hence, looked at the bay as though the facility constructed there would be relatively small. Moreover, only the north end of the bay would seem amenable to such a facility. The southern half shows both physical and biological signs of very intense wave focus. Large waves, wrapping around the extreme north end of the island, were indeed crashing into this part of the bay during our study.

Since absolutely no data were provided, we are assuming some kind of limited mooring facility near the cliff at the north end of Lamanibot Bay. We have no way of knowing whether or not a breakwater will be built around the facilty, but suspect that water depth might be prohibitive for such a venture. Again we have no physical dimensions, structural information, or idea of the nature of harbor operations. Most certainly one of the two proposed harbor sites must have plans for POL handling as well as dry cargo. The "draft study" (DEIS) should include a consideration of potential hydrocarbon spills.

<u>Uani Dangkulo</u> (Figs. 2 and 5)

This was designated Site III on the contract map. The local people refer to this as "Long Beach," and we understand it is a popular picnic area. None of the project engineers seemed to be aware of any subtidal facilities construction planned for this site. Instead, it was apparently chosen to provide a windward site for comparison of environmental conditions with three leeward construction sites. We are therefore assuming no construction and/or discharge in the marine environment at Site III.

Peipeingul Bay (Figs. 2 and 6)

This was designated Site IV on the contract map. We were unable to find a definite name for this bay, **north** of San Jose Harbor. We have been advised that a sewer outfall for up to 0.5 MGD capacity will be constructed somewhere between this small bay and Puntan Diablo to the west. We were also told that other outfalls might be needed, but locations had not been selected. No information was available as to type of outfall to be used in the bay, depth of release, diffuser design, and the like.

SCOPE OF WORK

Purpose

Request

"To perform a marine environmental impact survey at Tinian to evaluate all aspects which may have potential significant adverse (or beneficial) effects on the marine environment as a result of the proposed Air Force action to develop a military base on Tinian".

Comment

It was not possible to evaluate "all aspects" of potential adverse environmental effects because a total account of the "proposed Air Force action" was not available to the authors.

Objectives

Request

a. "Develop by biological sampling and documentation a description of the existing environmental conditions with regard to water quality and the marine ecosystem zones for the shoreline areas of Tinian".

b. "Evaluate ocean current studies with respect to the discharge of pollutants into the shoreline areas of Tinian".

c. "Evaluate the probable short and long term environmental impact of the harbor construction, harbor operations and discharge of pollutants".

d. "Prepare an inventory of the dominant species of the benthic and pelagic elements in the marine biota".

e. "Provide a discussion and observation of the marine environment related to discharge of pollutants and harbor operations and Federal standards for water quality".

Comment

a. Several months of field sampling would be necessary to answer this requirement in detail. Fortunately we had some general information from previous sampling and survey data for the island's shoreline regions (Tsuda et al., 1970). Even so, the time alloted for this study was inadequate for a thorough consideration.

b. Ocean currents throughout the Marianas are subject to seasonal changes because of changes in strength and direction of the north equatorial drift and the driving tradewinds. Hence, an annual cycle based current study is a must and this preliminary study in no way satisfies that requirement. Furthermore, no definite data were provided about the pollutants to be discharged or the actual site of discharge. The selected sites for the current studies are, therefore, largely the result of guesswork.

c. No data were provided on harbor construction (at either site), harbor operations or discharge of pollutants. We were, therefore, unable to give more than cursory answers to these questions.

d. This was a logical request, based on the general sites marked on the construction map. However, major pelagic species are not common in the inshore sites chosen and were not considered.

e. The problems we have here are the same as those in (c) above.

In general we have attempted to deal, in so far as possible, with the above objectives but have been severely limited by the short contract period and lack of detailed information on construction and operation of the proposed facilities.

Assumptions
(Provided on Request from the Air Force)

Certain assumptions may be required during the course of the study. These assumptions will be made by the technical representative of the contracting officer. The following assumptions are made:

a. "Domestic and industrial waste water will be treated before discharge into the receiving ocean. Industrial waste will be treated initially, separately, and then discharged into the sanitary sewer system for further treatment and dilution. Domestic sewage shall be provided secondary treatment".

b. "Storm water discharges will occur but will not be significantly altered from present conditions by the proposed plan".

c. "Ocean cooling water will not be required for power plant operations and therefore there will be no significant discharge of higher temperature waters".

d. "Sewage outfall(s) will be engineer designed for feasible solutions. Location(s) of outfalls are not presently known. Sewage volume may be estimated initially at approximately 0.2 MGD increasing to 0.5 MGD on a long term basis; these may be discharged in several outfalls".

e. "Solid wastes will be disposed of by sanitary landfill and/or incineration".

f. "Pesticides will be monitored by medical personnel and applied by trained and certified personnel".

LOGISTICS

The 50' catamaran "Havaiki" was chartered to transport all equipment and part of the team to Tinian (Plate 1A). This beamy vessel was not only a useful transporter of our considerable equipment inventory but also served as an oceanographic platform for the 24-hour current studies and provided living quarters and cooking facilities for the team. One room was rented ashore as a home base for working sessions in data analysis. Some meals were obtained ashore. The majority of our food and other supplies were transported from Guam aboard the research vessel.

Equipment included two inflatable rubber boats with outboard drive (Plate 1B), air compressor, diving gear, underwater camera gear and tape recorders, navigation instruments and lights, drift drogues, quadrats, transect tapes, collecting equipment and preserving solutions, microscopes, and other associated requirements for marine surveys. In addition, because of the fuel shortage, considerable quantities of outboard fuel and oil were included. A truck was rented for shore surveys.

ACKNOWLEDGEMENTS

We would like to thank Captain Adolph Flouryanovitch of the Yacht "Havaiki" for making his vessel available.

We owe a considerable debt of gratitude to graduate students Gawel, Strong, and Wooster. They shared with us the many long, cold, and wet hours on the all night current surveys. They were also helpful as collectors of specimens and helped immensely in making contact with the youth sector of Tinian's community.

Marine Technician Ted Tansy likewise shared the load on the 24-hour surveys but, in addition, put in long hours filling SCUBA tanks and keeping all our gear in working condition. Tansy and Strong provided most of our photographs.

We are indebted to Dr. L. G. Eldredge for providing the list of invertebrates (Table 3) and the references pertinent to Tinian (Appendix B), and to Bill Fitzgerald for processing the photographs.

We are most grateful for aid via the radio communication network at the Bar-K Ranch.

Our final note of appreciation goes to the wonderful people of Tinian who were both friendly and helpful to our team, regardless of their feelings about the proposed military base. Particular thanks are due Joe Cruz and his family for the hospitality they provided. Similarly, we are grateful to Al Fleming and his family (Mike, Jim, Connie, and Mrs. Fleming) for their help with communications and other problems. Others who helped us were Distad Representative Frank Chong and his assistant Manny Villagomez, Mayor

Antonio Borja, Ben Manglona, Ben and Joe Sablan, Jerry San Nicholas and his son, Serafin Dela Cruz, and many others whose names we failed to record. We thank you all very much.

DAILY LOG OF OPERATIONS

Field work was conducted from 3 January to 9 January. Daily operations are spelled out in Appendix A.

DESCRIPTION OF METHODOLOGY

Current Studies

Except for Site III all current studies were conducted over a 24-hour period to ensure that normal semidiurnal tidal influence was covered. The research vessel was anchored at the sites shown in Figures 7-10 and 12, 13. Standard survey techniques were used to locate bearing points ashore. Drift drogues were released together at intervals from the vessel (or the channel buoys at Site I) and tracked by small boat. The drogue tracks were plotted by fixing their positions periodically with hand bearing compass lines of position on the known shore points. Between sunset and sunrise, the bearing points ashore were equipped with navigation lights and the drogue buoys were fitted with strobe lights. Drogues were released in pairs with one member of the pair set at 1 m; the other, at 5 m. Since the offshore part of Site III was inaccessible because of rough sea conditions that prevail on windward Tinian during the month of January (Doan et al., 1960), we attempted to inject dye over the reef margin with a crude catapult. This method was not successful in that the dye always landed in the zone of wave transport and was carried immediately back to the reef flat. We then elected to substitute the reef flat for our current study. These data should be useful in the general USAF planning but are of no value in detecting offshore water mass movement. A transect line was stretched from the beach to reef margin and fluorescein dye was released at 20 m intervals. Set and drift of the dye was measured at the end of one minute periods.

Transects

Our survey methods had to be quick and simple because our field time was limited to less than one week. For this reason, transect surveys and data recorded concentrated on three of the more conspicuous features of the reef biota-corals, fishes, and benthic algae. In addition, notes were taken on other organisms found on the transect lines and the general substratum type. A diver-tow survey was conducted at both Sites II and IV to obtain an over-all impression of the structural and developmental aspects of the areas. These surveys helped the authors in placement of transects to cover the dominant community types. Ten study transects 100 m in length were run, three each at Sites I, II, and IV and one at Site III. A transect line marked in one meter intervals was used. The transect sites are shown on Figures 3 to 6. Once the general community types had been identified, a small boat was anchored in the general vicinity of the reef section to be studied. Transect lines were laid from the anchor, parallel to the general contour line under the boat, usually in the reef front zone. Each of the transects was put in place by swimming over the middle part of the reef front zone and letting the line sink to the bottom (Plate 1C). The transect sites were, therefore, basically determined from the boat and not from the water. At Site III the transect was laid perpendicular to the shoreline from the beach to near the reef margin.

Corals

The coral community was analyzed by using a point-centered quarter technique (Cottam et al., 1953). For this technique a series of 10 points, 10 m apart, were selected from the 100 m transect line. The area around each transect point was divided into four equal quadrants. The coral nearest the transect point in each quandrant was located, and its specific name, diameter or basal area, and center of the corallum point to transect point distance was recorded.

From the above data coral density, percentage of substratum coverage by living corals, and frequency of occurrence can be determined. By summing the relative value of each of these parameters an overall Importance Value was assigned to each transect species. A more detailed analysis of the overall species diversity was achieved by making a twenty minute search along the general area on both sides of the transect line.

One hundred-sixty eight coral specimens were collected during the course of the study. These specimens were collected to establish a general reference collection from the study sites.

General Macroinvertebrates

No systematic analysis of the macroinvertebrates other than corals was made. Instead, a general search was made in the vicinity of the transects for specimens, and qualitative observations were noted as to their distribution and abundance.

Fishes

An underwater tape recorder was used to aid in a visual census of fishes (Plate 2A). Animals were counted if they fell within one meter to either side of the transect line and 2 m above it. The 100 m transect was divided into five increments of 20 m each. The total transect consisted of 200 m^2 and each interval was 40 m^2. In all, 2000 m^2 was covered on the 10 transects.

A 100 m transect count usually requires about 20 minutes or less to complete and the observer is restricted to the 2 m wide band centered on the transect.

Such counts frequently overlook many species. Moreover, the transects are not large enough or, in this report, frequent enough by any means to show all available species in these largely nonhomogeneous reef habitats. The counts are relative only, and at best are simple approximations of the fish community. To aid in a measure of the adequacy of the transects, a second count was made in the vicinity of each. This count consisted of a 20-minute random search and was not confined to transect dimensions.

Relative density, relative frequency, and relative random occurrence were computed for the combined transects, and these data were summed to give an Importance Value.

Comparisons were made between transects by computing the Shannon-Wiener diversity index (Pielou, 1966). Direct comparisons were made between each pair of transect components to calculate coefficient of community (Oosting, 1956).

Benthic Algae

The algal community was analyzed by a modified point method designed to incorporate small quadrats (25cmX25cm) placed at 5 or 10 m intervals on a 100 m line transect (Plate 2B). The quadrat frame was divided into a grid of 25 squares, each 5cmX5cm, providing 16 interior "points" where the grid lines intersected. Each species and its average height or width (depending on the growth habit of the alga) was recorded at every "point" at which it occurred. The latter measurements were used to calculate relative dominance. If no alga was found under any of the "points", then whatever was present, e.g., sand, dead coral, live coral, was recorded.

Fine filamentous-like algae, e.g., *Polysiphonia*, *Ceramium*, and *Microcoleus*, were at times difficult to differentiate in the field. In such cases, specimens were collected and later identified with the aid of a microscope.

From these data, values for relative abundance, relative frequency, relative dominance, and the Importance Value (RA + RF + RD) were calculated for each species on each of the 10 transects. In addition, the percent of algal cover in relationship to the amount of dead coral, live coral and sand present in each area was calculated by considering every item recorded at all "points". Coefficient of community (Oosting, 1956) was also calculated for certain transects.

It should be pointed out that the small number of quadrats, 10 or 20, used on each line transect would favor only the more dominant algae being considered in the area. A detailed search made for other algae present within the vicinity of each transect provided a more meaningful checklist of the flora.

RESULTS

General Description of Study Areas

<u>Site I - (Tinian or San Jose Harbor)</u>

This site is located on the southwest corner of the island (Figs. 2 and 3). The harbor area was originally a natural lagoon partially enclosed by a barrier reef that extends from the shore about a mile toward the south and southeast, in a gentle convex arc. The barrier reef has been greatly modified by the construction of an interlocking sheet steel breakwater along its length. Similarly, the original topography of the enclosed lagoon has been nearly obliterated by dredging and filling.

The site is located on the southwest coast of a long low valley or depression zone that trends in a northeast-southwest direction. This narrow depression bisects the island, and the northeast border is located on the east coast at Unai Masalog (near Site III). The physiographic unit has been designated as the "Median Valley" division by Doan <u>et al</u>. (1960) and is bounded on the north side by a broad central plateau unit and on the south side by the high southeastern ridge unit (Fig. 2). The depression was formed originally by faulting, forming a graben valley. The valley was formerly inundated with the southwest coast being the last part to emerge (Doan <u>et al</u>., 1960).

The southern end of the Median Valley division is a flat region with little relief and constitutes a marine terrace generally less than 20 m in elevation. At the harbor area the coast is developed upon an exposure of Mariana limestone, constructional algal facies, which was formerly covered by raised beach sand and gravel. These beach sand and gravel deposits have apparently been mostly removed by excavation. South of the harbor area, the coast is developed upon Mariana limestone, detrital facies, and isolated stretches of beach deposits.

The shoreline at the harbor constitutes a land fill and a 2000-foot long wharf bulkhead and two parallel finger piers (Fig. 3). South of the harbor the shoreline consists of low-lying, solution-pitted exposures of limestone that has been eroded into irregular ridges and pinnacles. Several narrow beaches occur intermittently along the solution-pitted limestone shoreline. The largest of these is located immediately south of the sheet piling wharf bulkhead.

A calcareous sand and gravel Shioya soil (Doan et al., 1960) is developed along the shoreline at the harbor area. To the north and south, the shoreline consists of sloping (8-15%) limestone rock land. Along the wharf to the north end of the harbor the shoreline consists of artificial land fill.

There are no streams developed on the surface of the Median Valley land and drainage is by percolation into the porous limestone.

Site II - (Lamanibot Bay)

This site is located at an embayment along the northwest coast, between Puntan Lamanibot-San Hilo on the north and Puntan Lamanibot-San Papa on the south (Figs. 2 and 4). The bay is about 1900 yards long and about 750 yards in width at its southern end. Judging from the interruption of the coralliferous limestone belt along the coast to the north and south and the cliffed headlands forming the shoreline, it seems that the bay had its origin by gravitational slumping.

The site is located at the northwest corner of the Central Plateau physiographic division. This division makes up the middle and some of the northern parts of Tinian (Fig. 2). Near the station site it consists of a broad exposure of westward-sloping limestone land which is interrupted somewhat to the east of the bay by low fault scarps and faultline scarps which trend more or less in a north-south direction. The coast bordering the bay itself consists of a seaward-sloping terrace with a low undulatory relief.

The coastal land bordering Lamanibot Bay is all developed upon Mariana limestone, detrital facies, except for a narrow coastal strip of constructional coralliferous facies about 200 to 300 m wide.

The shoreline bordering Lamanibot Bay consists of vertical to overhanging seacliffs on the north and south ends and a vertical to near vertical cliff along the head of the bay. The long cliffline bordering the head of the bay is about 50 m high and has a talus slope of large blocks and boulders along much of its base (Plate 2C). The cliffs at the north and south ends of the bay slope seaward from about 30-40 m, where they join those at the head of the bay, to 10-20 m or less at their seaward margins.

Well developed sea level and raised "nips" or notches are cut into the limestone headlands at various elevations. The most prominent raised nips are located between 6 and 13 m above sea level and at places are interrupted and offset by small faults. The sea level nips are most prominent at the north and south ends of the bay where the headland is overhanging 6 m or more. Maximum depth (horizontal) at the nips are not at mean sea level, but slightly above mean high water level. The height of the sea level nips range from less than a meter to nearly five meters at some places.

There is no soil developed along the coastal region of this site. The entire coastline consists of very steep limestone rock land.

No surface streams have developed on the surface of the Central Plateau physiographic division and drainage is by percolation into the porous limestone.

Site III - (Unai Dangkulo)

This site is located on the windward, east side of the island (Figs. 2 and 5). The site consists of an embayment 2.7 miles in length located between Puntan Asiga on the north end and Puntan Masalog on the south end. Steep rocky slopes, cut benches, and cliffed headlands, up to 40 m high, border the coasts along the embayment, except for several small stretches where beach deposits have accumulated behind a fringing reef (Fig. 5). The largest of these beaches is located near the mid-point of the bay. At a few places, beach rock has developed along the intertidal parts of this beach. A narrow fringing reef platform, about 1300 m long and up to 150 m wide, has developed along the inner part of the embayment.

The coastal land along this site has developed upon three physiographic divisions (Fig. 2). The most northern part, from Puntan Asiga to where the depressed region of the Median Valley unit reaches the coast, is located within the Central Plateau division. South of this division, the depressed region extends southward to the higher Southeastern Ridge division, in which the southern part of the coastal embayment is included.

All of the above physiographic divisions which border the coastal regions of the site, are developed upon the Mariana limestone, constructional algae facies, except the Southeastern Ridge, which is developed upon Mariana limestone, detrital facies.

Except for the scattered beach deposits, the coast is composed of rocky limestone land with moderate to very steep slopes and seacliffs. There is little to no soil developed upon this land except for localized patches that have accumulated in small holes and depressions.

There are no streams developed on the surface of the coastal regions bordering the embayment and drainage is by percolation into the porous limestone.

Site IV - (Peipeinigul Bay)

This site is located in a small embayment between Puntan Diablo and a small point about a mile north of the most northern part of the barrier reef at Tinian Harbor (Figs. 2 and 6). It is part of the Central Plateau physiographic division and consists of a low limestone terrace along the coastal part of the site. At the shoreline the terrace consists of irregular seacliffs 5 to 20 m high which at places are cut at the base by narrow benches. A narrow fringing reef platform borders all the seacliffs and cut benches along the site except for a one mile section located east of Puntan Diablo. Sea caves are a conspicuous feature along the coastal cliffs at the east end of the embayment.

The coastal terrace is developed upon Mariana limestone, detrital facies. Along the shoreline, particularly where the fringing reef platforms are developed, there are block-boulder, talus accumulations located at the base of the seacliffs. Prominent nips are cut near sea level along some of the headlands.

The shoreline consists primarily of seacliffs and steep sloped rocky land upon which very little to no soil has developed except for localized patches in cracks, holes, and depressions. A small patch of beach deposits have accumulated at the eastern end of the embayment.

No streams have developed on the surface of the coastal regions bordering the embayment and drainage is by percolation into the porous limestone.

Current Studies

General Comment

The following general comments are in part from Jones and Randall (1973). Transport of water masses around islands in the Marianas is similar to that for most islands in the Central Pacific (Avery et al., 1963). The prevalent northeast tradewinds of the area play a major role in generating the enormous North Equatorial Drift Current which sweeps past the islands from east to west. This great current is responsible for much of the energy that transports water along the coasts of Tinian. The response of the current around Tinian is presumed to be much like that reported by Emery (1962) from Guam. The current tends to split on the north or northeast corner of the island and streams around both the north and south ends. These two streams then may pass along the west coast where they would theoretically converge and continue in a westerly or southwesterly direction. This general pattern is probably far more complicated for Tinian than Guam because of the presence of the island of Saipan immediately up current (Fig. 1) from Tinian. The so called "island effect" may possibly place Tinian in the North Equatorial Current's turbulent slipstream that is induced by Saipan. Downstream of Tinian lies the island of Aguijan (Fig. 1) which may complicate the normal convergence expected to the west of Tinian.

As the North Equatorial Current sweeps along Tinian's coast, the near shore portions of the streams are distorted and forced into complex eddy systems by prominent headlands and local submarine topography. These currents may also alter their flow because of seasonal changes in strength and direction of the North Equatorial Current. They are further complicated in many areas by tidal currents superimposed on them, often resulting in a temporary reversal of direction with changes in tide (Jones and Randall, 1971). Doan et al. (1960) report that the crest of the tidal wave is distorted as it passes through the islands. The resultant tidal flow in the Saipan-Tinian Channel is north northwest on flood tides (2.5 kts) and southeast on ebbs (1.25 kts). They point out that there is a frequent wave chop in the channel created possibly by interference between waves generated in the northeast and the southeast flowing ebbs. The same authors note a similar tidal flux in the Tinian-Aguijan Channel but no actual measurements were made. Tidal difference between Guam and Tinian is about 15 minutes. In addition to the North Equatorial Current and tidal currents, there are also local wind induced surface currents along the shoreline.

Where fringing reefs occur, inshore water movement is generated primarily by tide changes and wave action. These two forces combine to transport water over the reef margin onto fringing reef platforms around the island. This is the case for the reef flats at Site III, but the effect is insignificant at the other three sites where reef flats are poorly developed. Water thus transported then moves in longshore currents for varying distances and finally escapes seaward through surge channels as rip currents.

Site I

Figures 7 and 8 show the results of the 24-hour current survey near the San Jose Harbor entrance. One set of drift drogues was dropped in the harbor itself and, except for number 3i, they generally indicated that there is little circulation of water in the harbor. Most of the flushing is probably tidal, or wind drift from the surface to the harbor mouth and then replacement from deeper layers. No measurements were made of this phenomenon.

The basic pattern for the drogues released at the outer harbor buoys was bidirectional (northwest to southeast). We believe that this is basically a tidal shift with the dominant pattern being northwesterly on ebb tides and southeasterly on floods. From low high to high low water and back to higher high water, the energy in the system is low and changes in tidal current direction may either not occur or may be variable. The movement of the water mass is weak. Greater changes in the tide height such as those between higher high to lower low water and back to high low water result in more consistent changes in tidal current direction and greater velocities.

Average speed for the 1 m drogues was 0.39 kts; for the 5 m drogues, 0.37 kts. The speeds ranged from 0.02 to 1.45 kts.

Site II

Figures 9 and 10 show the results of the 24-hour current study at the north end of Lamanibot Bay. As in the previous example, the drogue movement was basically bidirectional and was again most consistent where the magnitude of tide rise and fall was most pronounced. However, the system was reversed from that at Site I. At Site II, the predominant pattern was north to north-west on floods and south on the strong ebbs.

Average speed for the 1 m drogue was 0.15 kts; for the 5 m drogue, 0.13 kts. The speed ranged from 0.05 to 0.37 kts.

Site III

Because of rough seas, no offshore 24-hour current study was conducted at Unai Dangkulo. Figure 11 shows that the current on the broad reef flat there moved in a general southerly direction from the transect line. Speed at each of the stations at 20 m intervals along the transect line was constant and approximately 0.30 kts. This longshore current is a direct result of wave transport onto the reef flat.

Site IV

Figures 12 and 13 show the results of a 24-hour current study at Peipeinigul Bay. The very slow movement of the bay water mass and its often variable direction suggests that the bay is dominated by an inshore eddy. On only two occasions did pairs of drogues indicate an attempt to leave the bay. Both times the movement was westerly toward Puntan Diablo. Again, the strongest drifts occurred during the greatest tidal rise and fall. We suspect from the preliminary data that primary flushing of the bay may be because of strong north bound currents induced by ebb tides such as those at Site I to the south. These currents would tend to enter the bay and drive water in a westerly direction along its northern border. South bound flood currents would be less likely to influence the bay waters because of shielding by Puntan Diablo. The flood current might however induce an eddy in the bay.

General Physiography and Coral Distribution

Site I - San Jose (= Tinian) Harbor

The most conspicuous physiographic feature of the marine environment at Tinian Harbor is the long arcuate barrier reef which partially encloses a shallow lagoon (Fig. 3). Much of this environment has been greatly altered by the construction activities of building and maintaining the harbor facilities. Most severely disturbed areas are the upper surface of the barrier reef, by construction of a sheet pile breakwater; the shoreline, where the wharf bulkhead is located; and the natural lagoon, by the construction of finger piers and dredging to a reported depth of 36 to 42 feet (Doan et al., 1960). According to Doan et al. (1960), the original depth of the lagoon was probably no more than 20 feet. Regardless of these prior disturbances to the marine environment, the harbor area and lagoon barrier reef zones are at present recolonized by a considerable number of corals and associated reef organisms.

The barrier reef is about 150 m wide and a mile long. It is continuous with the fringing reef at the north end, where it attaches to the island, and extends south and southeast in an arcuate curve. At the widest point it is about 550 m from the original shoreline and at the southern end, which opens to the harbor channel, it is about 360 m from the narrow fringing reef platform located at the south end of the wharf bulkhead.

Three transects, numbers 7, 8, and 9 (Fig. 3), were run on the barrier reef and lagoon floor to determine the density, species composition, and percentage of substrate coverage by living corals.

Transect 8 was located on the lagoon side of the barrier reef (Fig. 3). The eastern end of the transect includes a portion of the old barrier reef flat platform and along the western end it includes a portion of the lagoon floor that was deepened by dredging. Tables 1 and 2 show that the total number of coral species encountered on the transect line was 3 and the total number observed within the general area of the transect during a 20 minute searching period was 15 species. Although 12 more species were observed in the general area than encountered on the transect line, the latter does reflect the dominant corals present. Many of the species encountered during the 20 minute search are represented by a single colony, and many were located because specific habitats were specifically searched for which would yield uncommon or rare species. Searching for these uncommon species is a worthwhile effort because they are, in many instances, more sensitive to environmental changes than the dominant corals present.

Figure 14 is a vertical profile of Transect No. 8. The east end of the transect passes over the lagoon side of the barrier reef surface. This surface is composed of coral-algal rubble and scattered patches of living corals, mostly Pocillopora damicornis. Aggregate clusters, of several colonies or more, of these corals were responsible for much of the relief encountered, but seldom did the clusters exceed a height of 0.5 m above the surrounding surface. Occasionally a small knoll, up to a meter in height, was encountered and it was these knolls where species other than P. damicornis were normally encountered.

A short slope, 5 m long, marks the location where the rubble, coral-algal surface of the barrier reef flat grades into the predominantly sand-covered lagoon floor. The sand of the lagoon floor is primarily of bioclastic origin composed of coral-algal mollusk rubble, Halimenda fragments, and foraminiferan tests. Much of the coral rubble encountered, both on the barrier reef surface and the lagoon floor, was composed of broken fragments of arborescent species of Acropora. These arborescent Acropora species were probably abundant before the original harbor construction activities, but few living colonies of these corals were encountered during the study. Widely scattered over the lagoon floor were coral mounds and knolls which ranged from mere clusters of corals less than a meter in height or width to mounds 10 m across and several meters in height. Species diversity was greater on these mounds than anywhere else on the transect although the total surface coverage by living corals was estimated to be less than 15 percent.

Table 1 shows an overall coral density for Transect 8, at $0.32/m^2$ and the total percentage of substrate covered by living corals at 0.87 percent. These values are considerably less than those for Transect No. 9 and about the same as that for Transect No. 7.

Coral growth at the present time is a community type of development consisting of scattered coral colonies which have contributed very little to the present substrate they are growing upon. Minor reef development in the form of small knobs and mounds is taking place on the barrier reef flat and to a somewhat greater degree on the lagoon floor mounds and knolls.

Transect 7 is located along the southern third of the wharf bulkhead (Fig. 3). It represents an area that was totally disturbed during harbor construction. The transect line was laid on the lagoon floor 1 to 2 m away from the bulkhead sheet spiling. Figure 15 is a vertical profile of the transect area. Depth along the transect ranged from 8 to 9 m depending somewhat on the local accumulation of metal junk and trash that was abundantly distributed along the entire bulkhead. Most conspicuous of this trash, but not because of size, was a cluster of three or four bombs that appeared to be in the 250 lb. class.

On the bulkhead itself corals were abundantly encrusting the metal surface from just below low tide level to the lagoon floor. The lagoon floor consisted of unconsolidated calcareous material, similar to that encountered along the lagoon side of the barrier reef (Transect No. 8), except for the presence of a greater fraction of fine sand, Halimeda fragments, and lime silt. On the lagoon floor corals were fairly abundant on scattered boulders, cement rubble, and the exposed surfaces of the various kinds of metal junk. The standing crop of Halimeda opuntia, a green calcareous algae, was exceptionally dense along the bulkhead and at places presented an entangled mat 10 cm or more in thickness. Farther away from the bulkhead the number of corals observed was less due to the presence of more sand and less hard rubble and junk for corals to colonize.

Table 1 shows that the total number of coral species encountered on the transect line was 15 and the total number observed within the general area of the transect during a 20 minute searching period was 50 species (Table 2). The species encountered on the transect line reflects the dominant corals present on the lagoon floor. Fungia scutaria, a solitary coral, was the most frequently encountered species, and Pocillopora damicornis was the second most commonly encountered. Except for the above, the species composition on the bulkhead wall was similar to that on the lagoon floor, but density and percentage of live coral coverage appeared to be greater. Acroporoid corals were widely scattered and rare as was found on Transect No. 8. Leptoseris species were fairly common on the lower part of the bulkhead wall which reflects somewhat on the increased turbidity of the water. Normally these corals are commonly found in deeper habitats except for cavernous regions in shallow water. But because of increased turbidity reducing the available light on the bulkhead wall, this habitat was similar to that found in deeper regions.

