AECOS No. 124

PRELIMINARY ENVIRONMENTAL IMPACT STUDIES ON THE MARINE ENVIRONMENT AT MAUNALUA BAY

Prepared for

Kentron Hawaii, Ltd.

by

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INTRODUCTION

The purpose of the present study is to provide an initial environmental assessment of Maunalua Bay as it relates to the proposed dredging of the existing channel, the construction of a docking facility on the shoreline in the vicinity of the Hawaii Kai Marina entrance channel, and the operation of the hydrofoil vessel. This study is not intended to be an in-depth scientific investigation, but rather an initial assessment resulting in preliminary predictions of environmental impact with recommendations for further study where required.

The scope of work for the study includes: (1) an outline of the physical parameters within the Bay that might have a significant effect on the construction and maintenance of a Jetfoil terminal; (2) a delineation of the baseline biological conditions within the Bay for predicting the effect of construction and operation of a Jetfoil terminal upon the biota; and (3) probable influence of construction and Jetfoil terminal operation on water quality within the Bay.

The physical study of Maunalua Bay consisted principally of an evaluation of existing circulation and sedimentation data. However, since the circulation and sedimentation data available for the Bay are nearly 15 years old, a two man-day reconnaissance of present field conditions was undertaken to update present sedimentary conditions.

The biological study was designed to include a field survey (6 man-days) of fishes and benthic (bottom dwelling) organisms - principally corals. Quantitative surveys or transects were established across the existing channel to quantify gradients in reef organisms. Qualitative surveys of the deeper water fronting the reef at the channel entrance and the extreme back reef environment in the vicinity of the proposed docking facility were also realized. The data from this survey were compared with existing biological data and with the results from the present physical study to evaluate potential impacts on the benthic community.

Water quality considerations were based solely on existing data for Maunalua Bay.

This environmental assessment was carried out under contract to Kentron Hawaii, Ltd. between July 8, 1975 and August 18, 1975.

SUMMARY AND RECOMMENDATIONS

The results for both the physical and biological studies follow:

1. Maunalua Bay is at present a siltation-dominated environment. Inside the reef the water is almost perpetually turbid. Suction dredging during the construction phase of a Jetfoil terminal will not produce silt conditions worse than those already existing on a rainy day with a falling tide. Curtains should be added to the dredging hose if monitoring shows that intolerable conditions are developing during initial dredging operations.

2. Regardless of terminal location and channel depths, siltation will occur due to drainage from the urban areas and the marina. To determine present rates of silt introduction into the Bay a specific study will be needed. Nevertheless, it appears, now, that siltation can be easily managed by maintenance dredging.

3. If the channel is dredged to a depth of 20 feet the sandbar extending across the gap in the reef (Fig. 1) may require continual dredging. Further study is strongly recommended to determine the rate of sand transport across this sandbar so that the sedimentation that will occur after dredging is completed can be estimated. It is necessary, further, to determine whether or not this sandbar is derived from material transported off Portlock Beach. If so, continual dredging could result in the destruction of Portlock Beach.

4. Calculations should be made to assure that the bow waves produced by the Jetfoil in the sheltered waters will not have a detrimental effect on the biological community and/or physical integrity of adjacent shorelines.

5. Moving from east to west at transect C (Fig. 1), the bottom rises gradually from a 10 foot depth to a shallower limestone reef platform for approximately the first half of the transect along which small coral heads are found. The remainder of the transect lies in a 3 foot deep wave washed area with little

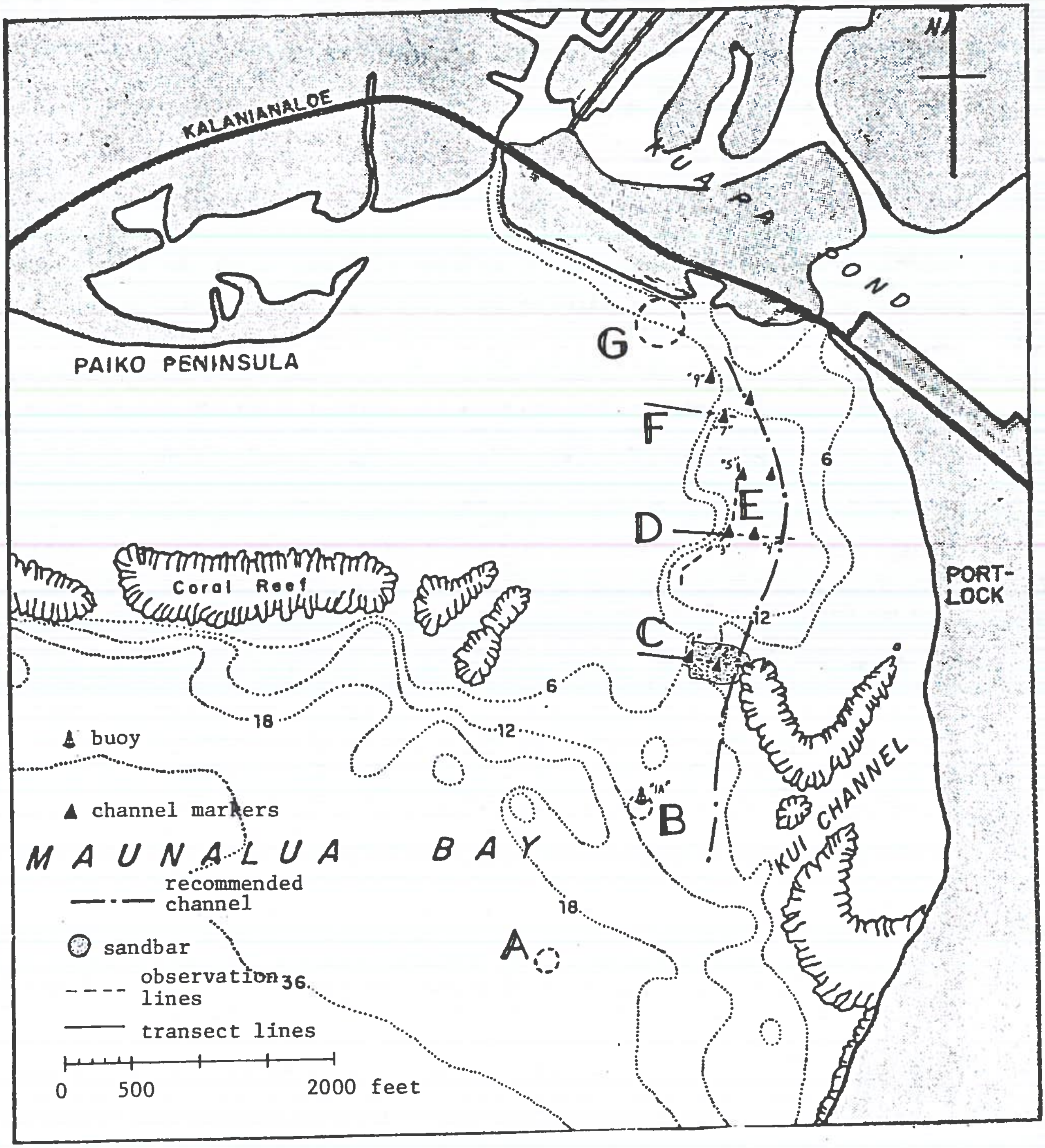

Figure 1: Summary figure of study area. (Soundings in feet; map from Marine Advisers, "Oceanographic Aspects - Kaiser Hawaii-Kai, Hawaii", 1961).

coral but extensive benthic algae coverage. Few fish were observed at this transect because of the lack of cover and wave action present on the reef platform.

6. The east side of transect D starts at approximately a 15 foot water depth in the boat channel, leads to the reef edge, and up across the reef flat in 3 feet of water. Extensive coral coverage is found on the steep areas of the channel margin. The greatest numbers of both species and individuals of fish were found on this transect but, nevertheless, the populations fall far short of a diverse Hawaiian community because of generally low coral coverage and poor water quality.

7. Transect F covered an area about 5 feet deep with little live coral, substantial sediment and detritus, and abundant benthic algae. The least numbers of both fish species and individuals were found at this transect, again, because of virtually non-existent coral coverage and poor water quality.

8. There appears to be a gradient of decreasing species diversity of fish from the offshore sampling sites to the marina entrance. The abundance of fish in Maunalua Bay correlates directly with cover and live coral distribution.

9. The existing environment along the shoreline in the areas proposed for construction of a turning basin is poor in terms of the biota presently found there (sampling area G). Damage to the reef flat community, as a result of dredging, will be temporary in adjacent areas and the new environment created after terminal and channel construction will resemble the present basin near the east entrance to Hawaii Kai Marina.