Coral growth on the bulkhead pilings and adjacent lagoon floor constitutes a coral community type of development which consists of scattered colonies growing upon a substrate other than that of its own development.

Coral density along the entire transect was $0.56/m^2$ and percentage of living coral coverage was 0.64 (Table 1).

These values are similar to that found at Transect No. 8 along the lagoon side of the barrier reef but considerably less than that found on the seaward side of the barrier reef (Transect No. 9).

Transect No. 9 is located on the seaward side of the barrier reef (Fig. 3) and represents a location which was relatively undisturbed during the harbor construction activities. The transect was placed parallel to the barrier reef margin, within the reef front zone, at a depth of 3 to 8 m. Figure 16 is a vertical profile through the seaward part of the barrier reef about mid-way along the transect length.

The barrier reef flat zone was not quantitatively measured, but observations there revealed more coral growth than on the lagoonward reef flat side.

A particularly rich growth of corals was found in this zone at the extreme southern end of the breakwater. The reef margin is a zone in which Acropora and Pocillopora coral species and encrusting red algae are abundant. Short surge channels and buttresses cut through the reef margin and are contiguous with the submarine channels and buttresses observed in the reef front zone. Where the transect line was run, these channels were 2 to 5 m in width, separated by lobate buttresses 5 to 15 m wide, and to 6 m in height. Irregular features on the upper surface of the buttresses such as knobs, pinnacles, and bosses sometimes extended upward to within a meter of the surface. A sandy floored terrace with scattered coral mounds borders the seaward side of the reef front zone. Table 1 shows a total of 21 species that were encountered on the transect line and a total of 76 species that were observed within the general transect area during a 20 minute search period (Table 2).

Coral density was $18.90/m^2$ and percentage of living coral coverage was 40.91 (Table 1). Species diversity, density, and percentage of living coral coverage is considerably greater on the seaward side of the barrier reef (Transect 9) than on the lagoonward side (Transect 8) and lagoon floor (Transect 7).

This region was observed by a team of divers in 1969, 1970, and 1971 and was found to have sustained considerable Acanthaster planci starfish (Plate 3A) damage. Both the 1969 and 1970 survey revealed an area of predominately dead corals, and the 1971 survey revealed some coral recovery. Observations and coral density and percent of substrate covered appear to indicate that coral recovery and recolonization is continuing following the damage caused by A. planci.

Brief examinations of the narrow fringing reef platforms south of the wharf bulkhead reveal a scattered growth of corals, sandy floored terraces, and isolated coral mounds and knolls. In comparison to other areas where quantitative measurements were made, the living coral covering the substrate appears to be less than 10 percent.

Site II - Lamanibot Bay

Three transects were laid at this site (Fig. 4). The entire shoreline consists of seacliffs which at some places are buttressed at the base by a talus slope of blocks and boulders (Plate 2C). Fringing reef platforms are absent along the shore at the north and south end of the bay and are intermittent and weakly developed along the long shoreline at the head of the bay (Fig. 4). The fringing reef platform is definitely better developed at the southern end and becomes increasingly less developed toward the northern end. Large amounts of metal junk have been dumped over the cliff at the north end and is now scattered over a considerable area in the vicinity of Transects 4 and 5 (Plate 4A). Transect 4 was laid in 8 to 10 m of water parallel to the shoreline at the north end of the bay (Fig. 4). Figure 17 shows a vertical profile located at approximately mid-point along the transect line. There is little to no reef development along the entire transect. Corals form a community type of development encrusting an older substrate surface. From the cliff edge, the floor slopes rather steeply downward to about 8-10 m and then slopes less steeply to a submarine terrace at about 15 to 25 m in depth. The coral community is more dense along the upper stretches of the slope which is 2 to 8 m in depth. In this upper region Pocillopora species were dominant. A rather unique feature of the population is that all the colonies are of a rather small uniform size range (Plate 3B). Very few of these colonies exceeded 15 to 20 cm in diameter. Colony size and density decreased as the flat barren rock floor of the submarine terrace was approached, but coral diversity increased.

The submarine terrace floor consisted of a flat jointed limestone pavement (Plate 3C). At places it was extremely sand scoured with few coral colonies present. Most corals on the terrace were restricted to places where rocky knobs or low patches of boulder rubble had accumulated. Table 1 shows the species occurring on the transect and Table 2 shows those observed during a 20 minute search period. Small encrusting patches of Leptastrea purpurea and small cespitose clumps of Pocillopora meandrina were the most commonly encountered corals.

Forty-nine species were observed in the general transect area (Table 2) and 11 species were encountered on the transect line (Table 1). Species density for this transect was $39.51/m^2$ and the percentage of substratum covered by living corals was 9.47 (Table 1).

Transect 5 is located parallel to the 40 m seacliff at the north end of the bay at a depth of 8 to 10 m (Fig. 4). A buttress talus slope of blocks and boulders forms the intertidal zone. A vertical profile taken at right angles to transect line about midway along it is shown in Figure 18. A very narrow platform borders the base of the cliff, from which the floor slopes very gently to the submarine terrace at 15 to 25 m in depth.

The upper part of the slope, from 2 to 8 m in depth, is characterized by an erosional spur and groove system. The limestone spurs are pavement like and sand scoured in places. The grooves are 2 to 8 m in depth, most with large rounded boulders on their floors, and are sand scoured.

The outer slope, from 8 to 20 m in depth, is a low-angled continuation of the shallower spur and groove system. It is at some places a flat, barren, jointed pavement of limestone, except where the shallow grooves cut across its surface. The relief is low and flat except where offsets occur in the jointing plains of the bedrock or an occasional mound or knob protudes from the surface. At other places the bedrock is veneered by a layer of sand and gravel and scattered blocks and boulders (Plate 4B).

Coral growth on these sand scoured slopes consists of small widely scattered encrusting colonies which constitute a community type of development. A small amount of developmental accretion is present in the form of small mounds, knobs, and pinnacles on the upper surface of relief features which are above the major zone of sand and boulder abrasion.

Twenty-six coral species were observed within the general transect area (Table

2) and 11 species were encountered on the transect line (Table 1). Species density for this transect was 1.96/m^2 and the percentage of substratum covered by living corals was 0.46 (Table 1).

Coral density and percentage of substratum covered by living corals is less on this transect than for Transects 4 and 6 (Table 1). Diversity of species is also lower than that of the other two transects (Table 2). Leptastrea purpurea is the dominant coral occurring on the sand scoured sand veneered slopes of this transect (Table 1). Most coral colonies are of encrusting growth form and of small size. Numerous dead colonies and partially dead colonies are abundant and seem to be caused, for the most part, by temporary burial and abrasive action of wave transported sand and gravel.

Transect 6 is located in the southern part of the bay (Fig. 4). It parallels a narrow fringing reef platform, in the reef front zone, at a depth of 8 to 10 m. Figure 19 shows a vertical profile taken at the mid-point and at right angles to the transect line. The shoreline consists of a 40-meter cliff which is buttressed by a talus slope of large blocks and boulders. A narrow fringing reef flat platform borders the block and boulder slope. The reef flat is flat and barren, cut by surge channel fissures and channels which vary considerably in width and depth. Very few corals were growing in this zone except for a few scattered colonies on the surge channel walls and in reef flat holes.

The reef margin and reef front zones consist of a buttress and channel system that slopes rather gently to a submarine terrace at about 20 m in depth. Deep submarine channels cut through the reef front zone giving the adjacent buttresses a relief of 5 to 10 m (Plate 4C). Boulders, sand, and gravel cover the floor of most channels and there is evidence of considerable erosion along the floor by the presence of undercut walls and smooth scoured floors. Some channels terminate at the seaward end in large potholes containing rounded boulders. Even though erosion is evident in the lower parts of the channels there is a considerable growth of corals on the upper parts of their walls and the upper surface of the long buttresses. Considerable reef development is taking place in the upper parts of these physiographic features giving them an irregular relief. Massive colonies of Goniastrea retiformis and Favia stelligera are the most common corals on the upper surface of the buttresses. These two species are responsible for the basic development of pinnacles, knobs, and bosses upon which numerous other corals develop secondarily. Lobophyllia costata formed large hemispherical heads on the upper margins of the channel walls, many of which, are over a meter in diameter. Encrusting patches of Montipora and corymbose colonies of Acropora were also common. Pocillopora species formed clusters at the upper margins of the reef margin surge channels.

Eighty-three coral species were observed within the general transect area (Table 2) and 18 species were encountered on the transect line (Table 1). Species density for this transect was 15.97/m^2, and the percentage of substratum covered by living corals was 13.27 (Table 1).

Except for coral density, species diversity and percentage of living corals covering the substratum was higher on this transect than on Transects 4 and 5 at the north end of the bay (Table 1).

The starfish survey teams of 1969 and 1970 found that the corals in Lamanibot Bay had sustained considerable damage from Acanthaster planci predation

(Tsuda et al., 1970). A tow survey of this entire region revealed that many of these corals were not entirely killed. Growth of small surviving patches plus recolonization by new corals is quite evident in most places (Plate 3D).

Site III - Unai Dangkulo

This site is located on the northeast, windward coast of Tinian (Fig. 2 and 5). High seas and swells prevented the investigation of the reef zones located seaward of the outer edge of the reef flat platform. Part of this large embayment is bordered by a reef flat platform that at places is over 100 m wide. Our team investigated the southern end of the fringing reef platform at Unai Dangkulo.

Transect 10 was run at right angles to the shoreline and reef margin (Fig. 11). Figure 20 shows a vertical profile of the reef flat platform at the transect location. A narrow band of seaward inclined beach rock occupies the intertidal zone. The fringing reef flat is 120 m wide and has no inner reef flat moat developed. The platform slopes seaward very gently from the shoreline to the algal ridge at the reef margin. The algal ridge forms a convex rim, 20 to 30 m wide, which is elevated about 0.5 m above the general level of the outer reef flat surface. Surge channels, 2 to 8 m in depth, cut through the reef margin. Some of the longer surge channels are 40 m long and are partly roofed over along their length forming cavernous sections which periodically open into pools. A rich growth of corals was found in the surge channel pools and other holes and depressions.

Between the algal ridge and the shoreline the reef flat platform is composed or rather solid reef rock. The reef flat surface is very irregular because of knobs, mounds, holes, and ridges. Maximum relief of these surface features is generally less than 0. 5 m. Corals were locally abundant in the depressed parts of the reef flat and less abundant where the reef flat level was higher. In general, coral density and diversity increased steadily toward the reef margin zone. The deepest part of the platform was about 2 m and occurred just before the algal ridge rise was encountered.

Thirty-five coral species were observed within the general transect area (Table 2) and 12 were encountered on the transect line (Table 1). Species density for this transect was 0.58/m^2, and the percentage of substratum covered by living corals was 3.32 (Table 1).

A rather conspicuous feature of the reef flat platform was the presence of a dense community of foraminiferans, Calcarina spengleri, entangled in the short algal turf. This foraminiferan community was rather uniformily distributed across the entire reef flat platforms.

Benches are cut into the rocky shorelines where fringing reef platforms are not developed. Many of these bench platforms have rimmed terraced pools on their upper surface. Calcareous red algae dominates these bench surfaces, but the pools, if well supplied with water by wave wash, contain numerous invertebrates and a few fishes and corals as well. High seas prevented collecting and quantitative assessment of these benches.

Site IV - Peipeinigul Bay

This site is located on the southwest, leeward coast north of San Jose Harbor (Figs. 2 and 6).

Narrow fringing reef platforms fringe much of the shoreline along the site except for the western arm of the bay which is bordered by narrow cut benches.

Transect 1 is located on the eastern shore of the bay (Fig. 6). It was laid down parallel to the reef margin along the reef front zone at a depth of 8 to 10 m. Figure 21 is a vertical profile of the mid-part of the transect, run at right angles to the shoreline.

The narrow reef flat platform is relatively flat and is cut by surge channels at the reef margin. A well-developed buttress and channel system occupies the reef front zone. The seaward edge of the reef front zone slopes downward rather rapidly to a sandy-floored submarine terrace, 16 to 20 m in depth. Isolated coral mounds and knolls are scattered over the surface of the terrace. Surface topography is very irregular due to numerous mounds, knobs, and bosses which have developed on the reef front buttresses (Plate 4D). Some of the wider submarine channels cut all the way through the ree front to the general level of the submarine terrace, while others are much narrower and shallower.

This region was moderately damaged by Acanthaster planci (Tsuda et al., 1970) and in most places shows considerable recovery from isolated growing patches of corals that survived the starfish predation and by recolonization by newly settled corals (Plate 3D).

Eighty-nine coral species were observed within the general transect area (Table 2) and 16 were encountered on the transect line. Species density for this transect was 15.29/m^2, and the percentage of substratum covered by living corals was 15.22 (Table 1). Porites (S.) iwayamaensis and P. (S.) convexa were particularly abundant in the reef front zones. Many of these Porites species of corals were not killed by Acanthaster planci, which now accounts for their abundance.

Transect 2 is located along the northern shore of the bay (Fig. 6). A narrow fringing reef flat borders the shoreline at this location. This Transect was laid down parallel to the reef margin, in the reef front zone at a depth ranging from 6 to 8 m. Figure 22 is a vertical profile of the mid-part of the transect run at right angles to the shoreline.

The reef flat platform surface and reef margin edge are very irregular. This irregularity is because of the presence of surge channels at least in part, which, in places, are enlarged into holes 5 to 10 m across. The reef front and reef margin buttress and channel system is also irregular when compared to Transect 1. At some places erosion seems to be taking place while at other nearby locations there are developmental features present. Boulder rubble is present in the submarine channel floors and at places they are worn smooth by erosion. This rather irregular system of channels, grooves, and ridge-like buttresses ends rather abruptly on a boulder, sand, and gravel strewn submarine terrace about 8 to 15 m in depth. Mounds and knolls are scattered over the surface of the terrace, but only minor growths of living corals were observed on them. These isolated patches were probably more completely killed by Acanthaster planci predation and recovery is progressing more slowly.

Fifty-three coral species were observed within the general transect area (Table 2) and 18 were encountered on the transect line (Table 1). Species density for this transect was 21.05/m^2, and the percentage of substratum covered by living corals was 25.63 (Table 1). Coral species diversity is lower than that found at Transect 1, but coral density and percentage of substrate surface coverage is greater (Table 1). Pocillopora and Acropora species are more abundant here than on Transect 1.

Transect 3 is located on the extreme west end of the bay (Fig. 6). There is no fringing reef platform bordering the shoreline along this section of the bay. A rather irregularly margined narrow bench is cut into the low limestone seacliffs at the transect site (Plate 2D). The transect was laid down parallel to the cut bench at a depth of 8 to 10 m. Figure 23 is a vertical profile run at right angles to the bench margin at the mid-part of the transect.

The east half of the transect is located on a narrow shelf about 3 to 8 m in depth and 10 to 30 m wide. Coral growth on this shelf constitutes a community type of development, but some local patches of reef accretion are taking place along the margins of fissures and at isolated knobs and pinnacles which are scattered over the shelf. The seaward edge of the shelf drops off steeply to a rocky submarine terrace 20 to 35 m in depth.

Along the western half of the transect the shelf disappears and grades into a seacliff. The transect was run along the vertical face of the cliff. Coral density was much less on the seacliff face than on the narrow shelf to the east. At 20 to 30 m the seacliff grades into a rather barren rocky submarine terrace with little coral growth present.

Sixty-two coral species were observed within the general transect area (Table 2), and 25 were encountered on the transect line (Table 1). Species density was 19.37/m^2 and the percentage of substratum covered by living corals was 7.82 (Table 1). Coral species diversity and density is fairly high along the transect but the percentage of substratum coverage is lower than that found at Transects 1 and 2 (Table 1).

Acropora and *Pocillopora* species dominate the narrow shelf at the east end of the transect whereas encrusting species of *Montipora*, *Pavona*, and small nodules of *Favia* were more common on the seacliff face along the western end.

Macroinvertebrates

Table 3 lists the macroinvertebrates other than corals which were observed or collected near the four major study sites.

Fishes

Table 4 is a list of 246 fish species now known from Tinian. This probably includes about 30 percent of the total fish species from Tinian. The list includes 135 species observed or collected during a previous expedition. Many of the latter are from a rotenone station near Site IV. The present expedition yielded an additional 111 species. A total of 180 species were actually observed in the immediate vicinity of the 10 transects. This includes both the actual transect counts and the 20 minute random counts along the transects. Of the 180 species observed, 118 were counted on the transects (2000 m^2) and an additional 62 which were not seen on the transects were added by the random counts.

Table 5 summarizes the data in Table 4 by site. It shows that Site IV seems to be the most heavily populated area with regard to fishes. Sites I and II, the potential harbor sites, are rather similar. As would be expected, the reef flat area at Site III had the lowest population of fishes. This is to be expected not only because the area studied was only one third of the area (200 vs 600m^2) of previous sites but also because it reflects the normally depauperate fish community found on fringing reef flat platforms.

Table 6 indicates that Transects 1 and 2 of Site IV, 5 and 6 of Site II and 9 of Site I were high in most categories examined for the fish community. Transect 7 shows low numbers in most categories but a high Shannon-Wiener diversity index. This reflects a weakness of the index. The small number of individuals combined with a reasonably large number of species computes as high diversity. Transect 7 was obviously one of the poorer areas. Had it not been for the concentrating influence of metal debris jettisoned from the wharf, the number of species and individuals would have been much lower.

Table 7 shows a matrix of similarity coefficients. Except for some notable examples, agreement is low. There is good agreement between Transects 1, 2, and 6, fair agreement between 3 and 4, and good agreement between 3 and 5.

It would not be unreasonable to consider 3, 4, and 5 as a similar group. Transect 10 has little in common with any of the other transects. The similarities between 3, 4, and 5 are probably because of their related physiographic structure and therefore their similarity in physical habitat. All three are found along cliffbound coasts where fringing reefs including an actively growing coral matrix are absent or poorly developed. 1, 2, and 6 are all characterized by a well-developed and actively growing fringing reef. This results in a wider variety of physical habitats and, hence, a more complex fish community structure. It seems odd at first that Transect 9 does not fit well into this group. However, 9 is located on a barrier form of reef and not a typical fringing type. Its weak agreement with Transect 6. might be related to the fact that both are subjected to more frequent, heavy wave attack than any of the other transects.

Table 6 shows that the transect counts are not totally reliable in accounting for all species in a study area. The 20-minute random count, in most cases, doubled or nearly doubled the transect counts. The consistency of this relationship, however, does show at least a relative approximation of the fish community, complete with individual counts. As usual, both counts fail in an absolute estimation of the total community due to the general absence of both nocturnal and other cryptic species and the artificial time limits imposed.

Importance Values were calculated for each species on the combined transects. Table 8 provides rank order presentation of some of the more important species. The dominating families, with importance values greater than one, are the Pomacentridae (11 spp.), the Labridae (8 spp.), the Blenniidae (4 spp.), the Cirrhitidae and Scaridae (3 spp.each), and the Acanthuridae, Apogonidae, Eleotridae, Mullidae, and Serranidae (1 sp. each).

Benthic Algae

Table 9 lists the 84 species of marine benthic algae, thus far, collected or observed from Tinian. The compilation is based on three visits (June 1970, August 1970, and January 1974) and probably represents about 60% of the algal species that are actually present on Tinian. The presence or absence of the algal species is also denoted in the table.

During June and August 1970, 41 genera and 58 species were collected, cataloged (RT 33351-3366, 3571-3603, 3667-3714) and deposited in the University of Guam, Marine Laboratory's Herbarium. In contrast, 51 genera and 71 species were observed at the ten transect sites. A comparison of the number of species (Table 10) collected during June/August 1970 and January 1974, revealed that only 45 of the 81 species (coefficient of community = 53%) were similar. This difference reflects collecting effort rather than seasonality, since the 1970 collections were made from seven sites while the 1974 collections were based on ten sites. In addition, collections were made, for the most part, in different sectors of the island.

Table 11 summarizes the number of algal species observed at each transect site. Table 12 presents the relative abundance, relative frequency, relative dominance, and Importance Value of the major algae found at each transect area.

Site IV - Peipeinigul Bay

As related earlier, the three transects in this bay were chosen because of their different topographic features and organismal differences. The quantitative data accumulated on the algae reflects this in two ways. Firstly, only 12 of the 41 species observed in this bay were present at all three transects. The "coefficient of community" was a low 31.7%. Secondly, the most important species (IV) differed at each transect. *Amphiroa fragilissima*, *Dictyota bartayresii*, and *Microcoleus lyngbyaceus* had the highest Importance Value at Transects 1, 2, and 3, respectively. *Dictyota bartayresii* and *Jania capillacea* were present among the top five species in terms of

Importance Value at all three transects.

Site II - Lamanibot Bay

The three transects in this bay also were different in terms of algal importance. Only 10 of the 33 species (coefficient of community = 30.3%) were found at all three transects. Galaxaura fascicularis, Microcoleus lyngbyaceus, and Dictyota bartayresii were the most important species at Transects 4, 5, and 6, respectively. Microcoleus lyngbyaceus, Rhizoclonium samoense, and Ceramium sp. were the conspicuous algae in those areas covered with a thin layer of sand (ca. 2-3 cm deep) at Transect 5. Benthic algae were absent in deep sand pockets which constitute about 18% of the transect line.

Site I - San Jose Harbor

The algae found in this harbor (Transects 7 and 8) were similar to those one would expect on sand/silt substratum. Halimeda opuntia was the most important alga in both transect areas. At Transect 7, H. opuntia formed clumps up to 35 cm deep on the silty bottom. The majority of algae observed in this transect area occurred on the vertical steel pilings.

Transect 8, run in shallower water, revealed a somewhat more sand-oriented flora. Aside from H. opuntia, sand dwelling species such as H. macroloba, Caulerpa sertularioides, and the vascular plant Halophila minor were conspicuous. Dictyota bartayresii was by far the most abundant alga present on limestone substratum. The difference in the algal flora in Transects 7 and 8 can be seen by examining the coefficient of community. Only 13 of the 34 species (coefficient of community = 38.2%) observed in the harbor were present at both transects.

Transect 9 was run outside of the harbor proper and possessed a rich marine flora. A total of 32 species was found in this area alone. Short tufts of Gelidium pusillum, about 1 cm high, were distributed (RF=20.5%) throughout the area.

Site III - Unai Dangkulo

Only one transect was run on this fringing reef which explains the low number of species (23 species) observed here. Amphiroa fragilissima and Halimeda opuntia were the most important species (IV = 158.3 and 60.1, respectively). The absence of an exposed reef margin at low tide on this fringing reef is the primary reason for the absence of Sargassum cristaefolium (Tsuda, 1972) on Tinian. The absence of both Enhalus acoroides (sea grass) and Enteromorpha spp. were quite conspicuous here. This may be indicative of the limited freshwater runoff in this bay.

Marine Resources

We recognize four potentially valuable marine resources on the island.

1. Recreational/tourist facilities associated with the marine environment. This would include sportfishing, SCUBA, skin diving, and glass bottom boat industries. Development of these activities is contingent upon the concurrent development of tourist support facilities such as hotels. Such facilities are now being developed on Tinian.
2. Commercial harvesting of inshore fish species represents some potential promise.

We found only three fishermen on the island that made 50% or more of their living fishing. Numerous other people in San Jose Village were part-time commerical fishermen (less than 50% of living) or subsistence fishermen. The primary species taken are in the families Acanthuridae, surgeonfishes (Hugupau, Hijuc, and Tataga); Holocentridae, squirrelfishes (Sesiok and Sagsag); kyphosidae, rudderfishes (Guili); Labridae, wrasses (Tanguisun); Lutjanidae, snappers (Mafuti, Tagafi); Mullidae, goatfishes (Salmonete); Scaridae, parrotfishes (Lagua); Serranidae, groupers (Gadao); and Siganidae, rabbitfishes (Sesjun). The above species are taken in part with hook and line but in greater numbers by spearfishing, particularly at night. Although boats are used for some of this night fishing, we were given the impression that the leeward coast fishing sites were reached primarily by car. Very little spearfishing is done on the windward coast due to the heavy seas that prevail there during most of the year. Several of the fishermen complained about dynamite fishing conducted by boats home ported in Saipan. Evidence of dynamiting was found in several areas in the form of damaged coral heads, especially in Lamanibot Bay.

There is some limited fishing for pelagic species including Corphoenidae, dolphin or mahi mahi; Scombridae, wahoo (Tosun) and the yellowfin and skipjack tunas; and Sphyraenidae, barracudas (Alu). All fishermen interviewed indicated a rich potential in pelagic species but noted that the shark population offshore was large and make it difficult to successfully land fishes hooked by trolling.

3. It was evident from talking to Tinian's fishermen that there is a significantly larger spiny lobster (Panulirus) population than is

available on Guam. Our survey data do not indicate this because the spiny lobster in the Marianas is very cryptic and becomes active only at night, when the major fishery occurs. The presently low fishing pressure is no doubt a contributing factor to the abundnace of this animal.

4. The coconut crab (Birgus latro) is another invertebrate organism which is of considerable economic interest to the people. The adult animals are land dwellers and only the larvae are found in the sea. Further discussion of this animal will be left to the team doing the terrestrial portion of the EIS.

Previous Acanthaster Studies

Three previous Acanthaster surveys (Survey I - July 22 to August 2, 1969; Survey II - August 11, 14 to 16, 1970; and Survey III - October 19 to 20, 1971) have been conducted along the coast of Tinian. The purpose of these surveys was to observe population levels and general movement of Acanthaster planci, and to assess any reef damage caused by this predatory starfish.

The same survey procedure was used throughout. Two individuals were towed behind the boat at a speed of approximately two knots for 10 to 30 minutes. In the course of towing, each team member counted the number of fresh feeding sites (white patches) and A. planci seen on his side of the boat's wake. These numbers were totaled following the tow and provided a rough estimate on the population of Acanthaster in the area. The majority of the tows were made in a zigzag manner over the submarine terrace and slopes to insure that corals growing at various depths were observed. The maximum depth of visibility varied from 7 to 15 m depending on the turbidity of the water and the prevailing weather at the time the tows were made.

Survey I. Based on the July-August 1969 survey, Chesher (1969) cited *A. planci* in above normal concentrations at almost all stations and indicated five specific sites on his map where they were abundant. These locations were, 1) at the northern tip, 2) Unai Dangkulo, 3) Fanechiba Bay, 4) 1 km south of San Jose Harbor, and 5) Peipeinigul Bay.

Survey II. The 1970 team (Tsuda *et al*., 1970) found *A. planci* still present but in small numbers in two of the above areas (1 and 3). The other three areas possessed normal concentrations of starfish. The corals were for the most part dead except for a few scattered corals in shallow water. Only eight *Acanthaster* were observed during four tows totaling 45 minutes at Unai Dangkulo. A small population of actively feeding *Acanthaster* was seen on the northwestern tip where a 20-minute tow revealed 111 fresh feeding sites and 56 *A. planci*. The corals in this area were approximately 80% dead. However, live scattered corals persisted on the submarine terrace on the northeastern sector of Tinian. Three tows in Fanechiba Bay (SW side of island) revealed 57 *Acanthaster* and numerous fresh feeding sites in a period of 40 minutes. Fifty-three *Acanthaster* were found immediately below Pt. Castiyo.

In addition to the two infested areas found in 1970, another new population was located in Lamanibot Bay. A 20-minute tow revealed 49 fresh feeding sites and 27 *Acanthaster* in this bay. The corals on the submarine terrace were for the most part dead.

Survey III. Thirty-four *Acanthaster* and 27 fresh feeding sites were observed in October 1971 (Marsh *et al.*, 1971) at 13 stations on Tinian. The largest concentration was found just north of the harbor on reefs inside the surf in water 1 to 3 m deep. The four-member team spent 20 minutes snorkeling here and found 19 starfish and 25 feeding sites. Approximately 75% of the corals were still alive in this area.

Five starfish and one fresh feeding site were found in a 10-minute tow along the northwestern tip of the island where the 1970 team reported a small population of actively feeding animals. About 70% of the corals in this area were dead.

Only one feeding site and no starfish were found at the other stations on the leeward coast. Most of the scattered corals on the rocky submarine platform were dead. The windward side of the island was not surveyed because of heavy seas.

1974 Environmental Study. Very few *Acanthaster* were seen during the recent survey on Tinian. One of us (Jones) saw four starfish in Peipeinigul Bay. This was the largest quantity seen by any of the team members in the transect areas. However, at least one *Acanthaster* was seen in each transect area.

CONCLUSIONS

Site I San Jose Harbor

If our assumptions are correct, that : there will be no discharge of any kind into the harbor, there will be no increase in physical dimensions of the harbor, and the only construction will be redredging and repair of existing wharfage and breakwaters, then we can see no irreversible environmental damage that might occur in the harbor. The preliminary current data indicate that fine particles of dredge spoil might remain in suspension in the harbor for some time. Since most of the extant organisms will already be physically destroyed or driven from the harbor by dredging, the effects of sedimentation and turbidity will not be significant and should be of short duration. The current data indicate that sediments which remain in suspension and that are eventually carried to the harbor entrance, will be rapidly dissipated by the northwest/southeast flow. Fish and coral data both show that the harbor is not as rich a community as most of the other relatively undisturbed sites. Yet there are signs that there has been considerable recovery of marine organisms where substratum exists to provide a settling surface or shelter to the biota. This would indicate that once the construction activities have been terminated and the harbor waters clear, recolonization will begin again. Since the majority of the harbor bottom is primarily silt, the harbor will never have the species diversity or biomass that is associated with reef facies. We see no objection to renovating San Jose Harbor or the likelihood of irreversible damage. Of all the sites, this one seems least susceptible to the impact of the proposed development.