10. Dredging a deeper channel in the mud bottom of the existing basin will only temporarily disturb the impoverished fauna found there (the 12 foot depth contour surrounding the letter "E" in Fig. 1 delineates the basin margins). If dredging proceeds in a seaward to landward direction, much of the silt in the basin may be resuspended by increased wave action once the sandbar at

marker "1" is removed. The offshore environment (seaward of sampling area A) can easily handle moderate amounts of suspended material without damage to the existing biotic community should silt be carried out to sea. These fine sediments will not remain long on the bottom directly offshore and the character of this area will be unchanged.

11. An area of impressive coral bottom, developed prior to present day poor water quality, is found along the western margin of the boat channel in the general area of marker "3" (sampling area E, which is represented by a dotted line on Fig. 1 commencing at marker "5" and running at or near the reef margin to a point several hundred yards beyond marker "3"). Destruction of this area can be avoided by displacing the proposed channel eastward of the present boat channel (see Fig. 1 for recommended location). The reef margin east of channel marker "2" is scoured by shifting sand and should be sacrificed in preference to dredging activities along the western margin of the existing boat channel and basin.

12. The greatest damage to existing biotic communities as a result of the proposed dredging will occur at the reef edge (area between buoy "1A" and channel marker "1"). The coral community in this area is not flourishing, and appears stressed.

13. It is predicted that the pumping system of the Jetfoil will adversely affect entrained pelagic organisms (i.e., phytoplankton, zooplankton, larval fish, larval stages of benthic organisms) over the entire track of operation. It is estimated, however, that the long term effects of this entrainment will be minor if not undetectable. An effort to actually quantify the effect of the Jetfoil pumping system on the pelagic community would be prohibitively costly to the point that further efforts in this area are impractical.

14. Water quality in Maunalua Bay is heavily influenced by the Hawaii Kai Marina and hence some areas of the Bay have high nutrient and

turbidity levels, exceeding state standards for Class A waters.

15. The impact of dredging a deeper channel on water quality will be a temporary and localized increase in nutrient and turbidity levels. If proper care is taken during the dredging operation this impact can be minimized.

16. The only impact on water quality of the Jetfoil operation could be a small increase in turbidity due to the resuspension of bottom sediments. This impact will not only be minor but would be difficult to measure since the effect would be heavily masked by water and silt flushing out of the marina.

PHYSICAL STUDIES

Objectives

The objective of this section is to assess the impact of a Jetfoil terminal on the physical environment of Maunalua Bay. Available data from previous research on Maunalua Bay is evaluated. Using this data the probable impact of a terminal on the sedimentary regime is estimated. Potential problems are identified and deficiencies in available data related to these problems are pointed out. Finally, recommendations are made for additional studies in order to permit a more complete assessment of the impact on the environment.

Previous Studies

There are two groups into which the works on sedimentation and related physical oceanography can be divided. The first is that work which is directly applicable to the Maunalua Bay sedimentation situation. The second group is work which either is not directly applicable to Maunalua Bay or to the sedimentary aspects of the problem.

Group 1 (direct application)

June 1961, Marine Advisers, "Oceanographic Aspects - Kaiser Hawaii-Kai Marina", prepared for Kaiser Hawaii-Kai Development Co., Honolulu, Hawaii.

May 1974, Gerritsen, F., "Coastal Engineering Study of Beach and Channel Conditions Near Hawaii-Kai Marine Bridge", Ocean Engineering Consultants, Inc., Tech. Rept. No. 105, prepared for Kaiser Aetna, Honolulu, Hawaii.

Aug. 1975, Lee, T.T., H.L. James and R.J. Merchant, "Site Selection and Conceptual Design for Hawaii Kai Jetfoil Terminal in Maunalua Bay, Oahu", Look Laboratory of Oceanographic Engineering,

Tech. Rept. No. 36, Department of Ocean Engineering, Univ. of Hawaii.

Group 2 (not directly related)

Sept. 1973, Water Resources Research Center, "Quality of Coastal Waters: Second Annual Progress Report", WRRC Tech. Rept. 77, pp. 78-95.

Jan. 1974, Caperon, J., "Environmental Impact on the Marine Ecosystem of a Storm Drain Outlet for the Hawaii Loa Development".

May 1974, Sunn, Low, Tom and Hara, Inc., "Investigation of Hawaii Kai Marina Waters", prepared for Kaiser Aetna, Honolulu, Hawaii.

April 1975, U.S. Army Corps of Engineers, "Draft Environmental Statement for the Dept. of the Army Permit Actions in the Hawaii Kai Marina, Oahu, Hawaii".

The WRRC report on coastal water quality discusses 7 sediment sample locations in the Maunalua Bay area which were sampled 8 times between July 1972 and March 1973. These samples were analysed for heavy metals, pesticides and nutrients. Unfortunately, size analysis and carbonate fraction analysis (that would have provided information on sediment sources and sinks) were not done.

Caperon (1974) took a series of sediment samples from the beach out to the outer edge of the reef flat in the Aina Haina area. These samples were analysed for size and showed mainly fine calcium carbonate sediments of reef origin over most of the area.

The Sunn, Low, Tom and Hara (1974) study was confined mainly to the interior of the marina, but can be used to estimate the water flow into the Bay from the marina. No data were taken on the amount of sediment suspended in these currents.

The Army Corps of Engineers report (1975) was essentially a summary of the above named studies and has little direct bearing on the present project.

Of all these reports, the 1961 Marine Advisers work had the most bearing on sediment and siltation conditions in Maunalua Bay. However, since this report was written, 14 years of intense urban development have taken place in the basin draining into the Bay. Also, a channel has been opened into the eastern side of the marina complex. These changes and developments seemed likely to have changed sedimentation patterns within the Bay. To obtain a qualitative impression on any changes, two days were spent in diving observations in Maunalua Bay on August 4 and 5, 1975.

The diving observations indicated that sediments in the western sector of the Bay appear unchanged from the description given in 1961. However, the eastern section of the Bay may have more land-derived sediments now than were present in 1961. To effect a baseline survey, prior to construction of the Jetfoil channel and terminal, the sample sites of Marine Advisers should be restudied.

Impact Assessment

In attempting to assess the impact of a Jetfoil terminal on the sedimentary regime of Maunalua Bay, certain assumptions will be made. These are:

1. The terminal will be located as recommended by Lee (1975) at a site 700 feet west of the Koko Marina entrance.
2. The entrance channel will be 20 feet deep, 200 feet wide and will follow the course of the present small boat channel or lie immediately to the east of the channel still within the basin (delineated by the 12 foot depth contour surrounding the letter "E" on Fig. 1).

Certain variations from these assumptions will also be discussed, such as a different terminal location and different depths in the channel and the turning basin.

The impact on the sedimentation regime can best be discussed in two phases: the construction phase and the operational phase.

During the construction phase the most significant effects will all be related to the dredging operations. A channel will be dredged from the ocean through several different sediment types. Starting from the seaward end, a sandbar crosses the channel where the gap in the coral reef is located. (See Fig. 2 for location of this sandbar.) The present depth here reaches a minimum of about 4 feet below MLLW. Progressing landward a basin with a mud bottom is encountered next. The depth in this basin averages around 15 feet and the sediment surface appeared undisturbed by wave action when visited on August 4 and 5, 1975. Shoreward of this basin dredging will be mainly in consolidated limestone areas with some mud in present channels and in patches on the inner reef flat.

The two principal problems with dredging will be the creation of turbid conditions due to the excitation of sediments and disposal of the dredge spoil. The degree of sediment suspension effected will depend on the type of substrate and the dredging technique used. If turbid conditions are to be minimized then the construction should commence using suction equipment with the immediate addition of curtains should use of the hose by itself fail to prevent excessive sediment suspension.

The outer bar is sand (estimated fine to medium grain size) and should not cause excessive difficulty with regard to minimizing turbidity (see Fig. 2). Once inside the bar the sediments are either entirely or at least contain significant quantities of mud and great care will have to be taken to avoid suspending excessive quantities of sediment in the water column.