Site II Lamanibot Bay

If our assumption is correct, in that any harbor facility built here would be small (perhaps a one ship berth or mooring) and that it would be located at the north end of the bay, then we would conclude that the environmental impact to the marine community would not be catastrophic. Transects 4 and 5 were conducted in this part of the bay and did not show a high community complexity. This area is basically scoured out and has poor to non-existent fringing reef development. The walls of the bay and bottom at the north end are of a monotonous configuration. Furthermore, it is the site of a World War II metal dump. The fish community owed much of its diversity to the tendency of this material to concentrate the fishes by providing habitat in an otherwise featureless area. The corals that occur here are found in scattered communities and do not form a complex, growing matrix.

Transect 6 at the south end of the bay contrasted considerably with the above. Here the reef framework was well developed and the community of marine organisms well developed. Should pier construction be considered for this end of the bay, considerably more damage to the environment could be expected. The intense wave force we noted at the south end of the bay is responsible to a large degree for the well developed fringing reef and associated organisms. It would seem that this phenomenon, which contributes favorably to the marine community, would be unfavorable to the construction and maintenance of harbor facilities.

Site III Unai Dangkulo

Since no actual construction projects were mentioned for this windward area, it is not considered in detail herein. The reef flat community is typical and shows no sign of previous disturbance by man. The real value of the area would appear to be recreational, and we would hope that the Air Force will recognize this value and avoid construction here. Our evidence, scant as it is, would indicate that possible ocean outfalls on the windward coast would be unwise at best. A large percentage of any sewage released offshore here, we feel, would be carried back to the beach.

The prevailing weather conditions prevented our working with offshore marine communities or currents. We would, however, expect the communities to be similar to those on windward Guam reefs, well developed in both diversity and biomass. The heavy and nearly constant surf on these shores results in a fast growing reef matrix. Evidence of this can be seen in the deep surge channels in the reef margin, some of which are overgrown by coral development, and thus form caverns. We regret that we are unable to provide transect data for the offshore portions.

Site IV Peipeinigul Bay

This bay is the possible choice for a sewer outfall. The bay itself would make a poor choice for such a venture due to poor circulation. We are studying a similar bay on Guam, also chosen for an outfall, and have reached the same conclusions there after many months of current studies. The preliminary data from Peipeinigul Bay show that movement of water out of the bay is often very slow. Furthermore, there is some indication of an eddy in the bay. All the above would tend to concentrate sewage effluent. Our transect work (1, 2, 3) indicates that the marine community is best developed in the bay itself and tends to decrease in complexity toward the cliff-bound coast of Puntan Diablo (Plate 2D). If an outfall is to be contemplated for this bay we would suggest it be placed at Puntan Diablo where the impact would be on a less well-developed marine community and the movement of the water masses would be more rapid and consistent. This is of course based upon very little data and the final location of the outfall should be based on a more detailed survey that includes both biologists, engineers and hopefully a physical oceanographer.

RECOMMENDATIONS

1. Conduct an annual cycle current study at the site of any proposed sewer outfall.

2. Resurvey each site once definite decisions have been made about construction, operation, and maintenance of facilities.

3. Arrange for consultation and periodic visits to construction sites by both terrestrial and marine biologists. Likewise, seek environmental suggestions during final planning stages. Small changes in planning may result in considerable reduction in environmental impact.

4. At Site I, avoid damage to the seaward side of barrier reef and the patch reef south of the harbor mouth. The latter is unique on Tinian, the only one of its kind there. If possible, leave the lagoon side of the barrier reef intact since it is the site of considerable recolonization of marine organisms. Consideration might be given to a small circulation channel through the barrier at the north end of the harbor to improve flushing. We would hope that launching and possibly some modest mooring facilities will be made available to the civilian community at the north end of the harbor. The same area could be used as a marina for R&R vessels, sport fishing boats, and sailboats of military personnel. Sites for such activities are limited on Tinian.

5. At Site II, confine facilities to the north end of the bay. Berthing

or mooring facilities should be limited, if possible, to one ship only.

6. At Site III, no indication was given of construction plans. This area should be considered primarily for its recreational potential (beach and picnic facilities).

7. At Site IV, the proposed sewer outfall should be located on or near Puntan Diablo, based on the limited data available. A long term current study should be conducted at this site prior to construction of the outfall. No sewage effluent should be released in the bay proper.

8. Marine resources should be available to both civilian and military personnel. Since many of the Island's subsistance and commercial fishermen now reach their fishing sites by road, it would be helpful if access to these sites could be preserved. The same rights should be preserved for boats operating in waters adjacent to military land. While the above remarks are not relevant to this environmental impact survey, our experience on Guam has shown considerable animosity developing between Guam's civilian and military communities in these matters. Negotiators on both sides could head off problems of this nature if they consider them now. Fruitful discussions could also be centered around joint use of some of the recreational beaches that may fall within military property. Similarly, access might be provided periodically to the Island's coconut crabbers.

9. A base with 4000-6000 personnel with the usual SCUBA clubs and sport fishing activities could place pressure on the inshore marine organisms. We have seem mollusc, lobster and fish populations greatly reduced on Guam due to heavy pressure from fishermen and sport divers of both the military and civilian communities. We would therefore strongly recommend that conservation regulations be established for base personnel and civilian personnel using military property. Again, consultation should be sought with marine biologists.

10. Finally, we would like to reiterate that our study has definite limitations. There was not enough information available with regard to facilities and not enough time to do a proper environmental survey. We therefore urge caution in acceptance of our conclusions. We trust that Air Force planning includes a continued effort toward a final impact statement based upon adequate survey documentation.

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Table 1. Living coral density, percent of substratum coverage, and frequency of occurrence. Importance Value is the sum of the above relative parameters. Corals are arranged in order of their Importance Value.

Transect 1	Density/m^2	Relative Density	Percent Coverage	Relative Percent Coverage	Frequency of Occurrence	Relative Frequency of Occurrence	Importance Value
Porites (Synaraea) iwayamaensis	3.13	20.45	6.26	41.13	.45	15.15	76.73
Porites (Synaraea) convexa	2.43	15.91	4.86	31.93	.45	15.15	62.99
Goniastrea parvistella	2.43	15.91	.80	5.26	.36	12.12	33.29
Favites chinensis	1.39	9.09	.08	.53	.27	9.09	18.71
Montipora verrilli	.93	4.55	1.05	6.90	.18	6.06	17.51
Pavona (Polyastra) venosa	1.04	6.82	.56	3.68	.18	6.06	16.56
Leptastrea purpurea	.93	4.55	.35	2.30	.18	6.06	12.91
Favia pallida	.93	4.55	.11	.72	.18	6.06	11.33
Psammocora nierstraszi	.46	2.27	.44	2.89	.09	3.03	8.19
Montipora patula	.46	2.27	.17	1.12	.09	3.03	6.42
Cyphastrea chalcidicum	.46	2.27	.13	.85	.09	3.03	6.15
Fungia paumotuensis	.46	2.27	.13	.85	.09	3.03	6.15
Montipora tuberculosa	.46	2.27	.13	.85	.09	3.03	6.15
Leptastrea transversa	.46	2.27	.06	.39	.09	3.03	5.69
Porites lutea	.46	2.27	.06	.39	.09	3.03	5.69
Porites lobata	.46	2.27	.08	.20	.09	3.03	5.50

Total species 16
Total genera 10
Overall density 15.29/m^2
Overall coverage 15.22%

Table 1. Continued

Transect 3.	Density/m^2	Relative Density	Percent Coverage	Relative Percent Coverage	Frequency of Occurrence	Relative Frequency of Occurrence	Importance Value
Porites (Synaraea) iwayamaensis	2.39	11.36	3.06	11.94	.27	8.33	31.63
Porites (Synaraea) convexa	1.44	6.82	4.79	18.69	.18	5.56	31.07
Montipora verrilli	1.91	9.09	2.58	10.07	.36	11.11	30.27
Goniastrea parvistella	3.34	15.91	.80	3.12	.36	11.11	30.14
Montipora ehrenbergii	.96	4.55	4.90	19.12	.18	5.56	29.23
Leptoria phrygia	.48	2.27	4.10	16.00	.09	2.78	21.05
Montipora hoffmeisteri	.96	4.55	2.22	8.66	.18	5.56	18.77
Favia stelligera	1.91	9.09	.32	1.25	.27	8.33	18.67
Pavona clavus	.96	4.55	.41	1.60	.18	5.56	17.71
Montipora granulosa	1.44	6.82	.52	2.03	.27	8.33	17.18
Leptastrea purpurea	1.44	6.82	.89	3.47	.18	5.56	15.85
Favia pallida	.96	4.55	.08	.30	.18	5.56	10.41
Platygyra sinensis	.48	2.27	.54	2.11	.09	2.78	7.16
Cyphastrea serailia	.48	2.27	.13	.51	.09	2.78	5.56
Lobophyllia costata	.48	2.27	.13	.51	.09	2.78	5.56
Montipora tuberculosa	.48	2.27	.10	.39	.09	2.78	5.44
Goniastrea retiformis	.48	2.27	.03	.12	.09	2.78	5.17
Pavona (Polyastra) venosa	.48	2.27	.03	.12	.09	2.78	5.17

Total species 18
Total genera 10
Overall density 21.05/m^2
Overall coverage 25.63%

Table 1. Continued

Transect 3.	Density/m^2	Relative Density	Percent Coverage	Relative Percent Coverage	Frequency of Occurrence	Relative Frequency of Occurrence	Importance Value
Platygyra sinensis	1.32	6.82	2.64	33.76	.27	7.89	48.47
Millepora platyphylla	1.32	6.82	2.41	30.82	.18	5.26	42.90
Leptastrea purpurea	3.08	15.91	.46	5.88	.36	10.53	32.32
Favites chinensis	1.76	9.09	.35	4.48	.36	10.53	24.10
Pocillopora meandrina	1.32	6.82	.37	4.73	.18	5.26	16.81
Montipora verrilli	.88	4.55	.28	3.58	.18	5.26	13.39
Millepora exaesa	.88	4.55	.13	1.66	.18	5.26	11.47
Cyphastrea chalcidicum	.88	4.55	.04	.51	.18	5.26	10.32
Leptastrea transversa	.88	4.55	.21	2.69	.09	2.63	9.87
Montipora subtilis	.44	2.27	.22	2.91	.09	2.63	7.71
Astreopora myriophthalma	.44	2.27	.17	2.17	.09	2.63	7.07
Goniastrea parvistella	.44	2.27	.12	1.53	.09	2.63	6.43
Montipora tuberculosa	.44	2.27	.09	1.15	.09	2.63	6.05
Acropora convexa	.44	2.27	.06	.77	.09	2.63	5.67
Alveopora verrilliana	.44	2.27	.06	.77	.09	2.63	5.67
Favites favosa	.44	2.27	.06	.77	.09	2.63	5.67
Favia stelligera	.44	2.27	.03	.38	.09	2.63	5.28
Psammocora (P.) haimeana	.44	2.27	.03	.38	.09	2.63	5.28
Favia pallida	.44	2.27	.03	.38	.09	2.63	5.28
Pavona varians	.44	2.27	.01	.13	.09	2.63	5.03
Porties lobata	.44	2.27	.01	.13	.09	2.63	5.03
Distichopora violacea	.44	2.27	.01	.05	.09	2.63	4.95
Montipora foveolata	.44	2.27	.01	.05	.09	2.63	4.95
Leptoria phyrgia	.44	2.27	.01	.13	.09	2.63	5.03
Stylocoeniella armata	.44	2.27	.01	.05	.09	2.63	4.95

Total species 25
Total genera 18
Overall density 19.37/m^2
Overall coverage 7.82%

Table 1. Continued

Transect 4	Density/m^2	Relative Density	Percent Coverage	Relative Percent Coverage	Frequency of Occurrence	Relative Frequency of Occurrence	Importance Value
Leptastrea purpurea	15.27	38.64	2.60	27.46	.64	24.43	90.54
Pocillopora meandrina	6.29	15.91	4.47	47.20	.45	17.18	80.29
Favia pallida	5.39	13.64	.22	2.32	.36	13.74	29.70
Porites lobata	3.59	9.09	.50	5.28	.27	10.31	24.68
Porites lutea	2.69	6.82	.54	5.70	.27	10.31	22.83
Favites chinensis	1.80	4.55	.14	1.48	.18	6.87	12.90
Cyphastrea chalcidicum	1.36	2.27	.38	4.01	.09	3.44	9.72
Pocillopora verrucosa	1.36	2.27	.38	4.01	.09	3.44	9.72
Cyphastrea serailia	1.36	2.27	.10	1.06	.09	3.44	6.77
Psammocora (Plesioseris) haimeana	1.36	2.27	.10	1.06	.09	3.44	6.77
Favites favosa	1.36	2.27	.04	.42	.09	3.44	6.13

Total species	11
Total genera	7
Overall density	39.51
Overall coverage	9.47

Table 1. Continued

Transect 5	Density/m^2	Relative Density	Percent Coverage	Relative Percent Coverage	Frequency of Occurrence	Relative Frequency of Occurrence	Importance Value
Leptastrea purpurea	.94	47.73	.24	52.17	.91	34.73	134.63
Porites lutea	.22	11.36	.01	2.17	.36	13.74	27.27
Porites australiensis	.18	9.09	.02	4.35	.27	3.44	23.75
Pocillopora meandrina	.09	4.55	.07	15.22	.09	3.44	23.21
Montipora verrilli	.09	4.55	.04	8.70	.18	6.87	20.12
Porites lobata	.09	4.55	.03	6.52	.18	6.87	17.94
Favia pallida	.13	6.82	.01	2.17	.18	6.87	15.86
Favites virens	.09	4.55	.01	2.17	.18	6.87	13.59
Favites chinensis	.04	2.27	.01	2.17	.09	3.44	7.88
Goniastrea parvistella	.04	2.27	.01	2.17	.09	3.44	7.88
Montipora hoffmeisteri	.04	2.27	.01	2.17	.09	3.44	7.88

Total species	11
Total genera	7
Overall density	1.96/m^2
Overall coverage	.46%

Table 1. Continued

Transect 6	Density/m^2	Relative Density	Percent Coverage	Relative Percent Coverage	Frequency of Occurrence	Relative Frequency of Occurrence	Importance Value
Favia stelligera	2.54	15.91	.76	5.73	.45	12.82	34.46
Porites australiensis	.36	2.27	3.60	27,13	.09	2.56	31.96
Leptastrea purpurea	2.18	13.64	.92	6.93	.36	10.26	30.83
Montipora hoffmeisteri	1.09	6.82	1.66	12.51	.27	7.69	27.02
Favites chinensis	1.81	11.36	.20	1.51	.45	12.82	25.69
Galaxea fascicularis	1.09	6.82	.88	6.63	.27	7.69	21.14
Lobophyllia costata	.36	2.27	2.03	15.30	.09	2.56	20.13
Goniastrea parvistella	1.09	6.82	.51	3.84	.27	7.69	18.35
Favia pallida	1.09	6.82	.09	.68	.27	7.69	15.19
Montipora verrilli	.73	4.55	.95	7.16	.09	2.56	14.27
Astreopora myriophthalma	.73	4.55	.19	1.43	.18	5.13	11.11
Favites favosa	.73	4.55	.18	1.36	.18	5.13	11.04
Platygyra sinensis	.36	2.27	.82	6.18	.09	2.56	11.01
Montipora tuberculosa	.36	2.27	.23	1.73	.09	2.56	6,56
Montipora elschneri	.36	2.27	.14	1.06	.09	2.56	5,89
Porites (Synaraea) iwayamaensis	.36	2.27	.07	.53	.09	2.56	5,36
Favia speciosa	.36	2.27	.03	.23	.09	2.56	5.06
Porites lutea	.36	2.27	.01	.08	.09	2.56	4.91

Total species 18
Total genera 10
Overall density 15.97/m^2
Overall coverage 13.27%

Table 1. Continued

Transect 7	Density/m^2	Relative Density	Percent Coverage	Relative Percent Coverage	Frequency of Occurrence	Relative Frequency of Occurrence	Importance Value
Favia speciosa	.09	15.91	.16	25.00	.55	17.86	58.77
Fungia scutaria	.13	22.73	.07	10.94	.55	17.86	51.53
Pocillopora damicornis	.11	20.43	.06	9.38	.45	14.61	44.44
Pavona (Polyastra) venosa	.03	4.55	.08	12.50	.18	5.84	22.89
Plesiastrea sp.	.01	2.27	.09	14.06	.09	2.92	19.25
Favites chinensis	.04	6.82	.02	3.13	.27	8.77	18.72
Leptastrea purpurea	.04	6.82	.03	4.69	.18	5.84	17.35
Cyphastrea serailia	.03	4.55	.01	1.56	.18	5.84	11.95
Lobophyllia costata	.01	2.27	.03	4.69	.09	2.92	9.38
Leptoseris mycetoseroides	.01	2.27	.03	4.69	.09	2.92	9.88
Goniastrea parvistella	.01	2.27	.02	3.13	.09	2.92	8.32
Fungia fungites	.01	2.27	.01	1.56	.09	2.92	6.75
Favia pallida	.01	2.27	.01	1.56	.09	2.92	6.75
Fungia paumotuensis	.01	2.27	.01	1.56	.09	2.92	6.75
Pocillopora danae	.01	2.27	.01	1.56	.09	2.92	6.75
Total species 15							
Total genera 11							
Overall density .56/m^2							
Overall coverage .64%							
Transect 8							
Pocillopora damicornis	.30	93.18	.80	91.95	1.00	78.74	263.87
Goniastrea parvistella	.02	4.55	.05	5.75	.18	14.17	24.47
Acropora kenti	.01	2.27	.02	2.30	.09	7.09	11.66
Total species 3							
Total genera 3							
Overall density .32/m^2							
Overall coverage .87%							

Table 1. Continued

Transect 9	Density/m^2	Relative Density	Percent Coverage	Relative Percent Coverage	Frequency of Occurrence	Relative Frequency of Occurrence	Importance Value
Goniastrea retiformis	4.30	22.73	1.68	4.11	.55	18.46	46.30
Goniastrea parvistella	2.58	13.64	3.12	7.63	.27	9.06	30.33
Montipora ehrenbergii	1.72	9.09	4.78	11.68	.27	9.06	29.83
Pavona clavus	.43	2.27	8.44	20.63	.09	3.02	25.92
Montipora verrilli	1.29	6.82	.84	2.05	.27	9.06	17.39
Pavona varians	.86	4.55	3.44	8.41	.09	3.02	15.98
Astreopora listeri	.43	2.27	4.14	10.12	.09	3.02	15.41
Montipora patula	.43	2.27	2.84	6.94	.09	3.02	12.23
Favia pallida	.86	4.55	.12	1.29	.18	6.04	11.88
Pocillopora ligulata	.43	2.27	2.65	6.48	.09	3.02	11.77
Montipora hoffmeisteri	.43	2.27	2.46	6.01	.09	3.02	11.30
Montipora tuberculosa	.43	2.27	2.46	6.01	.09	3.02	11.30
Pocillopora elegans	.86	4.55	1.15	2.81	.09	3.02	10.38
Platygyra sinensis	.86	4.55	.66	1.61	.09	3.02	9.18
Leptoria phrygia	.43	2.27	1.09	2.66	.09	3.02	7.95
Psammocora nierstraszi	.43	2.27	.48	1.17	.09	3.02	6.46
Cyphastrea chalcidicum	.43	2.27	.22	.54	.09	3.02	5.83
Favia speciosa	.43	2.27	.22	.54	.09	3.02	5.83
Leptastrea purpurea	.43	2.27	.06	.15	.09	3.02	5.44
Favites chinensis	.43	2.27	.03	.07	.09	3.02	5.36
Montipora elschneri	.43	2.27	.03	.07	.09	3.02	5.36

Total species 21
Total genera 12
Overall density 18.90/m^2
Overall coverage 40.91%

Table 1. Continued

Transect 10	Density/m^2	Relative Density	Percent Coverage	Relative Percent Coverage	Frequency of Occurrence	Relative Frequency of Occurrence	Importance Value
Porites lutea	.17	28.57	1.76	53.01	.57	17.38	98.96
Favia pallida	.15	25.00	.04	1.20	.86	26.22	52.42
Astreopora listeri	.02	3.57	.56	16.87	.14	4.27	24.71
Montipora tuberculosa	.02	3.57	.56	16.87	.14	4.27	24.71
Pocillopora damicornis	.04	7.14	.10	3.01	.29	8.84	18.99
Goniastrea retiformis	.04	7.14	.04	1.20	.29	8.84	17.18
Leptastrea purpurea	.04	7.14	.01	.30	.29	8.84	16.28
Goniastrea parvistella	.02	3.57	.11	3.31	.14	4.27	11.15
Montipora hoffmeisteri	.02	3.57	.05	1.51	.14	4.27	9.35
Pavona varians	.02	3.57	.04	1.20	.14	4.27	9.04
Porites australiensis	.02	3.57	.02	.60	.14	4.27	8.44
Porites lobata	.02	3.57	<.01	<.30	.14	4.27	8.14

Total species 12
Total genera 8
Overall density .58/m^2
Overall coverage 3.32%

Table 2. Checklist of corals occurring on or in the vicinity of the transects. 1, 2, and 3 are located at Site IV; 4, 5, and 6 at Site II; 7, 8, and 9 at Site I; and 10 at Site III. Corals observed or collected from locations other than Sites I through IV are listed in "other" column.

Transects	1	2	3	4	5	6	7	8	9	10	Others
Acanthastrea echinata (Dana)	x				x	x	x		x	x	x
Acropora abrotanoides (Lamarck)			x	x		x			x		
Acropora brueggemanni (Brook)		x	x								
Acropora convexa (Dana)			x	x		x			x	x	
Acropora delicatula (Brook)							x				
Acropora cerealis (Dana)				x							
Acropora humulis (Dana)	x	x		x		x			x	x	x
Acropora kenti (Brook)		x	x	x		x	x	x			
Acropora monticulosa (Bruggemann)	x								x		
Acropora nana (Studer)	x	x	x			x			x		
Acropora nasuta (Dana)	x			x		x			x	x	
Acropora ocellata Klunzinger			x			x			x		
Acropora palifera (Lamarck)	x					x			x		x
Acropora palmerae Wells	x		x			x			x		
Acropora rambleri (Bassett-Smith)	x	x									
Acropora rayneri (Brook)									x		
Acropora smithi (Brook)			x			x			x		
Acropora squarrosa (Ehrenberg)	x	x	x			x			x	x	
Acropora studeri (Brook)									x		
Acropora surculosa (Dana)	x		x	x		x			x	x	
Acropora syringodes (Brook)			x								
Acropora valida (Dana	x					x					
Alveopora verrilliana Dana	x		x								x
Astreopora gracilis Bernard	x					x	x				
Astreopora listeri Bernard					x		x	x		x	
Astreopora myriophthalma (Lamarck)	x		x			x	x	x	x		
Balanophyllia sp. 1											x
Coscinaraea columna (Dana)	x					x					x
Cyphastrea chalcidicum (Forskaal)	x		x	x	x		x		x		x
Cyphastrea serailia (Forskaal)	x	x	x	x			x		x	x	x

Table 2. Continued

Transects	1	2	3	4	5	6	7	8	9	10	Others
Dendrophyllia sp. 1											x
Diploastrea heliopora (Lamarck)						x					
Echinophyllia aspera (Ellis and Solander)	x		x	x		x	x		x		x
Echinopora lamellosa (Esper)	x	x	x			x			x		x
Euphyllia glabrescens (Chamisso & Eysenhardt)	x										
Favia favus (Forskaal)	x	x	x	x					x		x
Favia laxa (Klunzinger)	x			x	x						x
Favia pallida (Dana)	x	x	x	x	x	x	x		x	x	x
Favia rotumana (Gardiner)						x					
Favia speciosa (Dana	x			x		x	x		x		
Favia stelligera (Dana)	x	x	x	x		x			x	x	
Favites abdita (Ellis and Solander)					x	x			x		
Favites acuticollis (Ortmann)									x		
Favites chinensis (Verrill)	x	x	x	x	x	x	x		x	x	
Favites favosa (Ellis and Solander)	x		x	x		x	x	x	x		x
Favites virens (Dana)	x				x						
Fungia concinna Verrill				x					x		
Fungia fungites (Linnaeus)				x			x				
Fungia paumotuensis Stutchbury	x						x				
Fungia scutaria Lammarck	x			x		x	x		x		
Galaxea fascicularis (Linnaeus)	x	x	x			x	x		x		x
Goniastrea parvistella (Dana)	x	x	x	x	x	x	x	x	x	x	x
Goniastrea pectinata (Ehrenberg)	x			x		x	x	x		x	
Goniastrea retiformis (Lammarck)	x	x	x			x	x	x	x	x	
Goniopora arbuscula Vmbgrove	x	x				x					x
Goniopora minor Crossland	x				x						x
Herpolitha limax (Esper)							x				
Hydnophora microconos (Lammarck)	x	x	x			x				x	x
Leptastrea purpurea (Dana)	x	x	x	x	x	x	x		x	x	x
Leptastrea transversa (Klunzinger)	x	x	x	x					x		
Leptoria phrygia (Ellis and Solander)	x	x	x	x		x			x	x	x
Leptoseris hawaiiensis (Vaughan)				x							

Transects	1	2	3	4	5	6	7	8	9	10	Others
Leptoseris incrustans (Quelch)	x					x	x				x
Leptoseris mycetoseroides Wells							x				
Leptoseris solida (Quelch)							x				
Leptoseris sp.1							x				
Lobophyllia corymbosa (Forskaal)	x	x				x			x		
Lobophyllia costata (Dana)	x	x				x	x		x		x
Lobophyllia hemprichii (Ehrenberg)						x					
Merulina ampliata (Ellis and Solander)							x				
Montipora ehrenbergii Verrill	x	x	x					x	x		
Montipora elschneri Vaughan	x	x	x			x		x	x	x	
Montipora foveolata (Dana)	x	x	x	x		x	x	x	x		
Montipora granulosa Bernard			x			x	x				
Montipora hoffmeisteri Wells	x	x	x		x	x			x	x	x
Montipora patula Verrill	x	x	x		x	x	x	x	x	x	
Montipora socialis Bernard						x					
Montipora tuberculos (Lammarck)	x	x	x			x		x	x	x	x
Montipora venosa (Ehrenberg)	x	x					x		x	x	x
Montipora verrilli Vaughan	x	x	x		x	x			x		
Montipora verrucosa (Lammarck)				x							
Oulophyllia crispa (Lammarck)	x	x		x		x	x		x		x
Pachyseris speciosa (Dana)						x					
Pavona clavus (Dana)	x	x	x			x			x		x
Pavona varians Verrill	x	x	x		x	x			x	x	x
Pavona (_Pseudocolumnastraea_) _pollicata_ Wells						x			x		
Pavona (_Polyastra_) _obtusata_ (Quelch)	x						x		x		x
Pavona (_Polyastra_) _planulata_ (Dana)	x					x	x		x		
Pavona (_Polyastra_) _venosa_ Ehrenberg	x	x		x			x		x		x
Platygyra astreiformis (Milne-Edwards and Haime)				x	x	x	x				
Platygyra rustica (Dana)	x	x	x	x		x	x		x	x	x
Platygyra sinensis (Milne-Edwards and Haime)	x	x	x	x		x	x		x	x	x
Plesiastrea versipora (Lammarck)	x		x			x			x	x	x
Plesiastrea sp.1	x			x			x				x
Pocillopora brevicornis Lammarck			x	x		x				x	
Pocillopora damicornis (Linnaeus)	x	x	x	x	x	x	x	x	x	x	x
Pocillopora danae Verrill	x	x				x	x				x

Table 2. Continued

Species	1	2	3	4	5	6	7	8	9	10	Others
Pocillopora elegans Dana	x	x	x	x	x	x	x	x	x		
Pocillopora eydouxi Milne-Edwards and Haime	x	x	x			x			x		x
Pocillopora ligulata Dana		x	x	x		x			x		
Pocillopora meandrina (Dana)	x	x	x	x	x	x			x		
Pocillopora setchelli Hoffmeister	x	x	x	x		x			x	x	
Pocillopora verrucosa (Ellis and Solander)	x	x	x	x		x					
Porites australiensis Vaughan	x			x	x	x	x		x	x	x
Porites lichen Dana	x		x			x			x		x
Porites lobata Dana	x		x	x	x		x		x	x	
Porties lutea Milne-Edwards and Haime	x	x	x	x	x	x	x	x	x	x	x
Porites murrayensis Vaughan				x	x						
Porites (Synaraea) Hawaiiensis Vaughan	x					x			x		
Porites (Synaraea) iwayamaensis Eguchi	x	x		x		x	x		x		x
Porites (Synaraea) convexa Verrill	x	x							x		x
Porites sp. 1		x			x						
Psammocora nierstraszi van der Horst	x	x	x	x		x	x		x		x
Psammocora (Stephanaria) togianensis Umbgrove	x	x				x					x
Psammocora (Plesioseris) haimeana Milne-Edwards and Haime	x	x	x	x					x		x
Scapophyllia cylindrica Milne-Edwards and Haime		x	x	x						x	
Seriatopora angulata Klunzinger									x		
Seriatopora crassa Quelch	x										
Seriatopora hystrix Dana						x					
Stylocoeniella armata (Ehrenberg)	x		x			x	x				
Stylocoeniella guentheri (Bassett-Smith)							x				
Stylophora mordax (Dana)	x	x	x			x			x	x	
Turbinaria sp. 1	x										x
Distichopora fisheri Broch						x					
Distichopora violacea (Pallas)	x		x			x			x		
Stylaster sp. 1	x										
Millepora dichotoma Forskaal	x		x			x					

Species		1	2	3	4	5	6	7	8	9	10	Others
Millepora _exaesa_ Forskaal		x		x		x	x			x		
Millepora _platyphylla_ Hemprich & Ehrenberg		x	x	x		x	x			x	x	
Heliopora _coerulea_ (Pallas)		x					x					
Total Species	129	89	53	62	49	26	83	50	15	76	35	48
Total Genera	43	36	22	25	19	14	33	24	9	26	19	28

Table 3. List of Macroinvertebrates collected from the four sites.