Regardless of the precautions taken, some sediments will be agitated into suspension. It is therefore of interest to discuss where these sediments will settle. There are two indications of what happens to suspended sediments in

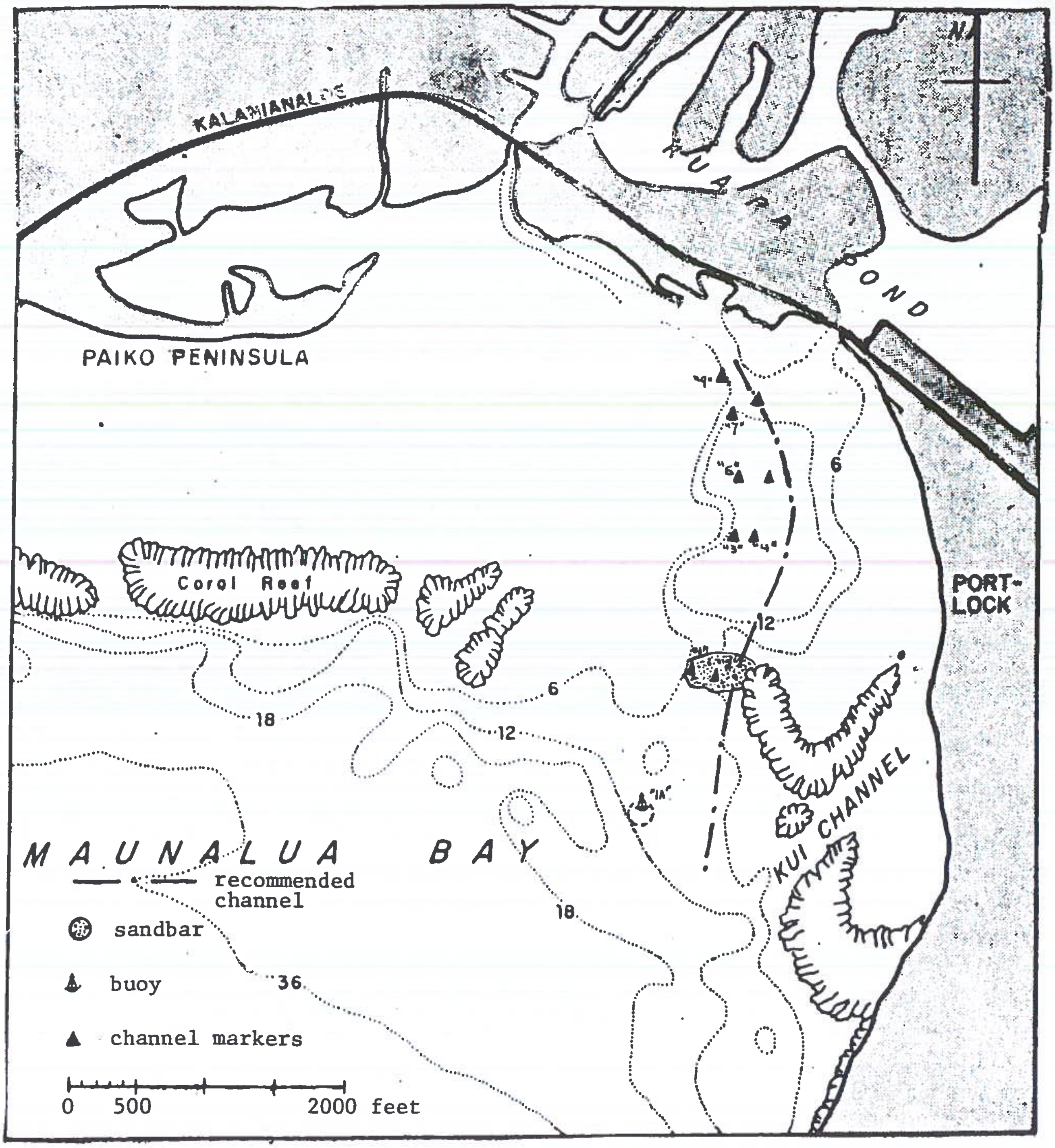

Figure 2: Map of study area showing present channel, recommended channel, and sandbar. (Soundings in feet; map from Marine Advisers, "Oceanographic Aspects - Kaiser Hawaii Kai, Hawaii", 1961).

this area. First, there are the current measurements made by Marine Advisers (1961) which should indicate the paths followed. Second, the present mud distribution is a primary indication of where suspended sediments are likely to settle out and remain.

Before becoming involved in tracing pathways of suspended sediments it should be noted that this area has been subjected to suspended sediments from land runoff for a long time. Thus, a moderate amount of turbid water from dredging would not differ significantly from present day wet weather conditions. Rather than review the Marine Advisers (1961) data here in detail, it should be referred to directly. In summary, currents move in and out of the channel and east and west on the reef flat with changes in the tide. The surface currents follow wind direction. This means a certain amount of transport west along the reef flat occurs with the trades. Once outside the reefs suspended sediments flow generally to the west along the south coast of Oahu, with a thin plume commonly split off to the east along the shore of Koko Head. Sheltered water is required for the suspended material to settle out of the water column, so sediment accumulation can be expected in the channels and any relatively deep spots protected by the reefs.