	SITES I	II	III	IV
Protozoa				
Foraminifera				
Calcarina hispida			x	
C. spengleri			x	
Homotrema rubrum			x	
Marginopora vertebralis			x	
Cnidaria				
Zoantharia				
Palythoa tuberculosa	x			x
Zoanthus sp.				x
Actiniaria				
Calliactis polypus			x	
Alyconacea				
Alcyoniidae				
Lobophytum sp. 1				x
Lobophytum sp. 2				x
Sarophyton sp.				x
Sinularia sp. 1				x
Sinularia sp. 2				x
Unident sp.			x	
Annelida				
Polynoid sp.			x	
Sabellastarte sp.	x			
Mollusca				
Arcidae				
Arca sp.	x			
Cerithiidae				
Cerithium aspera				x
Clypeomorus sp.			x	

Table 3. Continued

	SITES I	II	III	IV
Conidae				
Conus flavidus	x			
C. miles	x			x
C. millaris	x		x	
C. pulicarius				x
C. sponsalis			x	x
C. litteratus			x	
C. ebraeus			x	
C. lividus			x	
Conus sp.			x	
Cymatidae				
Cymatium nicobaricum			x	
C. moneta	x			
Fasciolariidae				
Latirus nodatus	x			
Peristerna nassatula				x
Littorinidae				
Littorina coccinea			x	
L. pintada		x		
Tectarius trochoides		x		
Mitridae				
Mitra stricta		x		
Muricidae				
Drupa morum	x			x
D. ricinus	x		x	
Morula uva	x		x	x
Thais armigera		x		x
Mytulidae				
Septiter sp.			x	
Neritidae				
Nerita plicata			x	
Patellidae				
Acmea sp.			x	x
Strombidae				
Gibberillus gibberillus			x	

Table 3. Continued

	SITES I	II	III	IV
Terebridae				
Terebra dimidiata				x
T. maculata	x			
Tonnidae				
Tonna perdix			x	
Tridacnidae				
Tridacna maxima				x
Trochidae				
Tectus pyramus	x			x
Trochus niloticus	x			
Vasidae				
Vasum turbinellus	x		x	
Turbinidae				
Turbo argyrostomus			x	
Anthropoda				
Crustacea				
Calcinus sp.			x	
Dardanus guttatus			x	
Grapsus grapus			x	
Lissocarcinus orbicularis			x	
Trapezia sp.				x
Zosymus aeneus			x	
Echinodermata				
Holothuroidea				
Actinopya mauritiana	x		x	x
A. miliaris			x	
Actinopyga sp.			x	
Bohadschia argus			x	x
Dendrochirotid sp.			x	

Table 3. Continued

	SITES I	SITES II	SITES III	SITES IV
Holothuria atra	x		x	x
H. leucospilota			x	
Holothuria sp.			x	
Polyplectana kefersteinii			x	
Stichopus chloronatus	x		x	x
Echinoidea				
Diadema setosum				x
D. savignii				x
Echinometra mathaei	x			x
Echinothrix diadema			x	x
Tripneustes gratilla			x	
Heterocentrotus mammillatus		x		
Asteroidea				
Acanthaster planci				x
Asterina anomala	x			
Culcita novaeguineae				x
Gomophia egyptica				x
Ophiuroidea				
Ophiocoma sp.	x			

Table 4. Results of fish counts on the 10 transects. T= No. of individuals of a species observed on a given transect. I= No. of intervals occupied by a species on a transect. R= Notes presence (+) of a species from the 20 minute random count. ΣI= Total individuals observed of a given species. I.V.= Importance Value. This is a summation of relative density, relative frequency and relative occurrence as random species on the transects. *= Observed or collected on a previous expedition. AF= Observed during the present expedition.

		SITE IV									SITE II									SITE I									SITE III				
		1			2			3			4			5			6			7			8			9			10				
		T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	ΣI	IV
Acanthuridae																																	
Acanthurus gahhm	AF															+																	.2
A. glaucopareius	*	4	2	+			+			+			+			+			+							1	1	*				5	2.04
A. guttatus	*									+																		+			+		.5
A. lineatus	*				1	1	+			+							1	1	+						+	2	2	+	2	1	+	6	2.29
A. nigrofuscus	*	4	2	+	5	3	+	3	1	+			+	2	2	+	10	3	+			+			+	8	4	+			+	32	6.3
A. olivaceus	*												+			+									+								.5
A. pyroferus	*																																
A. thompsoni	*																																
A. triostegus	*												+																2	2	+	2	.8
A. xanthopterus	*															+						+	1	1	+							1	.55
Ctenochaetus binotatus	*	5	3	+																												5	1.04
C. hawaiiensis	AF																																
C. striatus	*	13	4	+	4	2	+			+	1	1	+			+	2	2	+	1	1	+			+	1	1	+				22	4.8
N. brevirostris																	1	1	+													1	.45
N. hexacanthus	AF									+																							.2
N. literatus	*			+	2	1	+			+			+			+			+									+			+	2	1.7
N. unicornis	*															+			+												+		.5
Paracanthurus hepatus	*																																
Zebrasoma flavescens	AF	2	2	+						+									+													2	1.0
Antennaridae																																	
Antennarius altipinnis	*																																

Table 4. Continued

		1 T	1 I	1 R	2 T	2 I	2 R	3 T	3 I	3 R	4 T	4 I	4 R	5 T	5 I	5 R	6 T	6 I	6 R	7 T	7 I	7 R	8 T	8 I	8 R	9 T	9 I	9 R	10 T	10 I	10 R	ΣI	IV
Apogonidae																																	
Apogon erythrinus	*																																.5
A. exostigma	*	2	2																													2	.59
A. menesemops	*																																
A. nigrofasciatus	*			+	1	1					1	1	+	1	1	+				1	1		5	1	+			+				9	2.24
A. novae-guineae																							4	2								4	.59
A. savayensis	*																																
A. trimaculatus	*																																
Cheilodipterus macrodon	*			+			+												+	2	1	+										2	1.0
Gymnapogon philippinus	*																																
Paramia quinquelineata	AF																																
Aulostomidae																																	
Aulostomus chinensis	AF																																
Balistidae																																	
Balistapus undulatus	*									+						+												+					.5
Balistes bursa	*							1	1	+			+			+	2	1	+													3	1.25
Melichthyes niger	AF						+																										.2
M. vidua	*			+			+			+						+			+														.8
Rhinecanthus aculeatus	*																					+	1	1	+							1	.55
R. rectangularis	*									+			+															+			+		.7
Sufflamen chrysoptera	AF			+						+			+	3	1	+																3	1.05
Blenniidae																																	
Aspidontis taeniatus	AF	5	2	+	1	1	+				4	1		2	1							+			+			+				12	2.38
Cirrhipectes variolosus	*						+	4	3	+							1	1								2	2	+				7	2.04
Ecsenius bicolor	*						+			+				2	2		1	1	+									+				3	1.45
E. opsifrontalis	*																																
Entomacrodus sp.	*																																

Table 4. Continued

		1 T	1 I	1 R	2 T	2 I	2 R	3 T	3 I	3 R	4 T	4 I	4 R	5 T	5 I	5 R	6 T	6 I	6 R	7 T	7 I	7 R	8 T	8 I	8 R	9 T	9 I	9 R	10 T	10 I	10 R	ΣI	IV
Istiblennius coronatus	AF						+	1	1	+																						1	.55
Meiacanthus atrodorsalis	*	10	4	+	7	2	+						+	1	1	+	3	3	+	2	1	+				2	2	+				25	5.0
Runula tapeinosoma	AF									+			+	1	1	+										18	4	+				19	2.62
Brotulidae																																	
Dinematichthys iluocoetoides	*																																
Callionymidae																																	
Synchiropus sp.	*																																
Canthigasteridae																																	
Canthigaster amboinensis	*				1	1	+	2	1										+									+				3	1.05
C. bennetti	AF																1	1														1	.25
C. cinctus	AF																											+					.2
C. jactator	*																																
C. solandri	AF						+			+						+				1	1				+							1	.95
Caracanthidae																																	
Caracanthus maculatus	AF	1	1	+	1	1																				1	1					3	.95
Carangidae																																	
Carangoides ferdau	AF							1	1	+																						1	.45
Caranx melampygus																																	
Scomeroides sancti-petri	AF									+																							.2
Carcharhinidae																																	
Carcharhinus amblyrhynchos	AF																																

Table 4. Continued

		1			2			3			4			5			6			7			8			9			10				
		T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	ΣI	IV
Chaetodontidae																																	
<u>Centropyge</u> <u>flammeus</u> (?)	AF			+	1	1								1	1	+	1	1														3	1.05
<u>C. flavissimus</u>	*			+																					+			+					.5
<u>C. nigriocellatus</u>	*																																
<u>Chaetodon auriga</u>	*			+												+				1	1	+			+			+			+	1	1.25
<u>C. citrinellus</u>	AF						+			+	1	1	+			+			+						+	1	1	+			+	2	1.9
<u>C. ephippium</u>	*									+												+	1	1	+						+	1	.95
<u>C. falcula</u>	*			+			+																		+			+					.7
<u>C. lunula</u>	*			+			+			+									+									+			+		1.0
<u>C. mertensii</u>	AF																																
<u>C. ornatissimus</u>	*			+			+						+						+									+					.8
<u>C. punctato-fasciatus</u>	AF			+	1	1	+			+						+	2	1	+													3	1.35
<u>C. quadrimaculatus</u>	*						+			+			+						+														.7
<u>C. reticulatus</u>	*	2	2	+	1	1	+			+			+						+									+				3	1.75
<u>C. trifasciatus</u>	AF			+			+												+						+								.7
<u>C. unimaculatus</u>	*																											+					.2
<u>Forcipiger longirostris</u>	*												+						+									+					.5
<u>Heniochus monocerus</u>	AF																					+											.2
<u>H. permutatus</u>	AF	1	1	+																3	2	+			+			+				4	1.49
<u>Pomacanthus imperator</u>	*						+												+														.3
<u>Pygoplites diacanthus</u>	*						+																										.2
Cirrhitidae																																	
<u>Cirrhitichthys serratus</u>	AF										1	1	+	4	2	+																5	1.14
<u>Cirrhitoidea bimacula</u>	*																																
<u>Cirrhitus pinnulatus</u>	AF																																
<u>Gymnocirrhites arcatus</u>	*	2	1	+	1	1	+	13	3	+			+	5	3	+	1	1	+							8	5	+				30	5.5

Table 4. Continued

		1 T	1 I	1 R	2 T	2 I	2 R	3 T	3 I	3 R	4 T	4 I	4 R	5 T	5 I	5 R	6 T	6 I	6 R	7 T	7 I	7 R	8 T	8 I	8 R	9 T	9 I	9 R	10 T	10 I	10 R	ΣI	IV
Neocirrhites armatus	*	1	1	+	6	2	+	3	2	+						+			+							1	1	+				11	2.74
Paracirrhites forsteri	*			+	1	1	+	2	2	+			+	1	1				+							4	2	+				8	2.59
P. hemistictus	*																																
Clinidae																																	
Helcogramma sp	*																																
Tripterygion brachylepis	*																																
T. sp.	*																																
Diodontidae																																	
Diodon hystrix	AF																												1	1	+	1	.45
Echelidae																																	
Kaupichthys diodontus	*																																
K. sp.	*																																
Eleotridae																																	
Eleotrioides strigatus	*						+			+						+	2	1											2	1	+	4	1.29
Eviota saipanensis	*																																
Eviota spp.	*	1	1																													1	.25
Nemateleotris magnificus	*																																
Ptereleotris tricolor	AF			+						+									+														.5
P. microlepis	AF													2	1	+																2	.5
Pogonoculius zebra	AF							7	1	+	4	1	+	23	2	+																34	2.5
Trimma sp.	*																																

Table 4. Continued

		1 T	1 I	1 R	2 T	2 I	2 R	3 T	3 I	3 R	4 T	4 I	4 R	5 T	5 I	5 R	6 T	6 I	6 R	7 T	7 I	7 R	8 T	8 I	8 R	9 T	9 I	9 R	10 T	10 I	10 R	ΣI	IV
Fistulariidae																																	
Fistularia petimba	AF																					+											.2
Gobiidae																																	
Amblygobius sp.	AF																			1	1	+	2	1	+							3	.85
Drombus plumatus	*																																
Hazeus unisquamis	*																																
Rhinogobius decoratus	*																																
Holocentridae																																	
Holocentrus caudimaculatus	AF			+									+			+			+						+			+					1.0
H. diadema	*																																
H. microstomus	*	1	1	+			+				2	1	+									+			+							3	1.35
H. sammara	AF																			3	1	+									+	3	.65
H. spinifer	*												+							1	1				+							1	.55
H. tiere	*						+												+									+					.5
H. tieroides	*																																
Holotrachys lima	*																																
Myripristis berndti	*			+			+						+						+	1	1	+			+			+				1	1.45
M. kuntee	*																			1	1	+										1	.45
M. multiradiatus	*	2	1	+																												2	.5
M. murdjan	*																																
Kuhliidae																																	
Kuhlia taeniura	AF																																
Kyphosidae																																	
Kyphosus vaigiensis	AF																		+													1	.2

Table 4. Continued

		1			2			3			4			5			6			7			8			9			10				
		T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	ΣI	IV
Labridae																																	
Anampses																																	
caeruleopunctatus	AF						+												+														.3
A. twisti	AF			+																													.2
Bodianus axillaris	AF						+							1	1	+			+													1	.75
Chelinus fasciatus	AF			+			+						+			+			+			+			+			+			+		1.5
C. rhodochrus	*	4	3	+	2	2	+			+	1	1	+	1	1	+	1	1	+													9	3.04
C. trilobatus	*						+																										.2
Coris aygula	*									+			+						+							1	1				+	1	.95
C. gaimardi		1	1	+												+			+									+					
Epibulus insidiator	*						+			+						+			+				2	1	+			+				2	1.3
Gomphosus varius	*	3	3	+	3	2	+												+						+	1	1	+				7	2.34
Halichoeres																																	
bioscellatus		3	2	+	1	1										+	1	1	+													5	
H. hortulanus	*			+			+												+	1	1	+			+			+			+		1.0
H. margaritaceus	AF				1	1	+						+	5	2	+	4	3	+				1	1	+	7	3	+	21	4	+	39	5.89
H. marginatus	*						+									+	2	2	+							2	2	+			+	4	1.79
H. trimaculatus	AF																					+	3	2	+				11	3	+	14	
Hemigymnus fasciatus	*			+	1	1	+			+			+			+			+										1				1.25
H. melapterus	AF			+																					+								.3
Labroides bicolor	*						+																					+					.3
L. dimidiatus	*	1	1	+	1	1	+	2	1				+	1	1	+	1	1	+							1	1	+			+	7	2.74
Macropharyngodon																																	
meleagris	AF																		+														.2
M. pardalis								3	2	+						+	2	2	+													5	1.54
Pterogogus guttatus	AF																					+			+								.3
Stethojulis axillaris	AF	2	2				+						+						+	1	1		9	4	4	3	2	+	8	4	+	33	5.2
S. linearis	*			+															+														
S. strigiventer	AF																								+								.2
Thalassoma																																	
amblycephalus	AF	2	1	+				2	2		5	1	+	17	4	+									+			+				26	3.66
T. fuscum	AF																														+		.2
T. hardwickei	AF															+									+						+		.5
T. lutescens	*	6	4	+	2	2	+				3	2	+				2	1	+						+			+	1	1	+	14	3.88
T. quinquevittata	AF			+	6	4	+	7	5	+	1	1	+	8	2	+	10	4	+						+	42	5	+				74	9.19
T. umbrastigma	AF												+													1	1		3	3	+	$	1.29

Table 4. Continued

		1 T	1 I	1 R	2 T	2 I	2 R	3 T	3 I	3 R	4 T	4 I	4 R	5 T	5 I	5 R	6 T	6 I	6 R	7 T	7 I	7 R	8 T	8 I	8 R	9 T	9 I	9 R	10 T	10 I	10 R	ΣI	IV
Wetmorella ocellata	*																																
Xyrichthys taeniourus	AF						+																										.2
Pseudocheilinus tetrataenia	*																																
Lutganidae																																	
Aphareus furcatus	AF			+						+			+			+			+														.8
Aprion virescens	AF																																
Caesio sp.	AF																																
Lethrinus microdon	AF															+																	.2
Lutjanus																				1	1				+							1	.45
argentimaculatus	AF						+						+	2	2	+																2	1.0
L. bohar	*															+																	.2
L. gibbus	AF																																
L. kasmira	AF																					+			+								.3
L. monostigmus	AF																																
L. vaigiensis	*			+						+						+				7	2	+			+							7	1.54
Macolor niger	*																		+														.2
Monotaxis grandoculis	*																																
Plectorhynchus sp.	*																																
Malacanthidae																																	
Malacanthus latovittatus	AF													2	1	+			+													2	.6
Monacanthidae																																	
Alutera scripta	AF			+			+																										.3
Amanses carolae	AF															+																	.2
A. sandwichiensis	AF			+									+																				.3
Paraluteres prionurus	AF																									1	1					1	.25

Table 4. Continued.

		1			2			3			4			5			6			7			8			9			10				
		T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	ΣI	IV
Pervagor melanocephalus	*																																
Mugiloididae																																	
Parapercis cephalopunctata	AF												+										2	2								2	.7
P. clathrata	*																								+								.2
Mullidae																																	
Mulloidichthys auriflamma	AF																		+	8	2	+										8	1.09
Parupeneus barberinus	AF																					+	1	1	+							1	.55
P. crassilabrus	AF						+			+	1	1	+			+			+							2	2	+				3	1.75
P. chryserydros	AF	5	1	+			+				1	1	+			+	1	1										+				7	1.74
P. multifasciatus	*	1	1	+	2	2	+			+	1	1	+	1	1	+	1	1	+	1	1	+	1	1	+			+			+	7	3.24
P. pleurotaenia	AF																					+			+								.3
P. pleurostigma	AF										2	1	+	1	1	+			+						+							3	1.25
Muraenidae																																	
Gymnothorax hepaticus	*																																
G. javanicus	AF																																
G. meleagris	AF																									1	1					1	.25
G. sp.	*																																
Rabula fuscomaculata	*																																
Uropterygius concolor	*																																
Ostraciontidae																																	
Ostracion meleagris	AF						+			+																		+					.5
Pempheridae																																	

Table 4. Continued

		1			2			3			4			5			6			7			8			9			10				
		T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	ΣI	IV
Pempheris oualensis	*						+												+							1	1	+				1	.75
Platycephalidae																																	
Thysanophrys sp.	*																																
Pomacentridae																																	
Abudefduf amabilis	*				1	1				+			+			+	4	2	+							30	5	+	37	3	+	72	6.69
A. curacao	AF																																
A. dicki	*				1	1		1	1																	10	4	+				12	1.98
A. glaucus	AF																												20	3	+	20	1.77
A. imparipinnis	AF							3	2	+			+													1	1	+				4	1.29
A. johnstonianus	*				1	1		2	1	+							1	1	+													4	1.09
A. lacrymatus	*	62	5	+	35	4	+						+	1	1		7	3	+				4	2	+	1	1					110	9.34
A. leucopomus	*						+			+				2	1		4	2	+							28	5	+	6	3	+	40	4.94
A. leucozona	AF																						1	1		1	1		3	2		5	1.24
A. saxatilis	*																																
A. septemfasciatus	AF																								+						+		.3
A. phoenixensis	*																																
Amphiprion chrysopterus	*			+																													.2
A. melanopus	*	1	1	+			+																									1	.55
A. sp.	*																																
Chromis caeruleus	AF																					+	6	2	+							6	.99
C. dimidiatus	AF	2	1	+						+						+										1	1	+				3	1.25
C. leucurus	*	2	1	+										3	1	+			+													5	1.04
C. vanderbilti	*	7	1	+						+			+	19	2	+			+							1	1	+				27	3.11
C. xanthochir	AF	2	2	+																												2	.7
Dascyllus aruanus	AF																			2	1	+	89	5	+							91	5.92
D. reticulatus	*	1	1	+				1	1	+																						2	.8
D. trimaculatus	*										1	1	+	1	1	+																2	.8
Pomacentrus albofasciatus	AF																						67	4	+						+	67	4.25
P. pavo	AF																			3	2	+	48	3	+							51	3.77
P. jenkinsi	AF				9	4	+	11	5	+	1	1	+	3	2	+	48	5	+							32	5	+			+	124	11.62

Table 4. Continued

		1 T	1 I	1 R	2 T	2 I	2 R	3 T	3 I	3 R	4 T	4 I	4 R	5 T	5 I	5 R	6 T	6 I	6 R	7 T	7 I	7 R	8 T	8 I	8 R	9 T	9 I	9 R	10 T	10 I	10 R	ΣI	IV
P. vaiuli	*	125	5	+	89	5	+			+	26	4	+	11	2	+	125	5	+	15	5	+	32	5	+	23	5	+				446	30.15
P. sp.	AF							125	5	+	35	3	+	86	3	+	7	1	+									+				253	15.48
Pseudochromidae																																	
Pseudochromis tapeinosoma	*																																
Pseudogramma polyacantha	*																																
Pseudoplesiops rosae	*																																
Scaridae																																	
Calatomus spinidenis	AF						+												+														.3
Chlorurus bicolor	AF			+									+			+			+									+			+		1.0
Scarus lepidus	AF	12	4	+	3	2	+			+			+	1	1	+	2	1	+													18	3.47
S. microrhinos	AF															+												+			+		.5
S. perspicillatus	AF																																
S. sordidus	AF	31	4	+	1	1	+			+			+			+			+						+			+			+	32	4.05
S. venosus	AF				1	1	+									+			+				5	1	+			+				6	1.49
S. sp. 1	AF	1	1		8	1							+			+																9	1.14
S. sp. 2	AF																					+											.2
S. sp. 3	AF						+													12	1	+	6	2	+							18	1.97
Scorpaenidae																																	
Pterois antennata	AF	1	1										+															+				1	.55
Scorpaenodes kelloggi	*																																
Serranidae																																	
Cephalopholis argus	*																																.2
C. urodelus	*	3	3	+	1	1	+			+	1	1	+			+																5	2.04
C. sp.	*																																
Epinephelus emoryi	AF			+																													.2
E. merra	AF																			1	1	+			+							1	.55

Table 4. Continued

		1			2			3			4			5			6			7			8			9			10				
		T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	T	I	R	ΣI	IV
E. sp.	AF																		+														
Grammistes sexlineatus	AF													1	1													+				1	.45
Liopropoma pallidans	*																																
Variola louti	AF									+																							.2
Soleidae																																	
Aseraggodes sp.	*																																
Syngnathidae																																	
Corythoichthys sp.	AF	1	1		1	1														2	1											4	.79
Synotidae																																	
Synodus sp.	AF			+			+										1	1														1	.55
Tetraodontidae																																	
Arothron nigropunctatus	AF						+																		+						+		.5
Teuthididae																																	
Siganus argenteus	*															+									+								.3
Triakidae																																	
Triaenodon obesus	AF									+																							.2
Trichonotidae																																	
Chalixodytes tauensis	*																																
Zanclidae	AF																																
Zanclus cornutus	*						+			+						+				1	1	+			+			+			+	1	1.25

Table 5. Summary of data for fish populations at each site.

Sites	Transects	Area Sampled	Total No. Individuals	Transect Species	Random Species	Transect & Random Species	Total Density
I	(7-9)	$600m^2$	641	69	109	116	1.07
II	(4-6)	$600m^2$	559	51	108	116	0.93
III	(10)	$600m^2$	128	14	38	39	0.64
IV	(1-3)	$600m^2$	733	62	114	123	1.22

Table 6. Summary of diversity indices, total density, and total frequency of each transect fish count.

Site	Transect	Area Sampled	Total No. Individuals	Transect Species	Transect & Random Species	Random Species	Total Density	Total Frequency	Shannon-Wiener Diversity Index
IV	1	$200m^2$	335	40	67	73	$1.68/m^2$	15.8	3.474
	2	$200m^2$	207	37	73	82	$1.04/m^2$	12.4	3.341
	3	$200m^2$	191	19	59	63	$0.96/m^2$	7.8	2.193
II	4	$200m^2$	93	20	58	59	$0.46/m^2$	4.8	2.904
	5	$200m^2$	215	33	68	74	$1.08/m^2$	10.	3.439
	6	$200m^2$	251	31	74	80	$1.26/m^2$	11.2	2.835
I	7	$200m^2$	82	27	37	43	$0.41/m^2$	7.2	4.022
	8	$200m^2$	298	23	56	61	$1.49/m^2$	8.6	3.305
	9	$200m^2$	261	35	69	76	$1.30/m^2$	15.4	4.308
III	10	$200m^2$	128	14	38	39	$0.64/m^2$	6.4	2.972
	TOTALS	$2000m^2$	2061	118	62	180	$1.03/m^2$	99.6	

Table 7. Coeficient of community calculations for each transect pair (%), based on fish counts.

	1	2	3	4	5	6	7	8	9	10
1	-	59	4	19	12	52	11	12	14	1
2		-	14	23	16	60	15	15	24	2
3			-	20	56	15	0	0	16	0
4				-	42	24	21	14	16	1
5					-	20	9	5	18	4
6						-	11	14	36	8
7							-	19	11	1
8								-	11	7
9									-	21
10										-

Table 8. Rank order of fishes, listed by Importance Values, from the combined transects.

Importance Value	Species
30	Pomacentrus vaiuli
16	P. sp. (blue/yellow)
12	P. jenkinsi
9	Abudefduf lacrymatus, Thalassoma quinquevittata
6	Abudefduf amabilis, Acanthurus nigrofuscus
5	Halichoeres margaritaceus, Dascyllus aruanus, Gymnocirrhites arcatus, Stethojulis axillaris, Meiacanthus atrodorsalis
4	Abudefduf leucopomus, Ctenochaetus striatus, Pomacentrus albofasciatus, Scarus sordidus
3	Thalassoma lutescens, Pomacentrus pavo, T. amblycephalus, Scarus lepidus, Parupeneus multifasciatus, Chromis vanderbilti, Cheilinus rhodochrus
2	Neocirrhites armatus, Labroides dimidiatus, Runula tapeinosoma, Paracirrhites forsteri, Pogonocullius zebra, Aspidontis taeniatus, Acanthurus lineatus, Gomphosus varius, Apogon nigrofasciatus, Acanthurus glaucopareius, Cirrhipectes variolosus, Cephalopholis urodelus, Scarus sp. 3, Abudefduf dicki

The remaining 143 species had Importance Values of 1 or less.

Table 9. Checklist of benthic algae. Transects 1 to 10 include both the species encountered on the transect line and those observed during random search in each area. Species listed alphabetically under respective Divisions.

Species	Peipeinigul 1	Peipeinigul 2	Bay 3	Transects Lamanibot Bay 4	Lamanibot Bay 8	Lamanibot Bay 6	San Jose Harbor 7	San Jose Harbor 8	San Jose Harbor 9	Uani Dangkulo 10	Previous Coll. June & Aug.1970
Cyanophyta - Blue-greens											
Anacystis dimidiata		+									
Microcoleus lyngbyaceus	+	+	+	+	+	+	+	+	+	+	+
Schizothrix calcicola	+	+		+			+	+	+	+	+
Schizothrix mexicana	+	+				+					+
Chlorophyta - Greens											
Avrainvillea obscura								+			+
Boergesenia forbesii									+	+	
Boodlea composita	+	+			+	+	+	+	+	+	+
Caulerpa cupressoides		+									
Caulerpa filicoides	+					+					+
Caulerpa racemosa	+	+	+				+			+	+
Caulerpa serrulata		+	+			+	+		+	+	+
Caulerpa sertularioides		+						+			
Caulerpa taxifolia						+	+	+	+	+	
Caulerpa urvilliana										+	+
Caulerpa verticillata											+
Chlorodesmis fastigiata	+	+	+			+			+	+	+
Cladophoropsis membranacea										+	+
Codium arabicum											+
Codium geppi		+					+		+		+
Dictyosphaeria cavernosa							+				+
Dictyosphaeria versluysii			+	+					+	+	+
Halimeda discoidea	+	+	+	+	+	+					+
Halimeda macroloba							+	+			
Halimeda opuntia	+	+	+	+		+	+	+	+	+	+

Table 9. (Continued)

Species	Peipeinigua 1	2	3	Bay / Transects Lamanibot Bay 4	5	6	San Jose Harbor 7	8	9	Unai Dangkulo 10	Previous Coll. June & Aug, 1970
Halimeda taenicola											+
Neomeris annulata							+	+			
Neomeris vanbosseae					+	+					
Microdictyon okamurai											+
Rhizoclonium samoense					+						
Rhipilia orientalis											+
Udotea argentea	+			+					+	+	+
Udotea geppii											+
Valonia fastigiata									+		+
Valonia ventricosa	+			+	+	+	+				+
Phaeophyta - Browns											
Ectocarpus breviarticulatus				+							+
Dictyota bartayresii	+	+	+	+	+	+	+	+	+		+
Dictyota divaricata				+	+	+	+				+
Dictyota friabilis							+		+		
Feldmannia indica			+				+			+	+
Hydroclathrus clathratus							+				
Lobophora variegata	+		+	+	+	+	+	+	+		+
Padina jonesii			+	+	+	+			+		+
Padina tenuis							+	+		+	+
Sargassum tenerrimum											+
Sphacelaria tribuloides		+					+		+		
Turbinaria ornata		+									+
Rhodophyta - Reds											
Actinotrichia rigida		+		+		+				+	
Amansia glomerata											+
Amphiroa foliacea	+	+	+								+
Amphiroa fragilissima	+	+	+	+	+	+		+	+	+	+

Table 9. (Continued)

Species	Transects: Peipeinigul Bay 1	2	3	Lamanibot Bay 4	5	6	San Jose Harbor 7	8	9	Unai Dangkulo 10	Previous Coll. June & Aug, 1970
Antithamnion sp.									+		+
Asparagopsis taxiformis			+								
Botryocladia skottsbergia							+				
Centroceras clavulatum	+										
Ceramium sp.					+				+		
Champia parvula									+		
Cheilosporum maximum										+	
Desmia hornemanni		+				+					+
Galaxaura fasciculata				+	+	+	+	+			+
Galaxaura marginata	+	+	+			+	+		+		+
Galaxaura oblongata						+	+	+			+
Gelidiella acerosa											+
Gelidiopsis intricata	+	+	+								
Gelidium pusillum			+			+		+	+		+
Gibsmithia hawaiiensis											+
Halymenia durvillaei											+
Halymenia cf. *floresia*											+
Hemitrema fragilis		+									
Hypnea cervicornis						+		+	+		
Jania capillacea	+	+	+	+	+	+	+		+	+	+
Jania dichotoma-decussata				+							
Laurencia sp.		+									+
Leveillea jungermannioides										+	+
Liagora sp.											+
Mastophora sp.										+	
Neogoniolithon sp.	+	+	+								+
Peysonnelia sp.		+				+					+
Polysiphonia sp.	+		+			+	+	+	+	+	+
Porolithom gardneri	+										+
Porolithon onkodes	+	+	+					+	+		+
Rhodymenia sp.								+			+
Spyridia filamentosa							+				+
Tolypiocladia glomerulata		+							+		
Wrangelia argus									+	+	

Table 10. Number of benthic algae collected or observed in June/August 1970 and January 1974.

Division	Number of Genera and Species					
	June/Aug. 1970		January 1974		Total	
	G	S	G	S	G	S
Cyanophyta	3	3	3	4	3	4
Chlorophyta	13	23	13	24	16	31
Phaeophyta	7	9	8	11	9	12
Rhodophyta	18	23	27	32	32	38
TOTAL	41	58	51	71	60	85

Table 11. Number of algal species present in each of the ten transect areas.

Divisions	Peipeinigul Bay			Lamanibot Bay			San Jose Harbor			Unai Dangkulo
	1	2	3	4	5	6	7	8	9	10
Cyanophyta	3	4	1	2	1	2	2	2	2	2
Chlorophyta	8	9	6	5	5	9	10	7	10	11
Phaeophyta	2	3	4	5	4	4	8	3	5	2
Rhodophyta	10	13	10	5	4	11	7	8	12	8
Total/Transects	23	29	21	17	14	26	27	20	29	23
Total/Area		(41)			(33)			(45)		(23)

Table 12. Relative abundance, relative frequency, relative dominance, and Importance Value of benthic algae present in the 10 transect areas. Algae arranged in order of Importance Value.

Species	RA	RF	RD	IV
PEIPEINIGUL BAY				
Transect 1 - 69% algal cover, 31% live corals (n=10)				
Amphiroa fragilissima	19.2	21.5	20.4	61.1
Porolithon onkodes	15.8	7.1	28.0	50.9
Jania capillacea	20.9	14.3	7.4	42.6
Polysiphonia sp.	15.0	10.7	5.3	31.0
Dictyota bartayresii	8.3	10.7	8.8	27.8
Microcoleus lyngbyaceus	6.7	7.1	7.1	20.9
Halimeda discoidea	2.5	7.1	8.8	18.4
Porolithon gardneri	2.5	3.6	8.8	14.9
Gelidiopsis intricata	2.5	3.6	1.8	7.9
Schizothrix calcicola	5.0	7.1	1.8	13.9
Boodlea composita	0.8	3.6	0.9	5.3
Lobophora variegata	0.8	3.6	0.9	5.3
Transect 2 - 78% algal cover, 21% live corals, 1% sand (n=10)				
Dictyota bartayresii	30.4	22.0	26.4	78.8
Galaxaura marginata	8.7	9.4	25.2	43.3
Gelidiopsis intricata	21.0	15.6	6.1	42.7
Halimeda opuntia	4.3	6.3	12.7	23.3
Jania capillacea	8.7	9.4	2.5	20.6
Neogoniolithon sp.	5.8	3.1	8.4	17.3
Microcoleus lyngbyaceus	4.3	6.3	3.8	14.4
Anacystis dimidiata	5.7	3.1	3.3	12.1
Tolypiocladia glomerulata	2.2	3.1	2.5	7.8
Porolithon onkodes	1.4	3.1	2.5	7.0
Sphacelaria tribuloides	2.9	3.1	0.8	6.8
Halimeda discoidea	0.8	3.1	2.1	6.0
Amphiroa fragilissima	1.4	3.1	1.3	5.8
Caulerpa racemosa	0.8	3.1	1.0	4.9
Actinotrichia rigida	0.8	3.1	0.8	4.7
Boodlea composita	0.8	3.1	0.6	4.5

Table 12. Continued.

Species	RA	RF	RD	IV
Transect 3 - 85% algal cover, 15% live coral (n=10)				
Microcoleus lyngbyaceus	18.1	18.1	31.6	67.8
Dictyota bartayresii	20.8	15.2	21.8	57.8
Jania capillacea	9.4	15.2	3.3	27.9
Porolithon onkodes	8.7	6.1	12.2	27.0
Cheilosporum maximum	11.4	6.1	8.0	25.5
Dictyosphaeria versluysii	8.1	9.1	5.6	22.8
Caulerpa serrulata	2.7	6.1	4.7	13.5
Gelidiopsis intricata	6.7	3.0	2.4	12.1
Lobophora variegata	2.7	6.1	2.8	11.6
Gelidium pusillum	4.0	3.0	1.4	8.4
Polysiphonia sp.	3.4	3.0	1.2	7.6
Amphiroa fragilissima	2.0	3.0	2.1	7.1
Halimeda discoidea	0.7	3.0	2.4	6.1
Padina jonesii	1.3	3.0	0.5	4.8
LAMANIBOT BAY				
Transect 4 - 92% algal cover, 3% live corals, 4% dead corals, 1% sand (n=10)				
Galaxaura fascicularis	41.9	22.2	70.9	135.0
Dictyota bartayresii	22.1	13.9	11.3	47.3
Amphiroa fragilissima	9.6	8.3	4.8	22.7
Microcoleus lyngbyaceus	6.6	11.1	4.4	22.1
Jania capillacea	7.2	8.3	1.2	16.7
Lobophora variegata	3.0	11.1	1.5	15.6
Valonia ventricosa	1.8	8.3	0.6	10.7
Actinotrichia rigida	1.8	5.6	1.2	8.6
Dictyota divaricata	2.4	2.8	1.2	6.4
Halimeda discoidea	1.2	2.8	1.6	5.6
Jania decussato-dichotoma	1.8	2.8	0.6	5.2
Halimeda opuntia	0.6	2.8	0.7	4.1
Transect 5 - 79% algal cover, 18% sand, 3% live corals (n=10)				
Microcoleus lyngbyaceus	21.7	20.0	33.8	75.5
Rhizoclonium samoense	23.2	15.0	12.0	50.2
Ceramium sp.	22.5	15.0	11.6	49.1
Dictyota divaricata	13.8	10.0	21.4	45.2
Jania capillacea	7.2	10.0	3.8	21.0
Neomeris vanbosseae	3.6	10.0	5.6	19.2
Dictyota bartayresii	4.3	5.0	6.8	16.1
Amphiroa fragilissima	1.5	5.0	2.3	8.8
Lobophora variegata	1.5	5.0	2.3	8.8
Padina jonesii	0.7	5.0	0.4	6.1

Table 12. Continued

Species	RA	RF	RD	IV
Transect 6 - 92% algal cover, 8% live corals (n=10)				
Dictyota bartayresii	20.2	12.8	22.0	55.0
Amphiroa fragilissima	17.0	12.8	18.5	48.3
Actinotrichia rigida	6.3	14.9	9.2	30.4
Gelidium pusillum	14.5	8.5	5.3	28.3
Jania capillacea	11.3	8.5	4.1	23.9
Galaxaura marginata	2.5	2.1	9.2	13.8
Microcoleus lyngbyaceus	3.8	2.1	6.9	12.8
Neomeris vanbosseae	2.5	6.4	3.7	12.6
Boodlea composita	3.1	4.3	3.4	10.8
Padina jonesii	4.4	4.3	1.6	10.3
Galaxaura oblongata	1.3	4.3	4.6	10.2
Polysiphonia sp.	5.0	2.1	1.8	8.9
Dictyota divaricata	2.5	2.1	2.7	7.3
Hypnea cervicornis	1.9	4.3	0.7	6.9
Peyssonelia sp.	1.3	2.1	1.4	4.8
Halimeda opuntia	0.6	2.1	2.3	5.0
Caulerpa serrulata	0.6	2.1	1.2	3.9
Schizothrix mexicana	0.6	2.1	0.7	3.4
Lobophora variegata	0.6	2.1	0.7	3.4
SAN JOSE HARBOR				
Transect 7 - 94% algal cover, 6% silt (n=20)				
Halimeda opuntia	58.6	43.6	89.8	192.0
Galaxaura oblongata	11.4	20.5	5.8	37.7
Polysiphonia sp.	16.0	12.8	0.8	29.6
Galaxaura marginata	2.6	5.1	1.3	9.0
Schizothrix calcicola	4.9	2.6	0.9	8.4
Dictyota bartayresii	2.8	5.1	0.4	8.3
Neomeris annulata	1.2	5.1	0.2	6.5
Microcoleus lyngbyaceus	2.2	2.6	0.6	5.4
Halimeda macroloba	0.3	2.6	0.2	3.1

Table 12. Continued

Species	RA	RF	RD	IV
Transect 8 - 46% algal cover, 54% sand (n=20)				
Halimeda opuntia	29.0	16.8	75.6	121.4
Dictyota bartayresii	47.0	16.8	12.2	76.0
Halimeda macroloba	4.0	13.3	5.1	22.4
Caulerpa sertularioides	0.7	13.3	0.6	14.6
Hypnea cervicornis	6.6	6.7	1.1	14.4
Padina tenuis	4.5	6.7	2.0	13.2
Porolithon onkodes	3.3	3.3	0.6	7.2
Galaxaura oblongata	0.7	3.3	0.6	4.6
Galaxaura fascicularis	0.7	3.3	0.6	4.6
Halophila minor	0.7	3.3	0.6	4.6
Microcoleus lyngbyaceus	0.7	3.3	0.4	4.4
Neomeris annulata	0.7	3.3	0.2	4.2
Rhodymenia sp.	0.7	3.3	0.2	4.2
Schizothrix calcicola	0.7	3.3	0.2	4.2
Transect 9 - 93% algal cover, 7% live coral (n=10)				
Gelidium pusillum	34.3	20.5	11.3	66.1
Galaxaura marginata	7.9	2.0	26.0	35.9
Lobophora variegata	8.4	14.4	8.5	31.3
Padina jonesii	10.7	6.2	14.1	31.0
Jania capillacea	7.9	8.2	2.6	18.7
Halimeda opuntia	2.2	6.2	7.4	15.8
Microcoleus lyngbyaceus	3.4	4.1	5.6	13.1
Porolithon onkodes	3.4	2.0	5.6	11.0
Boodlea composita	3.4	4.1	3.3	10.8
Dictyota friabilis	2.8	4.1	2.8	9.7
Hypnea cervicornis	2.8	4.1	1.9	8.8
Dictyosphaeria versluysii	2.8	2.0	1.9	6.7
Polysiphonia sp.	3.4	2.0	1.1	6.5
Dictyota bartayresii	1.0	4.1	1.1	6.2
Caulerpa taxifolia	0.6	2.0	1.9	4.5
Caulerpa serrulata	0.6	2.0	1.9	4.5
Chlorodesmis fastigiata	0.6	2.0	1.3	3.9
Antithamnion sp.	1.0	2.0	0.7	3.7
Sphacelaria tribuloides	1.0	2.0	0.4	3.4
Amphiroa fragilissima	0.6	2.0	0.6	3.2
Champia parvula	0.6	2.0	0.1	2.7
Ceramium sp.	0.6	2.0	0.1	2.7

Table 12. Continued

Species	RA	RF	RD	IV
UNAI DANGKULO				
Transect 10 - 100% algal cover (n=20)				
Amphiroa fragilissima	68.6	36.0	53.7	158.3
Halimeda opuntia	11.3	19.3	29.5	60.1
Wrangelia argus	5.5	11.1	4.3	20.9
Caulerpa urvilliana	3.4	5.6	7.0	16.0
Feldmannia indica	3.4	2.8	0.9	7.1
Polysiphonia sp.	0.8	5.6	0.2	6.6
Sphacelaria tribuloides	2.9	2.8	0.8	6.5
Mastophora sp.	1.3	2.8	1.3	5.4
Boodlea composita	0.8	2.8	0.7	4.3
Boergesenia forbesii	0.4	2.8	0.6	3.8
Jania capillacea	0.8	2.8	0.2	3.8
Chlorodesmis fastigiata	0.4	2.8	0.6	3.8
Dictyosphaeria versluysii	0.4	2.8	0.2	3.4

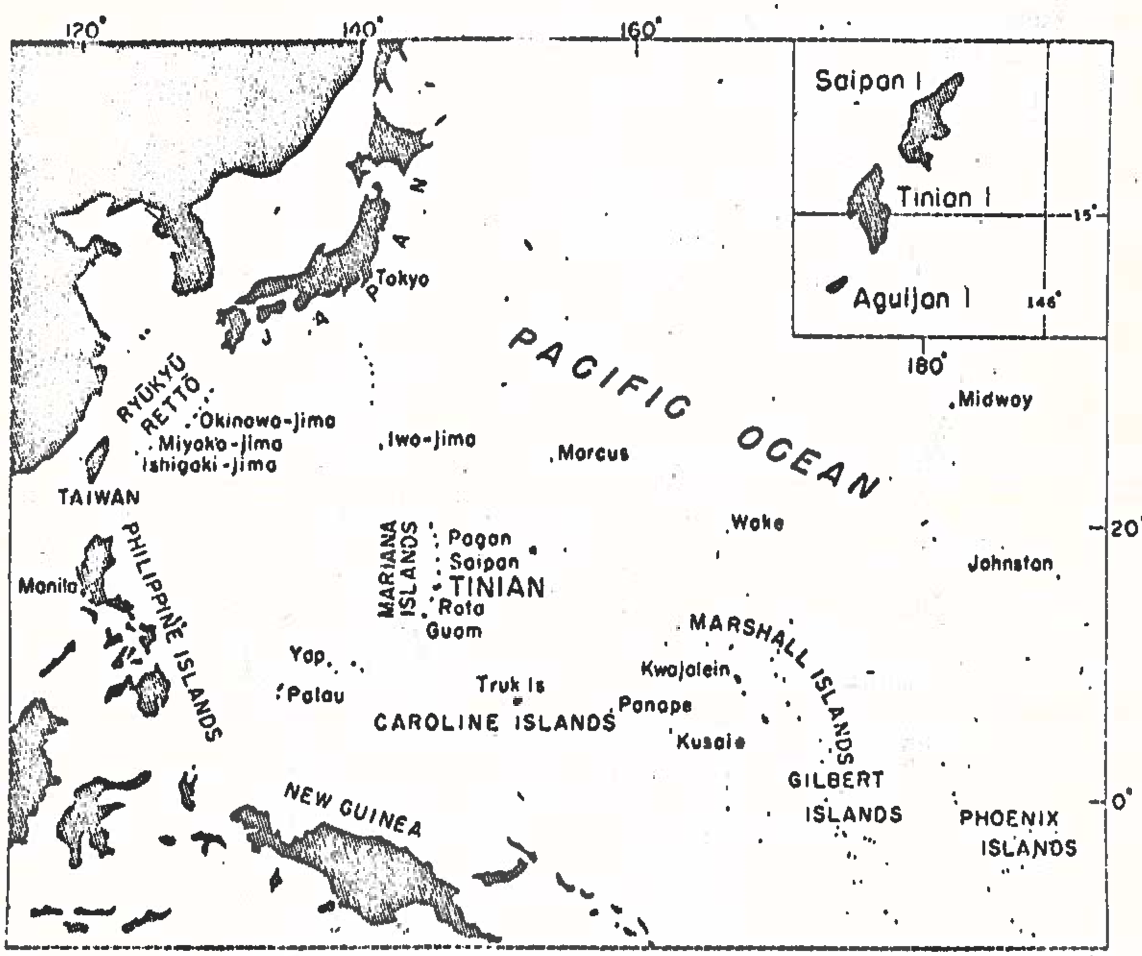


Figure 1. Western Pacific Ocean, with insert showing relationship of Saipan, Tinian, and Aguijan (From Doan et al., 1960).

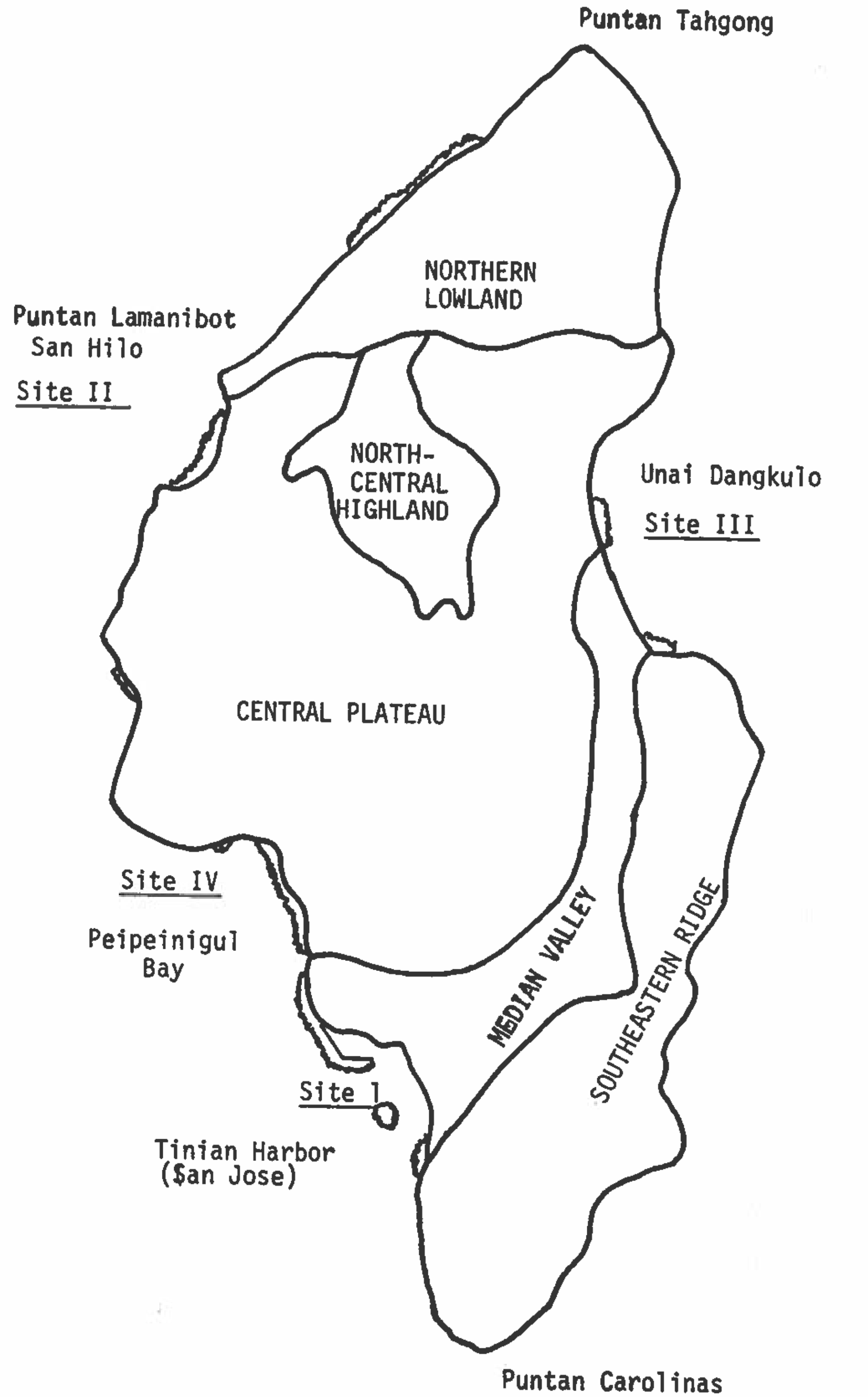


Figure 2. Physiographic divisions of Tinian and site locations (Modified from Doan et al., 1960).

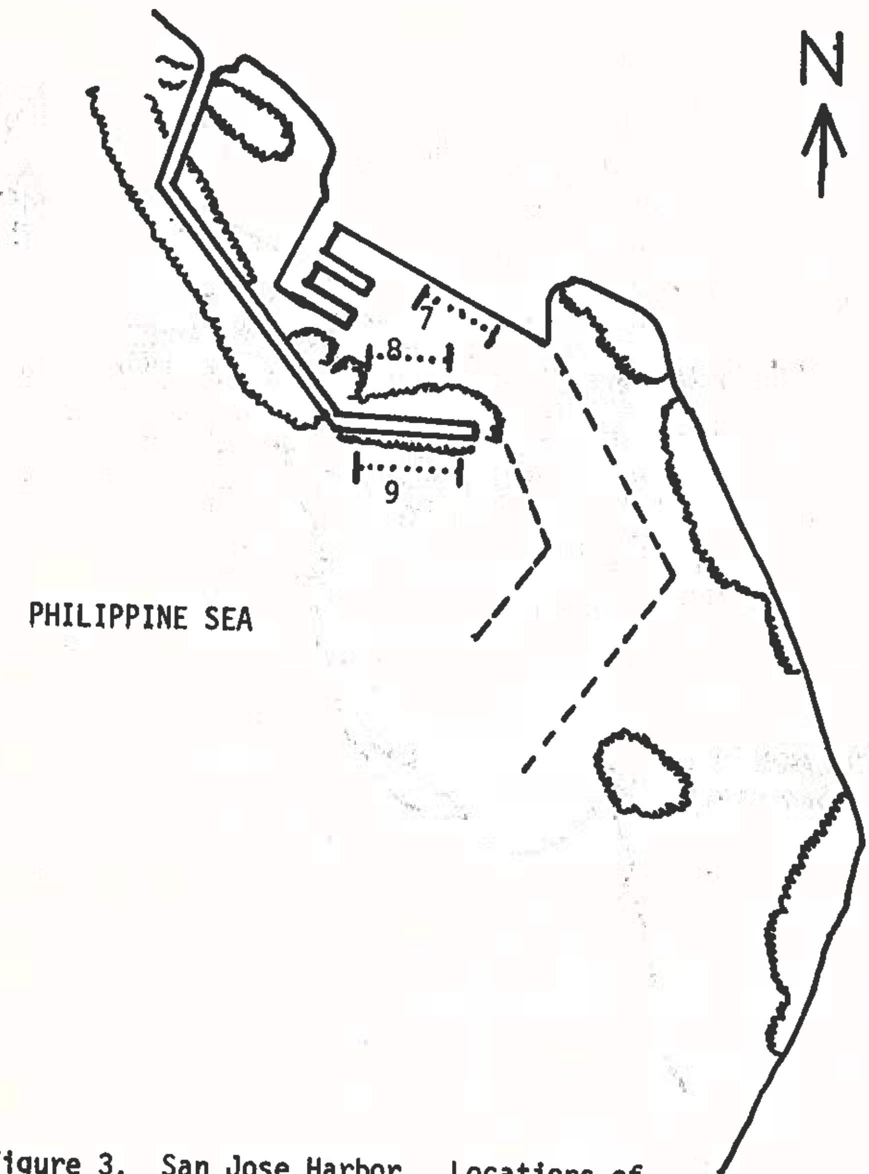


Figure 3. San Jose Harbor, Locations of Transects 7-9 are shown with dotted lines

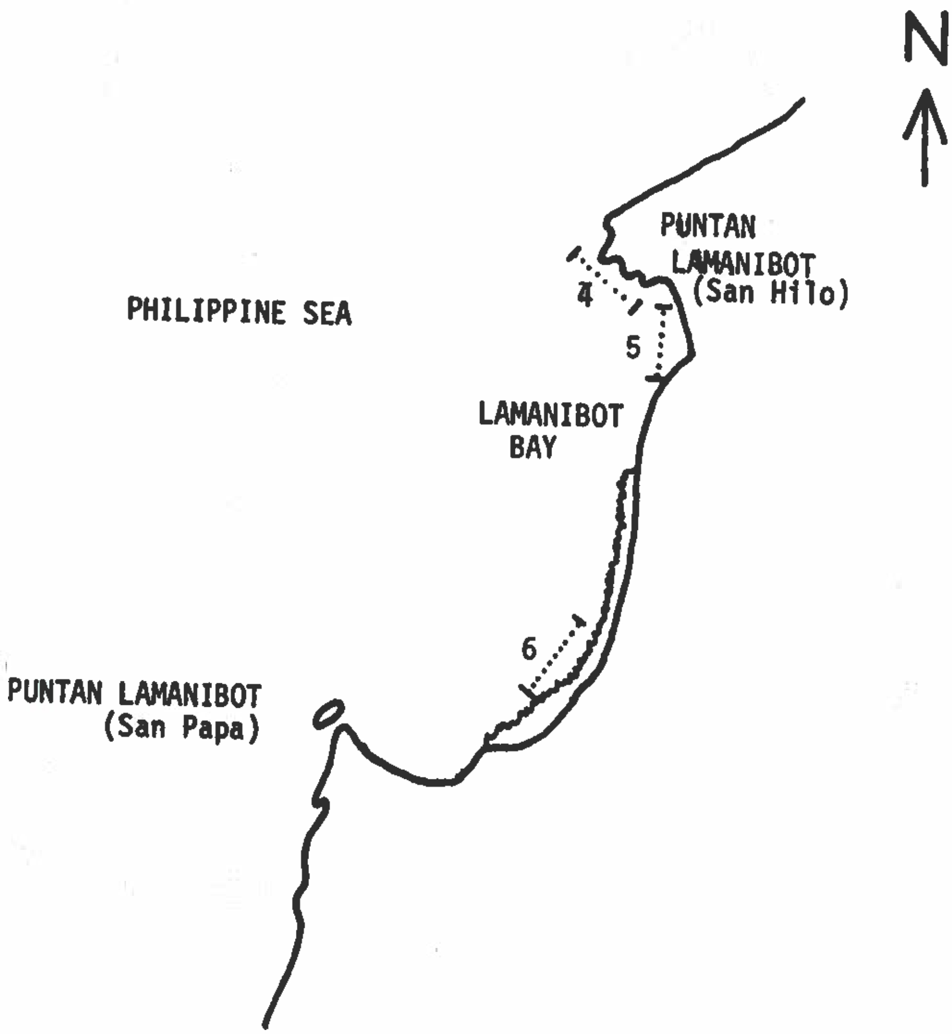


Figure 4. Lamanibot Bay. Location of Transects 4-6 are shown with dotted lines.

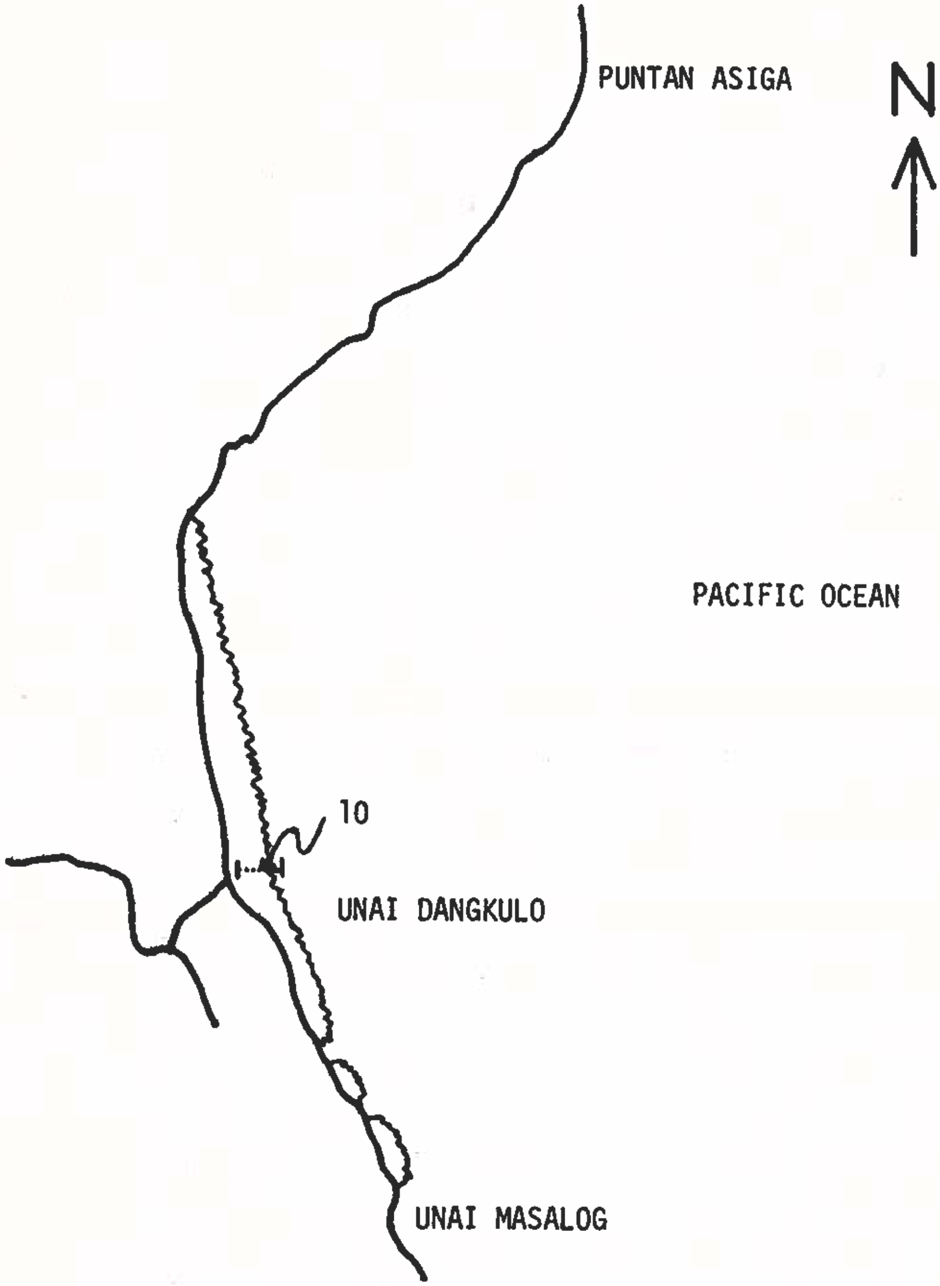


Figure 5. Unai Dangkulo. Location of Transect 10 is shown with dotted line.

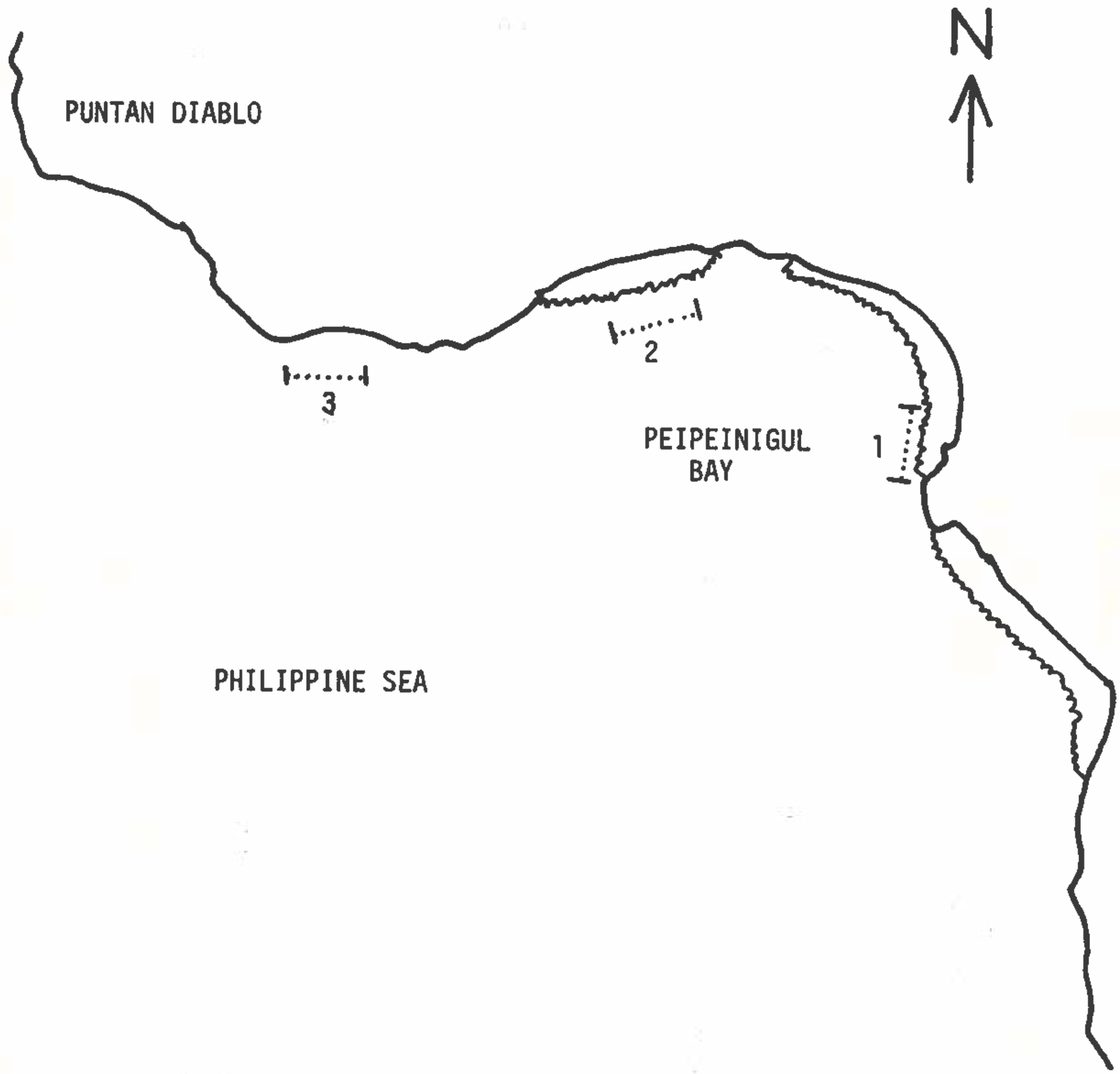
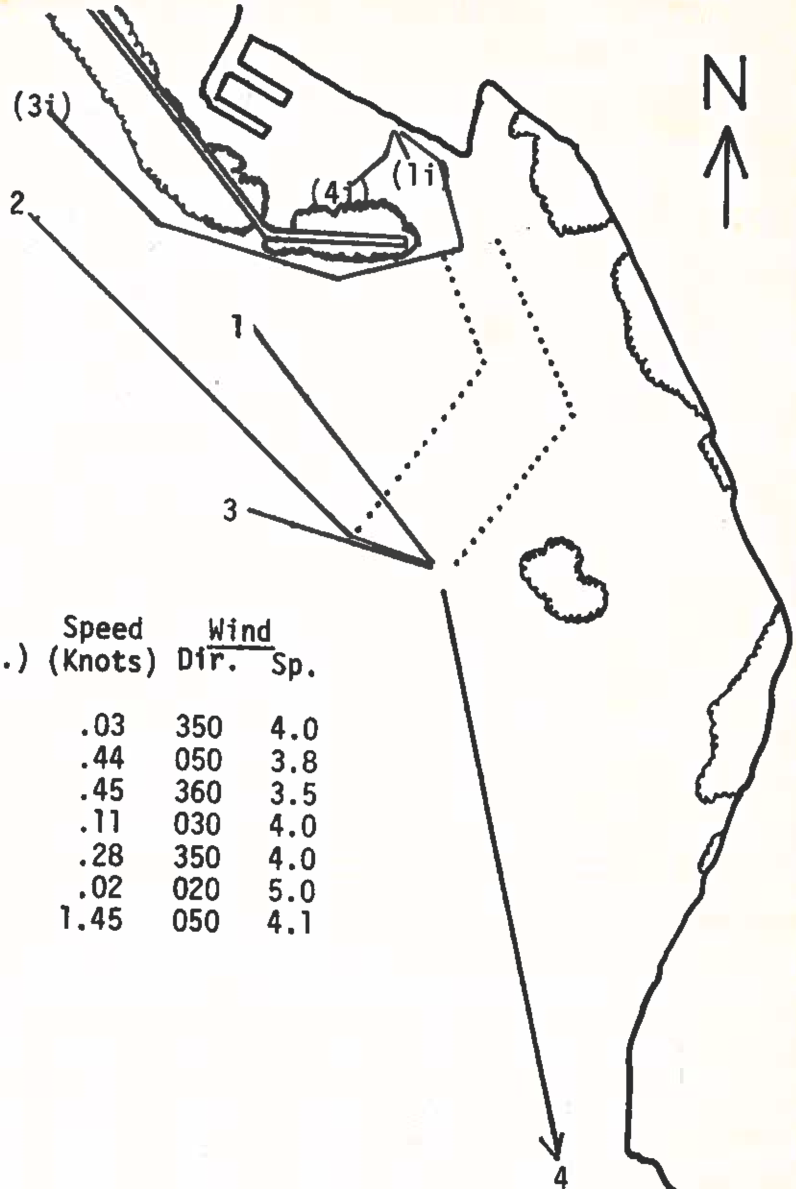


Figure 6. Peipeinigul Bay. Locations of Transects 1-3 are shown with dotted lines.



Drift	Start	ΔT(Hrs.)	Dist. (Naut.Mi.)	Speed (Knots)	Wind Dir.	Wind Sp.
1-i	0900	2	.06	.03	350	4.0
1	0900	1	.44	.44	050	3.8
2	1230	1.5	.65	.45	360	3.5
3-i	1800	8	.86	.11	030	4.0
3	1400	1	.28	.28	350	4.0
4-i	0200	6	.12	.02	020	5.0
4	1700	1.3	1.89	1.45	050	4.1

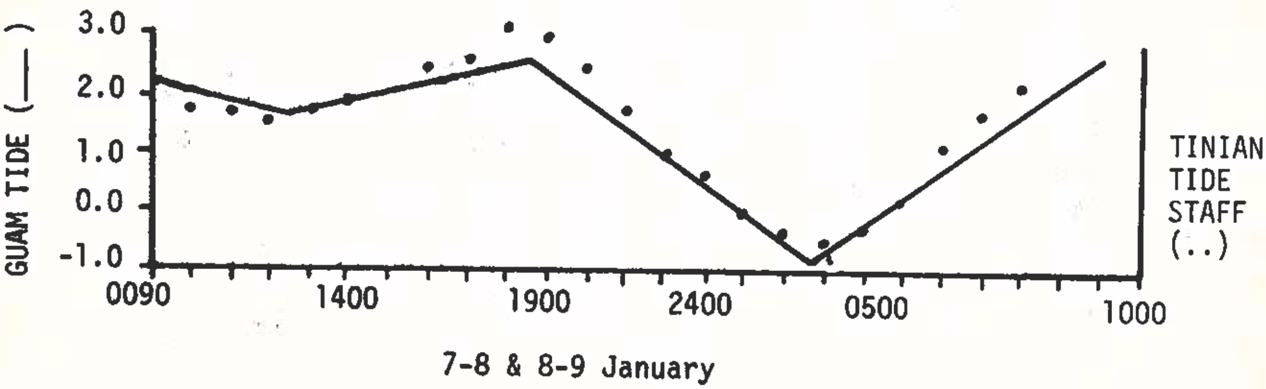
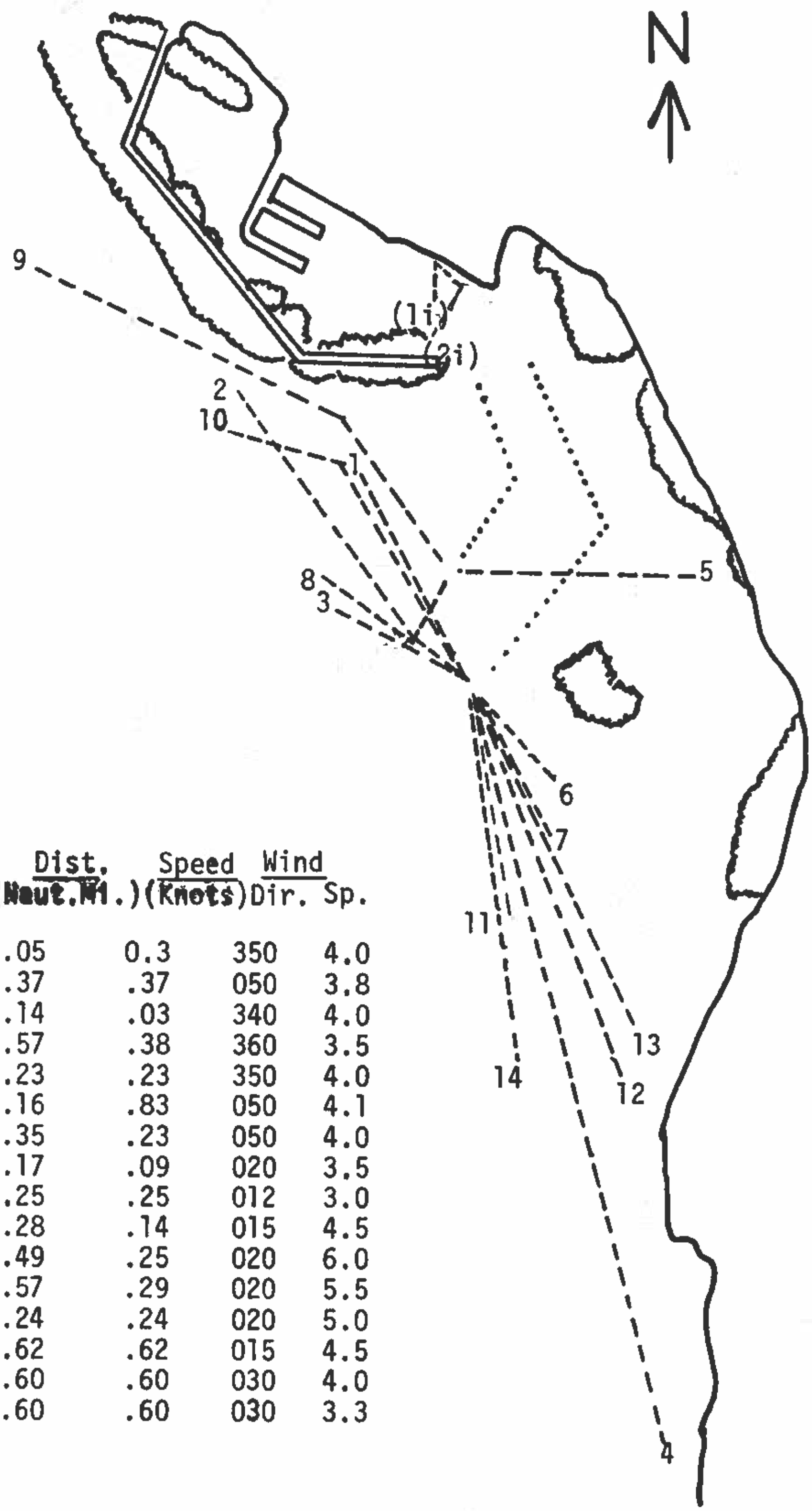


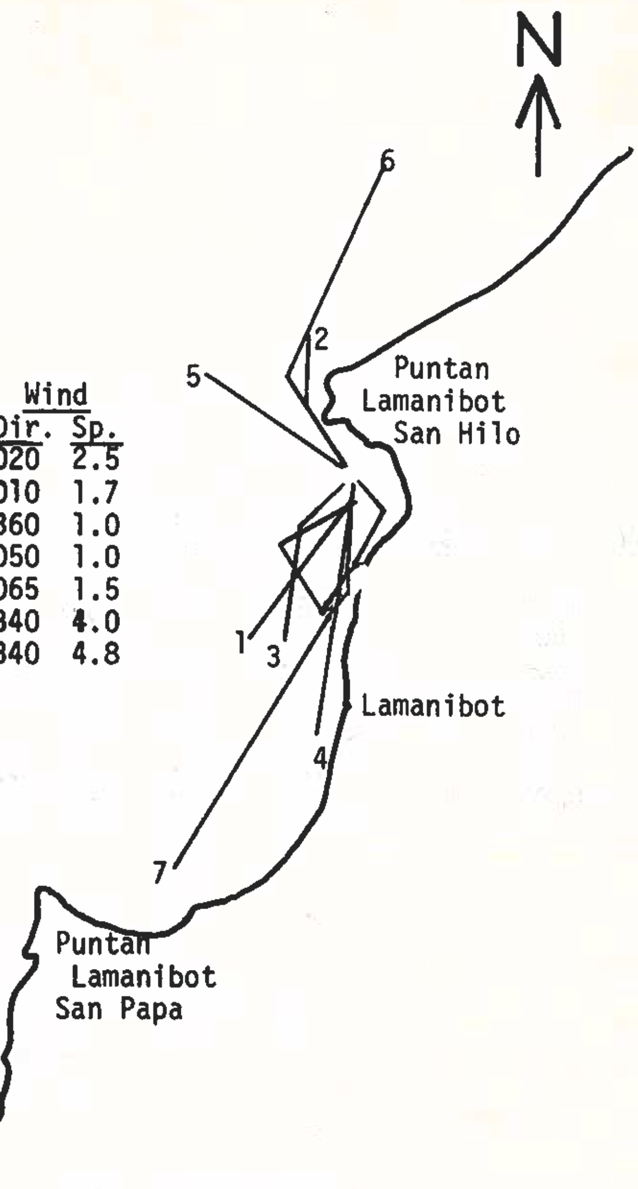
Figure 7. Site I, 1 m drift drogue track and tidal data. Use of the one meter drogues was abandoned because 4 of the drogues were lost in bad weather.



Drift	Start	ΔT(Hrs.)	Dist. (Naut.Mi.)	Speed (Knots)	Wind Dir.	Wind Sp.
1-i	0900	2	.05	0.3	350	4.0
1	0900	1	.37	.37	050	3.8
2-i	1100	5	.14	.03	340	4.0
2	1230	1.5	.57	.38	360	3.5
3	1400	1	.23	.23	350	4.0
4	1700	1.4	1.16	.83	050	4.1
5	1830	1.5	.35	.23	050	4.0
6	1900	2	.17	.09	020	3.5
7	2100	1	.25	.25	012	3.0
8	2200	2	.28	.14	015	4.5
9	2400	2	.49	.25	020	6.0
10	0200	2	.57	.29	020	5.5
11	0400	1	.24	.24	020	5.0
12	0500	1	.62	.62	015	4.5
13	0600	1	.60	.60	030	4.0
14	0700	1	.60	.60	030	3.3

Figure 8. Site I, 5 m drift drogue tracks.

Drift	Start	ΔT (Hrs.)	Dist (Naut.Mi.)	Speed (Knots)	Wind	
					Dir.	Sp.
1	1000	8	.90	.11	020	2.5
2	1200	2	.29	.15	010	1.7
3	1600	4	.34	.09	360	1.0
4	2000	4	.46	.12	050	1.0
5	0000	2	.32	.16	065	1.5
6	0200	2	.63	.32	340	4.0
7	0400	4	.78	.20	340	4.8



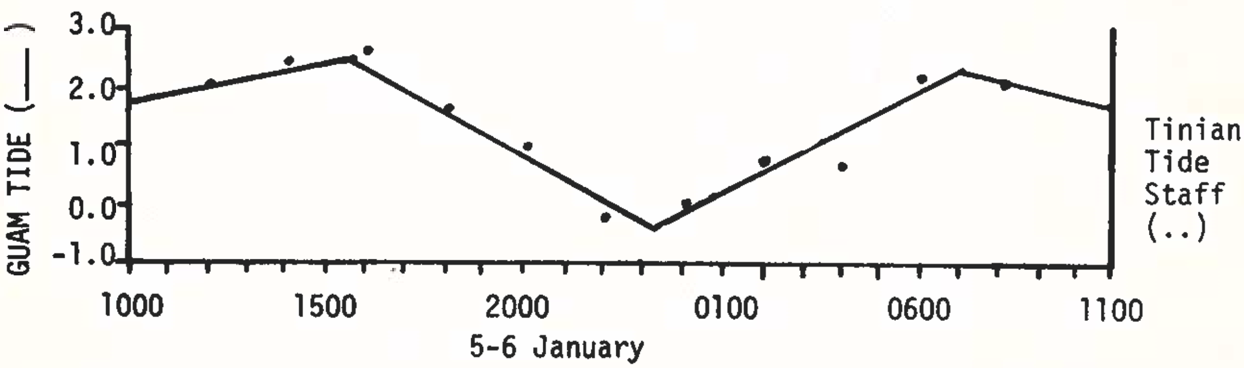


Figure 9. Site II, 1 m drift drogue tracks and tidal data.

Drift	Start	ΔT (Hrs.)	Dist (Naut.Mi.)	Speed (Knots)	Wind Dir.	Wind Sp.
1	1000	8	.67	.08	020	2.5
2	1600	4	.20	.05	360	2.0
3	2000	4	.33	.08	360	1.0
4	0000	4	.48	.12	050	1.0
5	0200	2	.22	.11	065	1.5
6	0400	2	.73	.37	340	4.0
7	0800	4	.41	.10	340	4.8

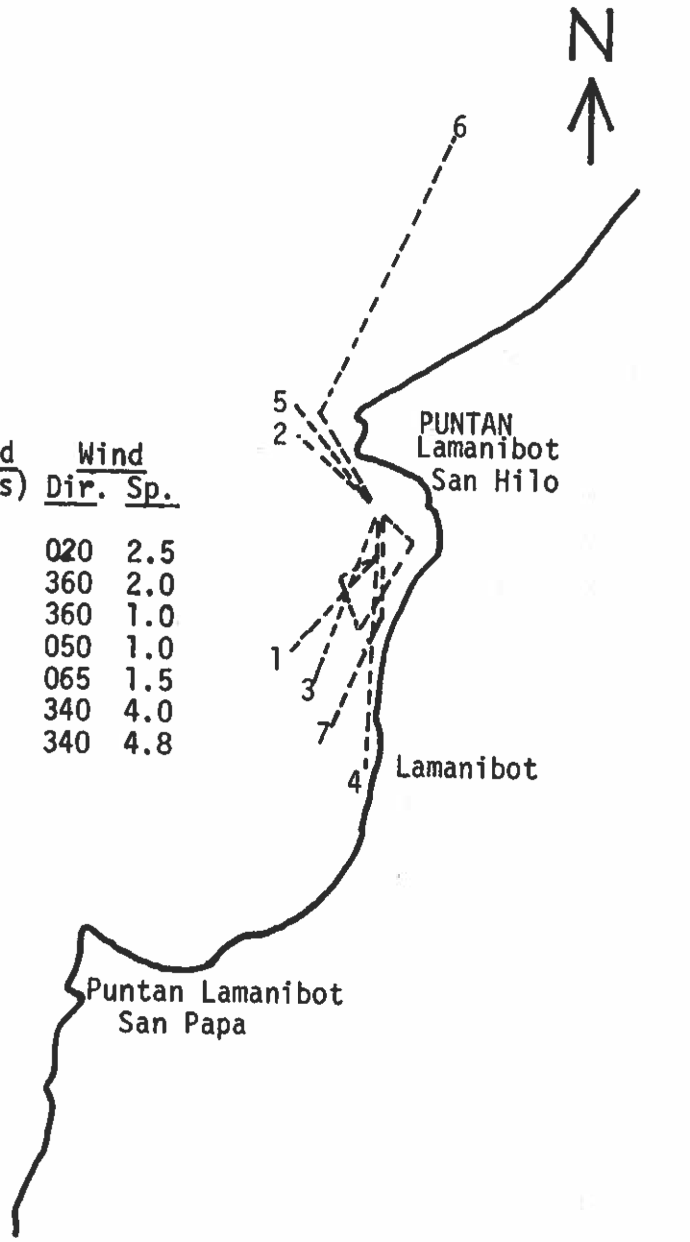


Figure 10. Site II, 5 m drift drogue tracks.

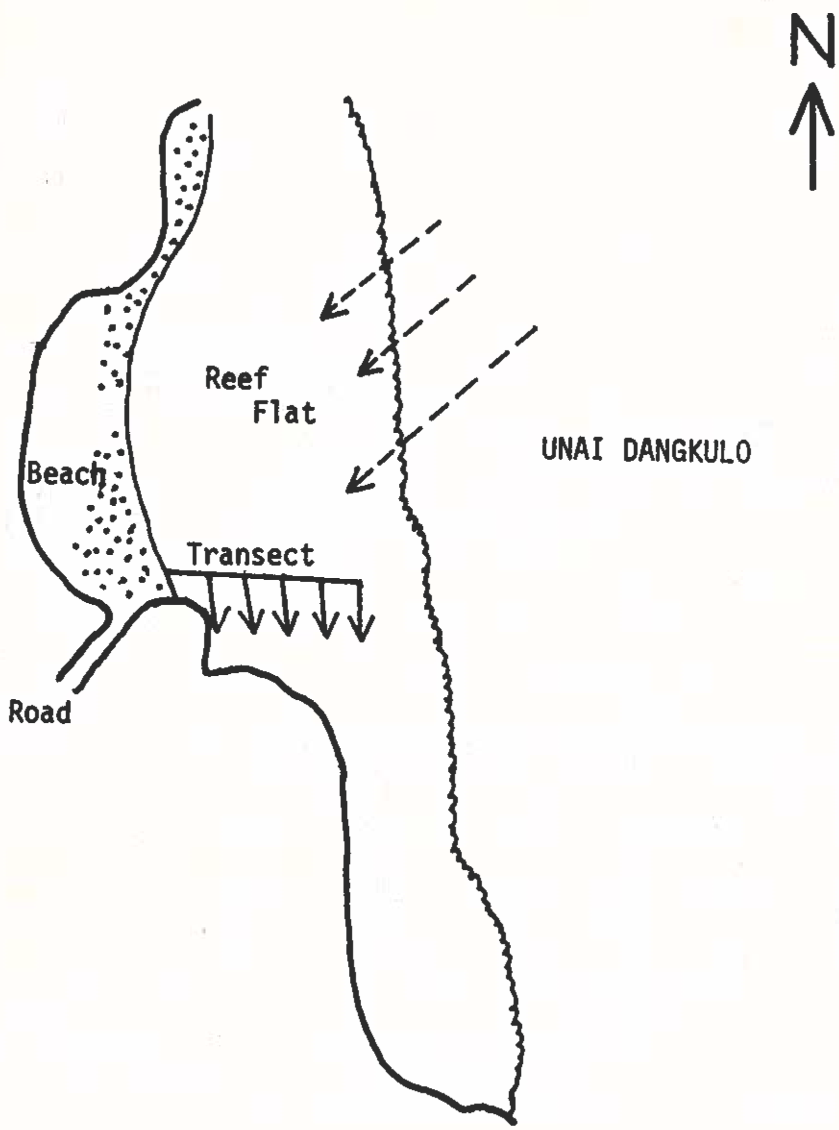
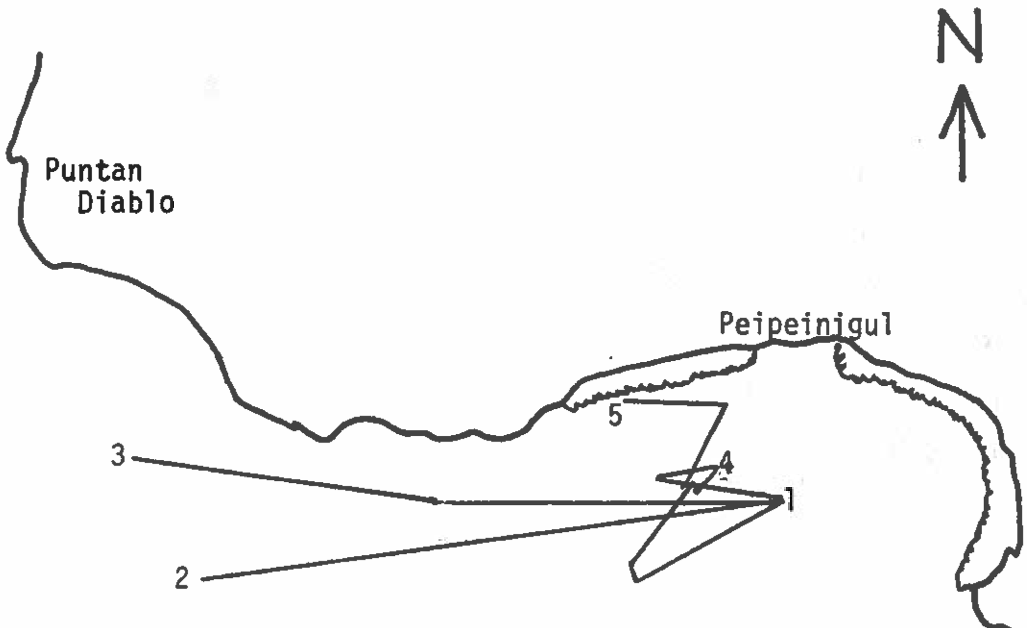


Figure 11. Site III, current patterns from fluorescein dye release at 20 m intervals. Dotted line shows wave transport.



Drift	Start	ΔT (Hrs.)	Dist. (Naut.Mi.)	Speed (Knots)	Wind Dir.	Wind Sp.
1	1330	4.5	.33	.07	100	4.5
2	1800	4.0	.32	.21	090	3.5
3	2210	2.8	.92	.33	070	2.8
4	0200	6.0	.43	.07	100	1.5
5	0830	4.0	.43	.11	150	5.0

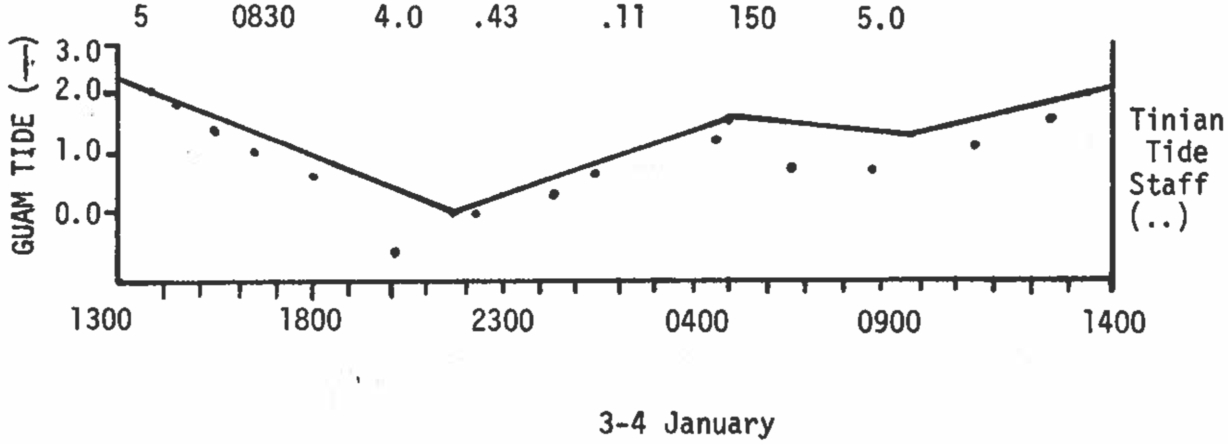
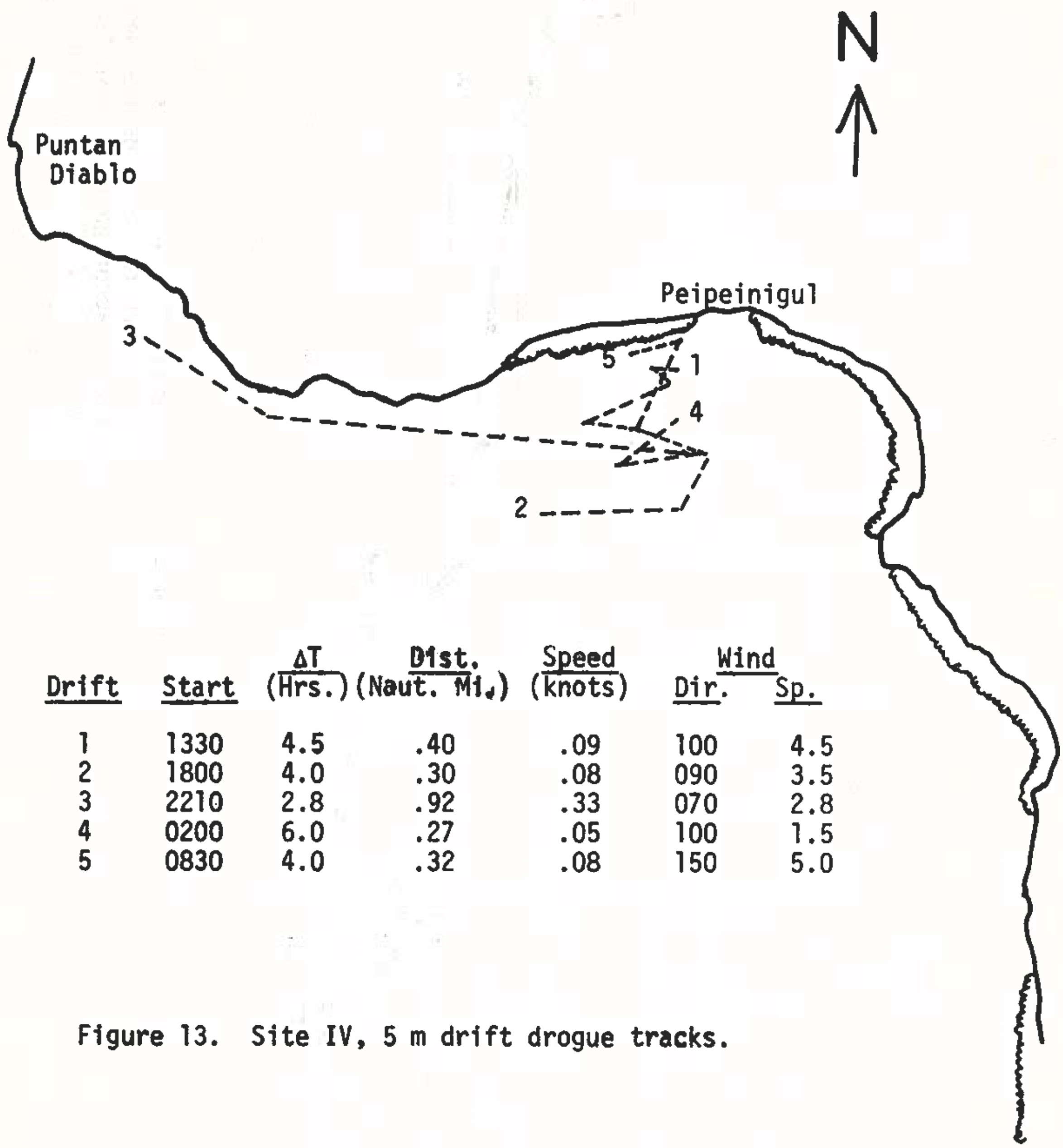


Figure 12. Site IV, 1 m drift drogue tracks and tidal data.



Drift	Start	ΔT (Hrs.)	Dist. (Naut. Mi.)	Speed (knots)	Wind Dir.	Wind Sp.
1	1330	4.5	.40	.09	100	4.5
2	1800	4.0	.30	.08	090	3.5
3	2210	2.8	.92	.33	070	2.8
4	0200	6.0	.27	.05	100	1.5
5	0830	4.0	.32	.08	150	5.0

Figure 13. Site IV, 5 m drift drogue tracks.

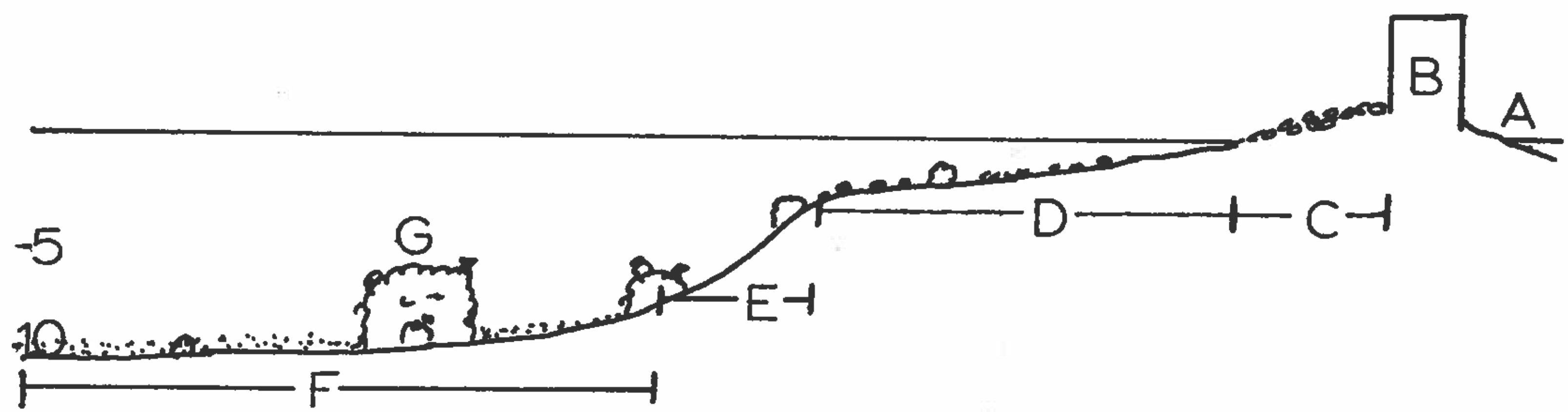


Figure 14. Vertical profile of Transect No. 8. A=seaward side of barrier reef, B=breakwater, C=boulder beach, D=lagoon barrier reef flat platform, E=lagoon slope, F=sandy lagoon floor, and G=coral mound. Depth of water is in meters.

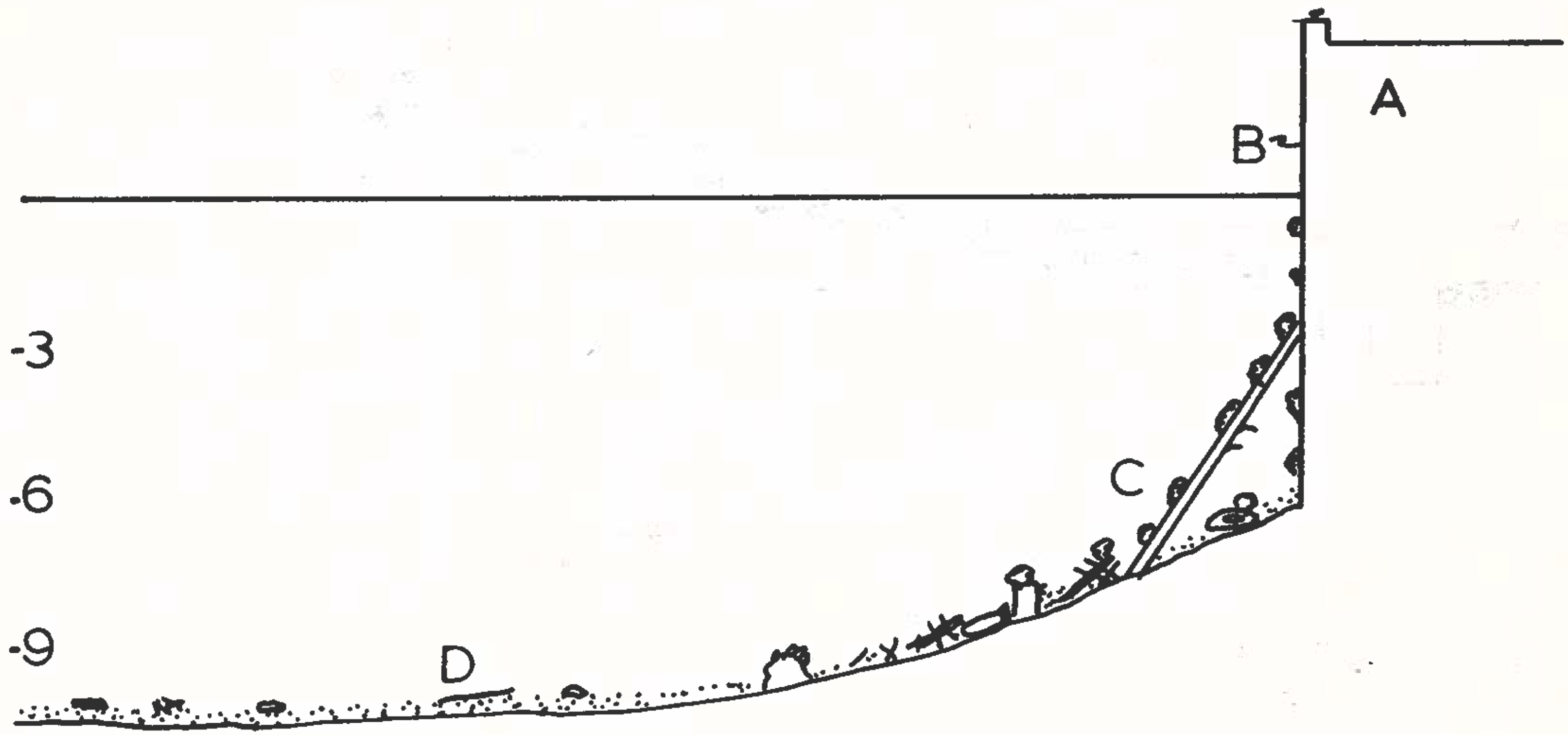


Figure 15. Vertical profile of Transect No. 7. A=wharf; B= bulkhead of interlocking sheet steel pilings; C=metal buttress, metal junk, and boulders with scattered small cespitose and encrusting corals; D=silt and calcareous sand covered lagoon floor. Water depth is in meters.

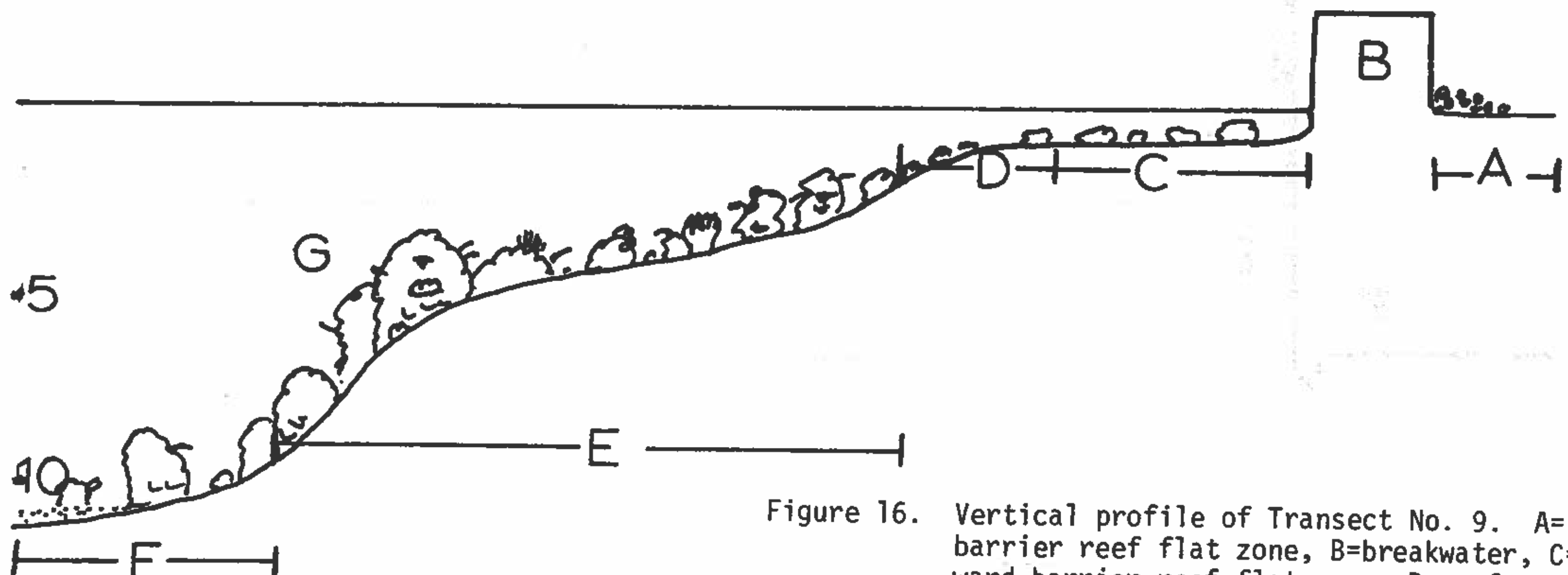


Figure 16. Vertical profile of Transect No. 9. A=lagoon barrier reef flat zone, B=breakwater, C=seaward barrier reef flat zone, D=reef margin zone, E=reef front buttress and channel zone, F=sand-floored submarine terrace, and G=large massive reef building coral colonies. Water depth is in meters.

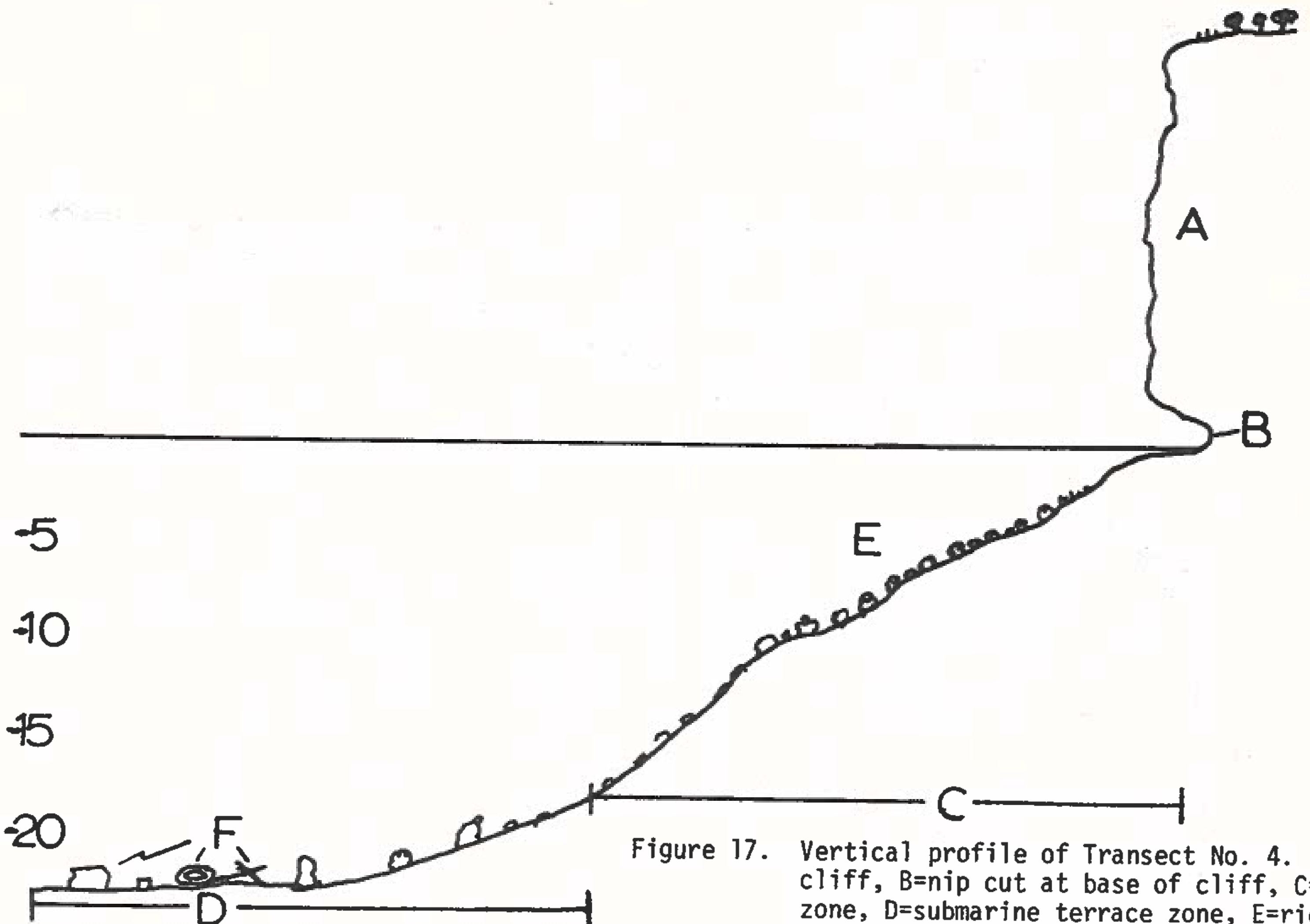


Figure 17. Vertical profile of Transect No. 4. A=limestone cliff, B=nip cut at base of cliff, C=seaward slope zone, D=submarine terrace zone, E=rich growth of small *Pocillopora* colonies growing on upper part of seaward slope, and F=scattered junk and coral mounds. Water depth is in meters.

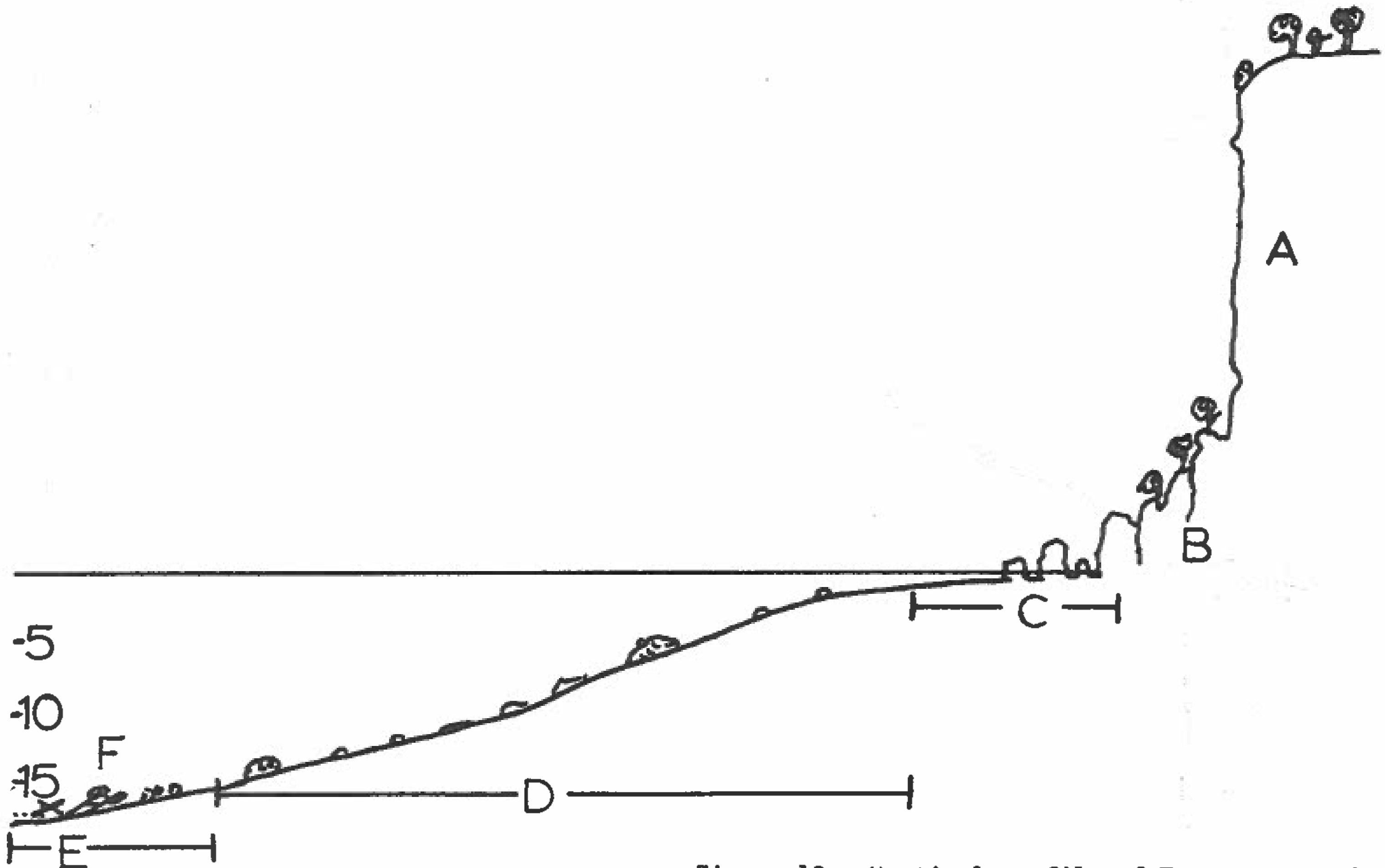


Figure 18. Vertical profile of Transect No. 5. A=40 meter limestone cliff, B=boulder-block talus slope, C=narrow reef flat platform zone, D=low angled seaward slope zone, E=submarine terrace zone, and F=junk and scattered coral mounds. Water depth is in meters.

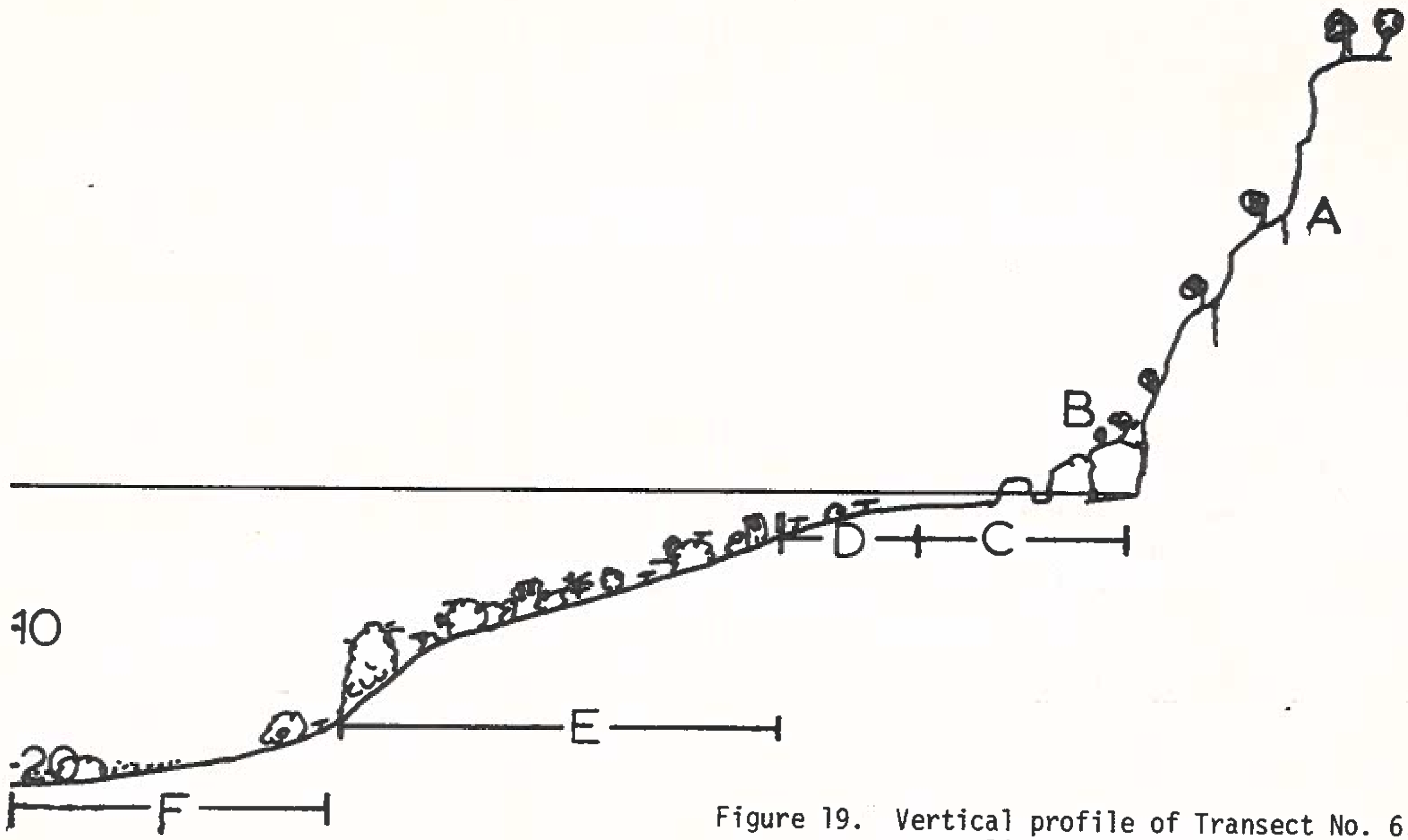


Figure 19. Vertical profile of Transect No. 6. A=40 meter limestone cliff, B=boulder-block talus slope, C=narrow reef flat platform zone, D=reef margin zone, E=reef front buttress and channel zone, and F=submarine terrace zone. Water depth is in meters.

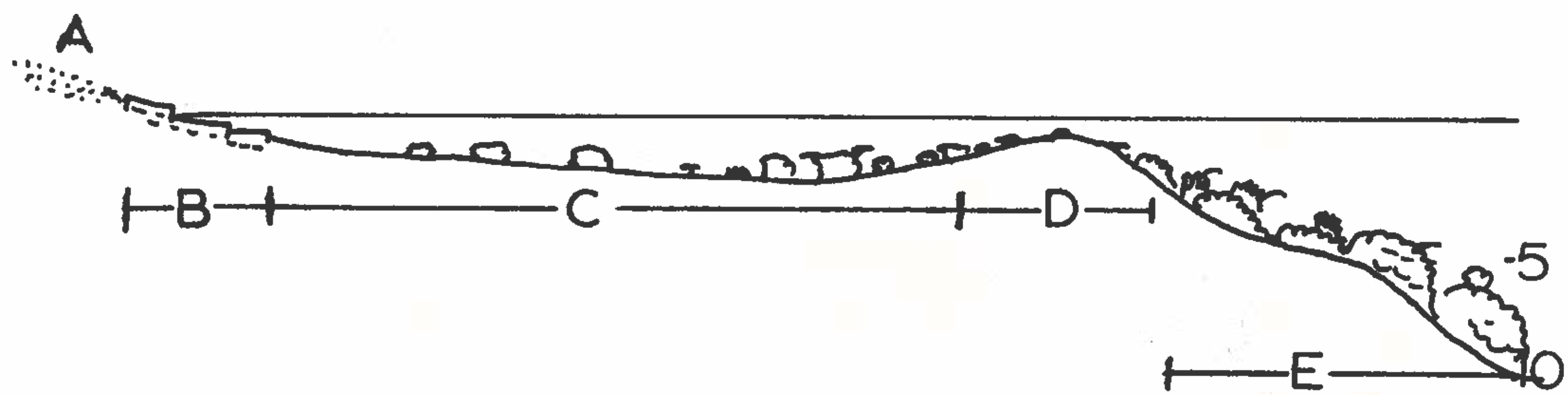


Figure 20. Vertical profile along Transect 10. A=beach, B=beachrock zone, C=fringing reef flat platform, D=reef margin and algal ridge, and E=reef front buttress and channel zone. Water depth is in meters.

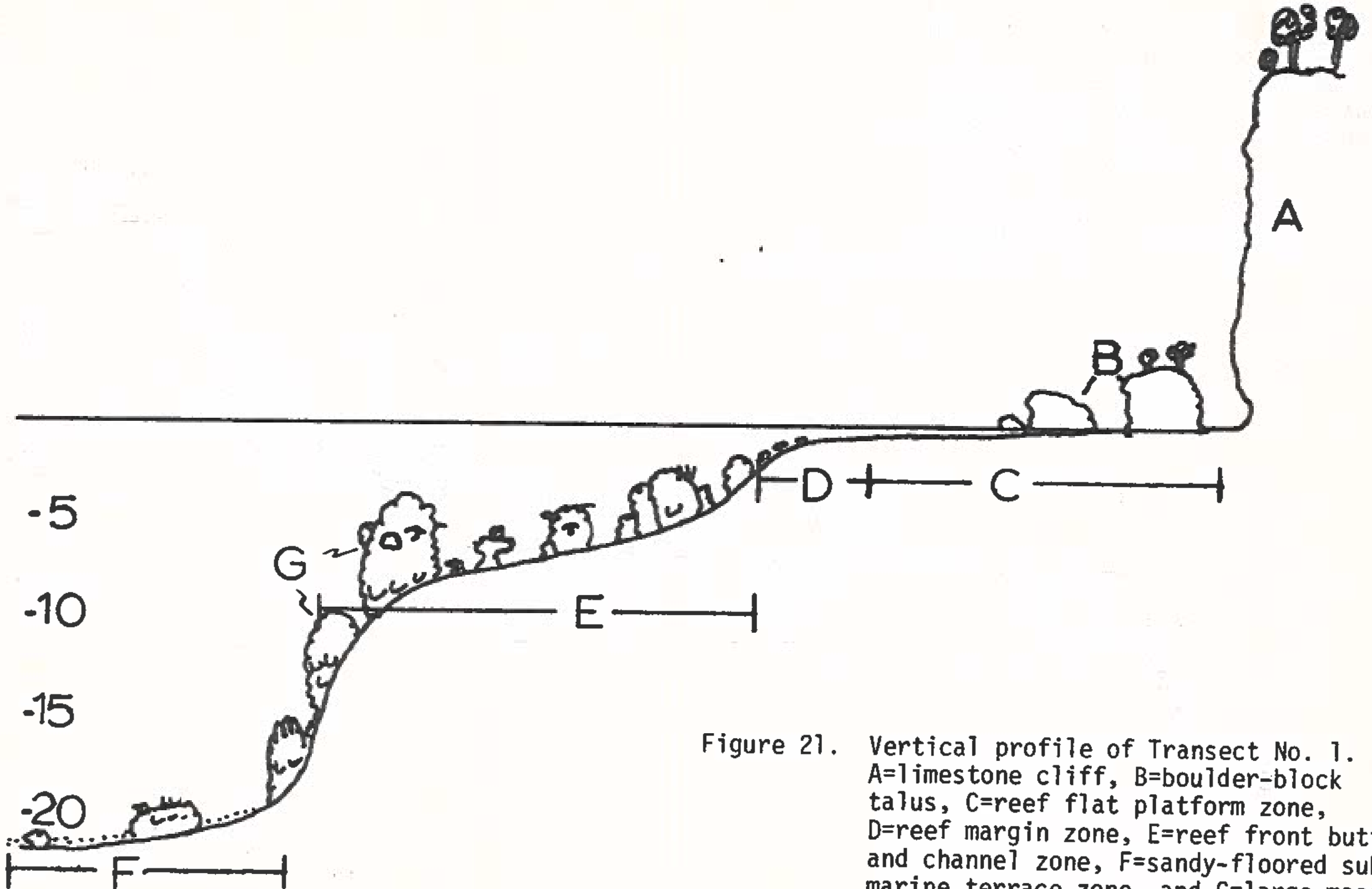


Figure 21. Vertical profile of Transect No. 1. A=limestone cliff, B=boulder-block talus, C=reef flat platform zone, D=reef margin zone, E=reef front buttress and channel zone, F=sandy-floored submarine terrace zone, and G=large masses *Porites* coral colonies. Water depth is in meters.

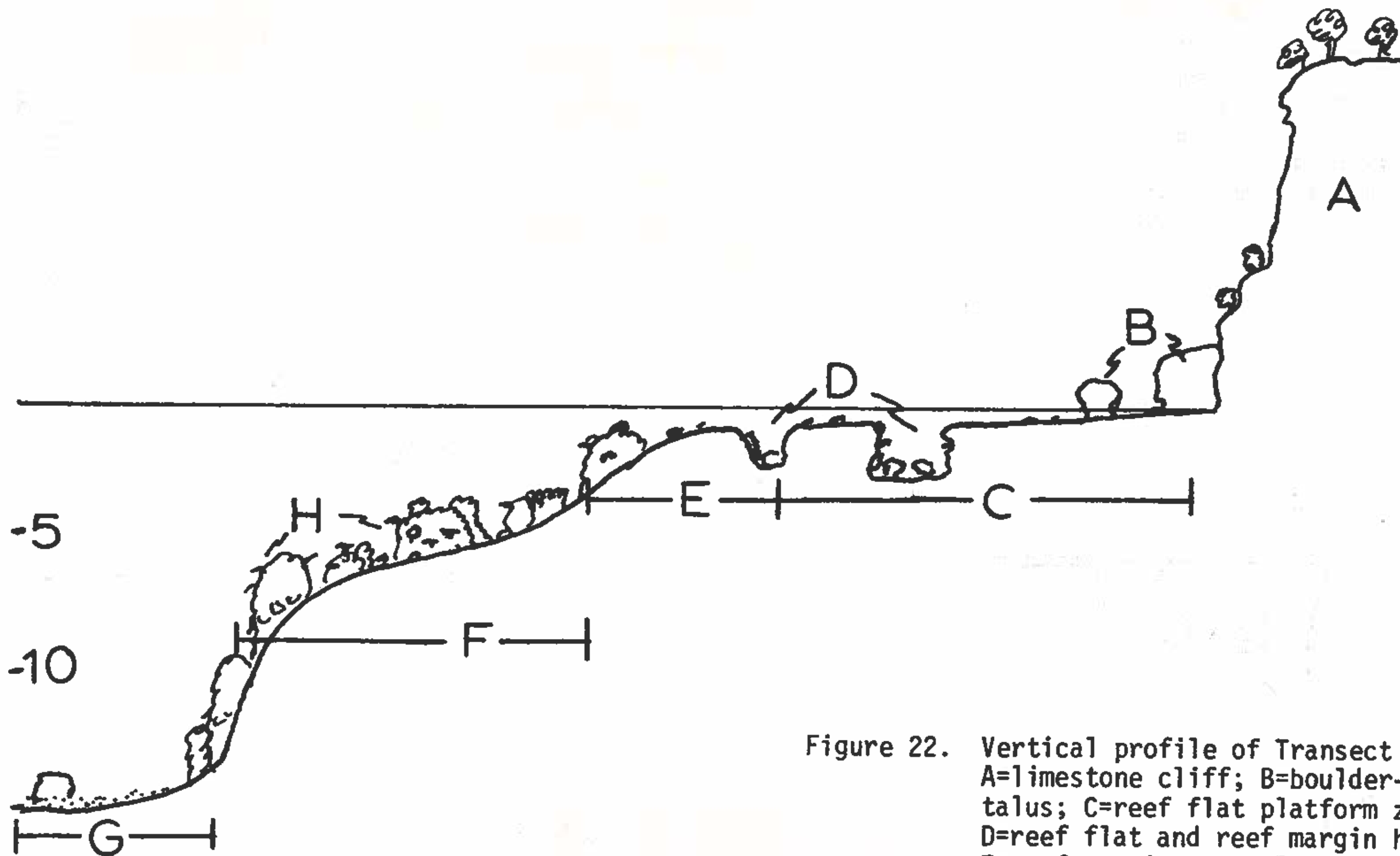


Figure 22. Vertical profile of Transect No. 2. A=limestone cliff; B=boulder-block talus; C=reef flat platform zone; D=reef flat and reef margin holes; E=reef margin zone; F=reef front buttress and channel zone; G=sandy-floored submarine terrace zone; and H=Large massive _Porites_, _Goniastrea_, and _Favia_ coral colonies. Water depth is in meters.

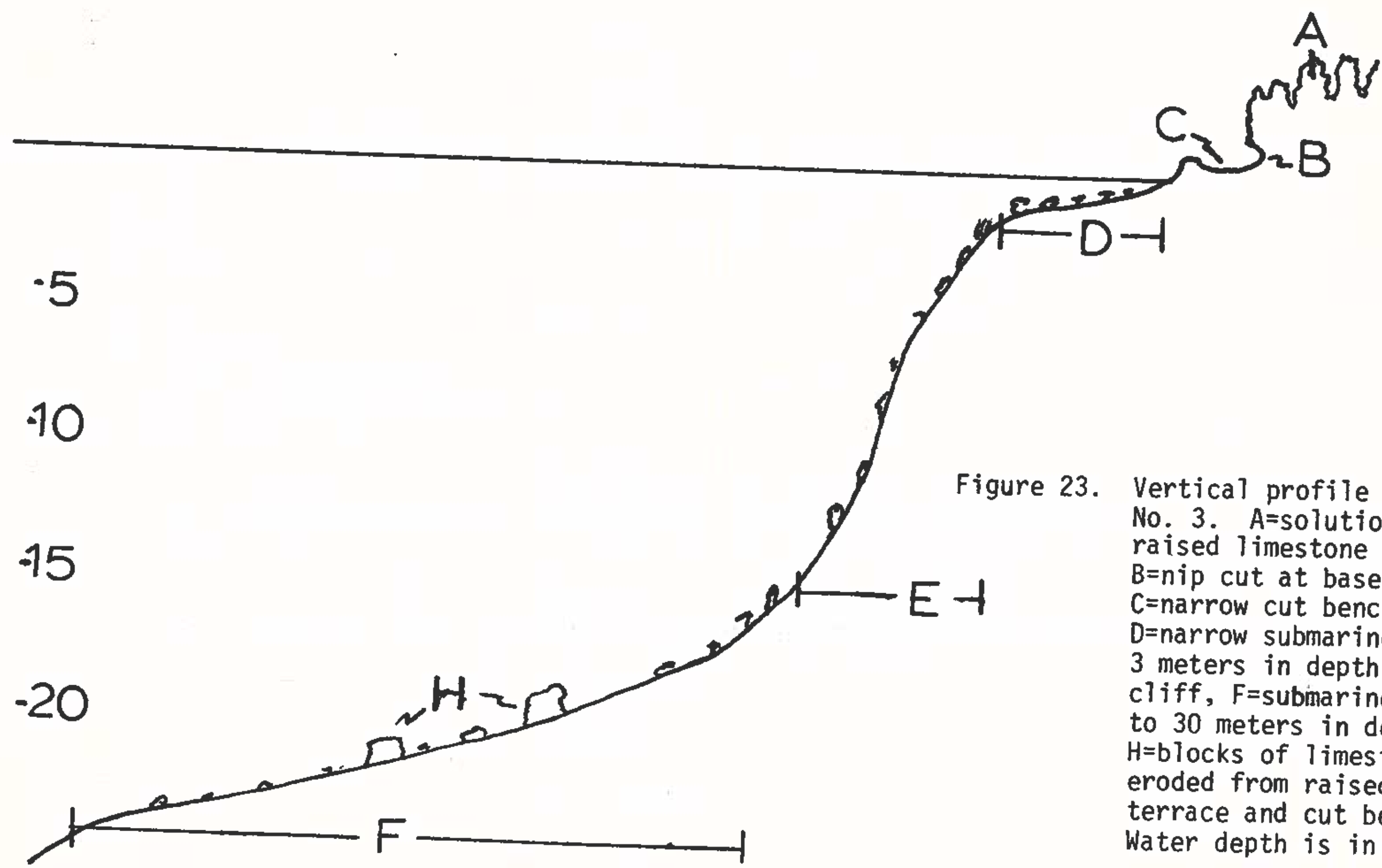


Figure 23. Vertical profile of Transect No. 3. A=solution-pinnacled raised limestone terrace, B=nip cut at base of terrace, C=narrow cut bench platform, D=narrow submarine ledge 2 to 3 meters in depth, E=submarine cliff, F=submarine terrace 20 to 30 meters in depth, and H=blocks of limestone that have eroded from raised limestone terrace and cut bench above. Water depth is in meters.

PLATE LEGENDS

Plate 1

A. Research Vessel "Havaiki" anchored in Lamanibot Bay (Site II).

B. Inflatable boat for inshore work and tracking drift drogues.

C. Laying transect line.

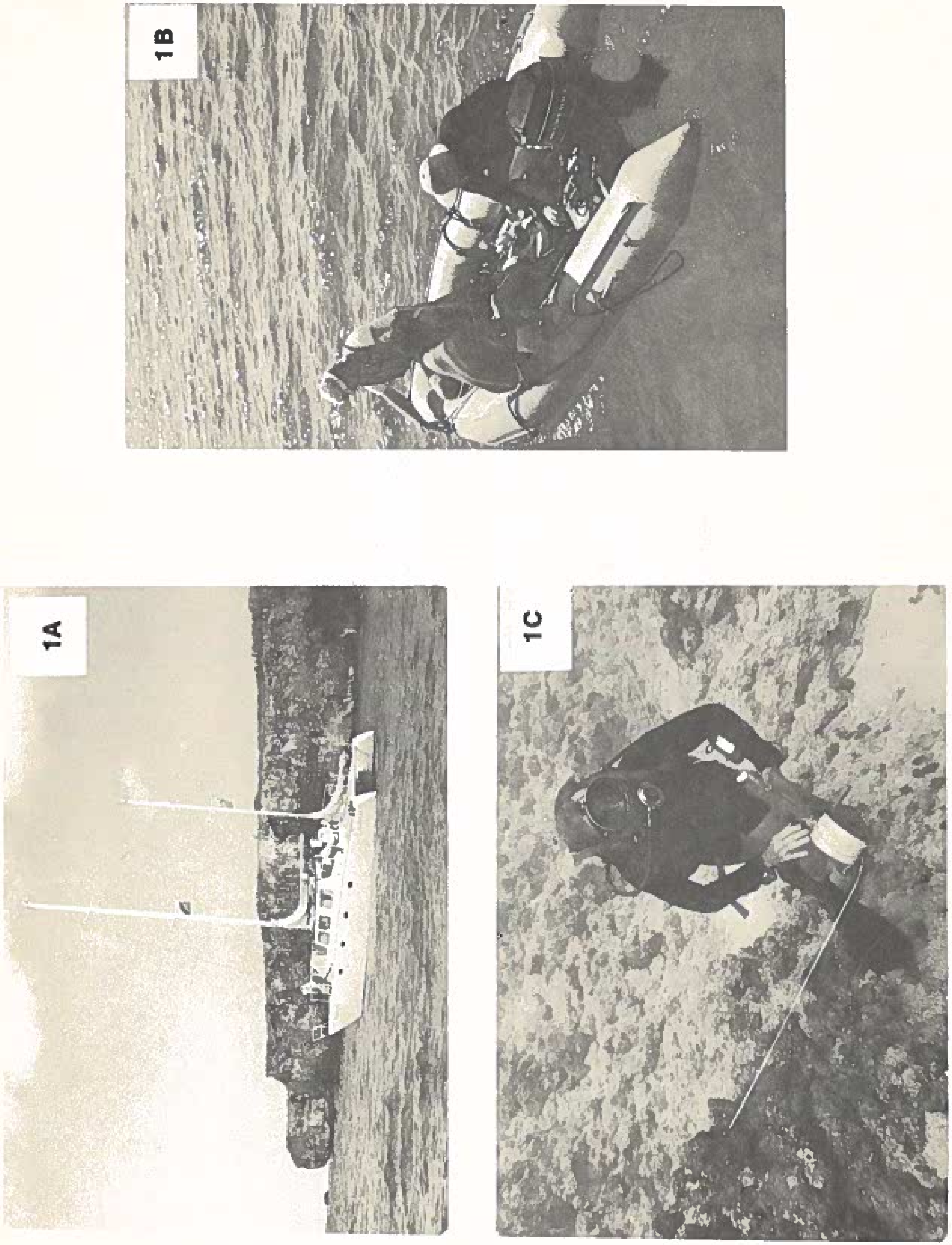

1B
1A
1C

PLATE LEGENDS

Plate 2

A. Tape recorder used on fish transects.

B. Quadrat sampling for benthic algae.

C. Talus slope of blocks and boulders at Lamanibot Bay.

D. Coastline at Peipeinigul Bay near Puntan Diablo. Note bench and well developed nip near the intertidal.

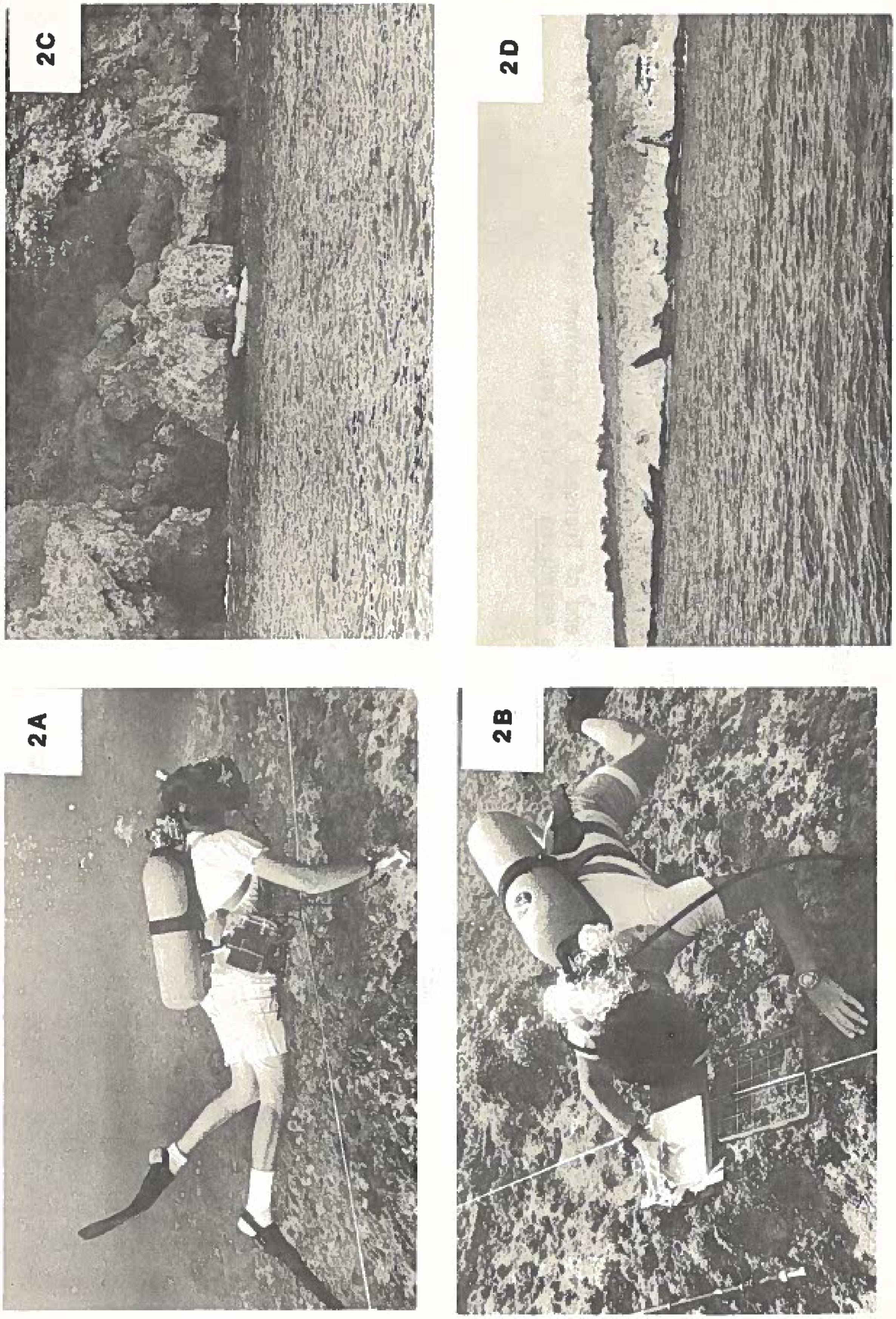

2C
2D
2A
2B

PLATE LEGENDS

Plate 3

A. *Acanthaster planci* feeding on *Porites lutea*.

B. Bottom of cliff slope at outer end of Transect 4, Lamanibot Bay. Note dense cover of *Pocillopora meandrina* on the slope.

C. Jointed, limestone pavement bottom near Transects 4 and 5, Lamanibot Bay.

D. Large *Porites lutea* colony, part of which survived the initial attack by *Acanthaster*.

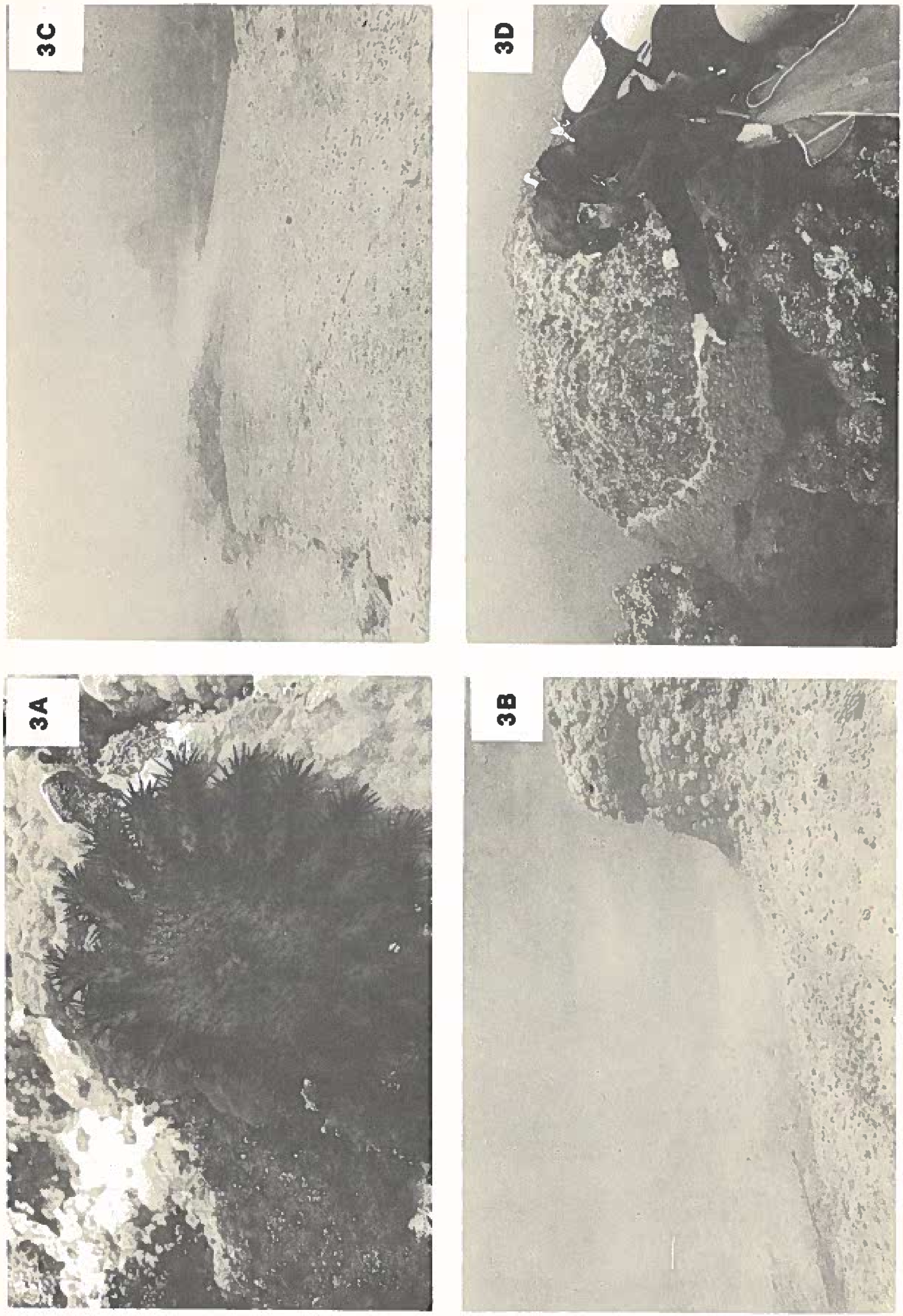

3A
3B
3C
3D

PLATE LEGENDS

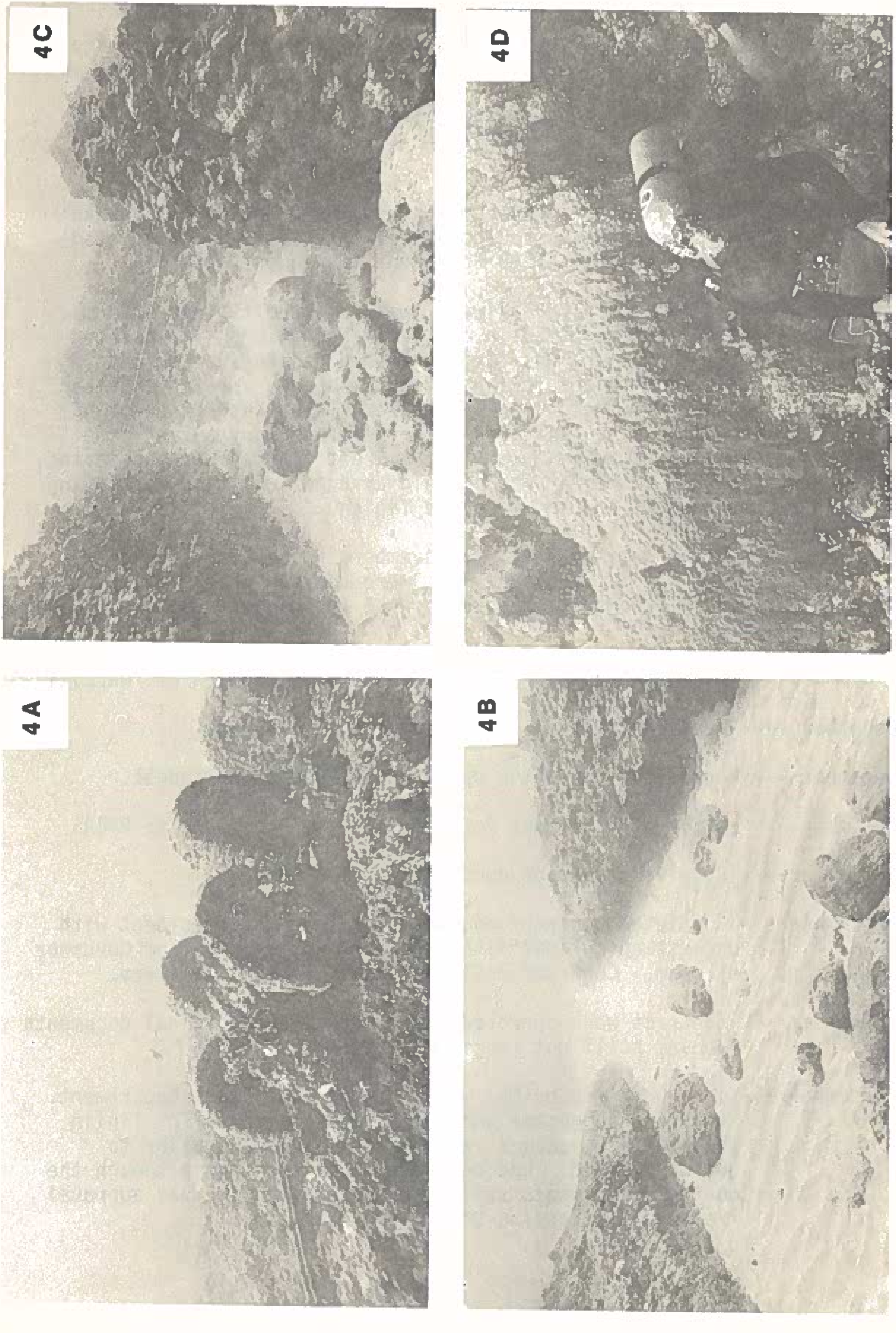
Plate 4

A. Debris dumped in the water at Transects 4 and 5, Lamanibot Bay.

B. Bottom with veneer of sand near Transect 5, Lamanibot Bay.

C. Submarine channels and buttresses on Transect 6, Lamanibot Bay.

D. Large massive *Porites lutea* colony on the seaward end of a buttress. This species is active in reef framework development.


4C
4D
4A
4B

APPENDIX A

Log of Operations
1973-1974

12 October --- Visited at Marine Laboratory by PACAF engineer Jonathan Kajiwara. Discussed possible Tinian Survey. Suggested letter from PACAF to President to request service.

18 October --- Visited again by Kajiwara, we requested further information that resulted in contract assumptions. We pointed out that there was still not enough data available on Air Force plans for an adequate survey. We were advised that it was still early for details because of on-going political negotiations and, therefore, any survey done would be preliminary. Survey cost figures were projected, assuming the Air Force would arrange logistics for moving personnel and equipment to Tinian.

29 November --- PACAF letter, dated 21 November, requesting service received by President. We were advised that all logistics would have to be handled by the contractor (University of Guam).

30 November --- Discussed charter possibilities with Captain of "Havaiki".

3 December --- Received approval to proceed from President.

4 December --- Worked out tentative operation schedule and budget.

5 December --- Letter of agreement for service from President to PACAF.

12 December --- Received contract documents from PACAF.

14 December --- Completed contract documents. Signed by President with understanding that final approval would come from Governor of Guam. Contract mailed airmail, special delivery.

26 December --- Contract work approved by Governor, but original documents (above) still not received by PACAF.

27 December --- Team briefing by Ms. Mary Trent of the State Department. Ms. Trent suggested that Jones leave at once for Tinian to establish contact with Tinian officials prior to holiday period. Lau called and advised that although the contract documents still had not arrived, we had approval from the Contracting Officer to proceed.

28 December --- Jones departed for Tinian by Air Pacific and made the required official contacts.

29 December --- Rest of team departed Guam aboard "Havaiki".

30 December --- Tsuda arrived Tinian by Air Pacific. Received word that "Havaiki" sustained structural damage in heavy seas and returned to Guam.

31 December --- Jones and Tsuda returned to Guam.

1 January --- Repair completed on "Havaiki" and she got underway again at 1730.

3 January --- "Havaiki" arrived Tinian in early a.m. Jones, Tsuda, Strong, and Wooster arrived Tinian by Air Pacific. Began survey at 1035. Set up bearing points and navigation lights at Site IV and started first 24 hour current study.

4 January --- Completed current survey and ran three transects. Returned to San Jose in late evening.

5 January --- Moved to Site II, set up bearing points and navigation lights. Started 24 hour current survey.

6 January --- Finished current survey and ran three transects. Returned to San Jose at sunset.

7 January --- Heavy rain and rough seas. Started 24 hour current survey at Site I. Four drift drogues lost because of bad weather. Operations were becoming hazardous off the harbor mouth. Suspended operation at sunset.

8 January --- Recommenced current survey of Site I and completed three transects. Took one small boat around south end of island to locate an alternate point for Site III (windward). Encountered heavy seas, boat nearly swamped. Returned to harbor. Took truck to Site III to evaluate sea condition. Water extremely rough offshore, heavy surf along fringing reef. Conditions unsafe for either small boat operation or the "Havaiki".

9 January --- Completed current survey at Site I. Returned by truck to Site III. Still too rough for boat operations. Attempts to cross reef margin from beach were defeated by heavy surf. Elected to survey reef flat. Met with PACAF engineer Dick Gordon. Still unable to answer definite questions about facilities.

10 January --- Gave briefing of our work to University of Hawaii socio-economic group and PACAF representatives Dick Gordon and Manuel Emiliano.

Settled financial accounts on Tinian and packed equipment. "Havaiki" departed for Guam. Jones, Tsuda, Strong and Randall returned to Guam by Air Micronesia.

12 January --- "Havaiki" arrived on Guam.

13 January --- Off load equipment.

14 - 28 January --- Data analysis and report writing.

APPENDIX B

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