Disposal of the dredge spoil from the outer sandbar should not be a problem. This is relatively clean sand and could be used for beach nourishment or landfill in the park area. The muds dredged from areas nearer shore, however, present a more serious problem. This material is unlikely to be suitable for landfill. One possible solution would be to take the spoil several miles out to sea and dump it, allowing it to disperse as it settles.

During the operational phase the sediment problems will be principally in the area of channel maintenance. The 25 foot deep, protected turning basin will act as a sediment trap for suspended material carried out of the marina. Since the channel will be 5 feet shallower than the turning basin this accumulation will be accentuated. At the present time the rates of sediment supply to Maunalua Bay are not known, and this would have to be determined before predicting the amount of maintenance dredging required. A second maintenance problem may occur due to the removal of a 200 foot portion of the outer bar. The bar appears to provide protection for the mud bottom in the basin behind it. Removal of 200 feet of the sandbar may allow enough wave energy through to resuspend the mud remaining in the basin. Ultimately, this material could be redeposited in the channel that is to be dredged through the basin. In actual practice it may be necessary to remove more than 200 feet of the protective bar in which case the siltation problem would be more pronounced. This resuspension and silting can be avoided by dredging the whole area clean of mud but since the basin is 4 to 8 times wider than the channel the expense would be high.

Sedimentation problems in the turning basin will be minor compared to those likely to be encountered at the sandbar between the reefs (see Fig. 2 for location). This sandbar is the result of ocean waves tending to block up the entrance channel with reef-derived sand. As local boat owners have discovered, it shifts with the seasons in response to changes in wave regime. If a 200 foot wide, 20 foot deep channel is dredged through this bar, almost immediately a problem will develop. Wave action on the remainder of the bar will shift sand into the channel. The rate of shift will be determined by the size of the waves and their direction. For example, if a large southern swell occurs soon after dredging, the channel will be rapidly blocked by shifting sand. The extent of the blockage cannot be estimated without knowing what fraction of the sandbar will be removed by the dredging operation. A rough estimate based on the length of the bar as about 800 feet would suggest filling of the channel to a depth of about 10 feet. If the bar is part of a larger sand body, extending as far as, and possibly including Portlock Beach, it could rapidly fill to its normal condition of 4-6 feet below MLLW. Two solutions seem apparent for this problem. The first consists of dredging the channel and then monitoring closely for indication of shoaling. This is especially important after moderate to heavy waves. The second solution is to remove the entire bar and possibly enough of any connected sand body to insure an open channel for some acceptable period of time (i.e., a few years). The problem with this solution is that too little is known from previous studies about the sandbar or its relation to other sand bodies in the area such as Portlock Beach. A study of the situation is mandatory before this approach can be recommended.

During operation of the terminal there is another possible effect on the sedimentary environment. Hullborne, the Jetfoil produces a bow wave. According to Lee (1975) this wave is at maximum from 15-22 knot speeds when the Jetfoil accelerates to the foilborne mode. It is possible, if the wave produced is excessive, that the natural littoral processes on the beach areas may be altered (such as sand transport and alteration of biological habitats). This is unlikely, but until the size of bow wave produced under operating conditions is known and the frequency of operation in the harbor determined, it should remain under consideration.

Variation of Design

Variations in the initial assumptions will, of course, vary the intensity of the problems discussed here. Two variations to be discussed here will be a different location of the terminal facility and a shallower channel and turning basin.

First let us consider a different location of the terminal. Since there are so many drawbacks to locating the terminal east of the marina entrance, that will not be considered here. To move the terminal farther west would have two main implications. First, more initial dredging would be required, increasing the duration of any problems associated with the actual act of dredging. Second, maintenance dredging would have to be carried out over a larger area. It might be argued that spreading the silt from the marina over a larger area would slow down the rate at which the basin fills, but this is debatable. A larger basin could act as a more efficient sediment trap and, therefore, silt in just as fast.

If the terminal were moved closer to the marina entrance but still on the west side, some reduction in initial and maintenance dredging would take place. However, this would probably not justify the increased danger due to the Jetfoil having to maneuver closer to the small boat traffic in and out of the marina.

If the Jetfoil is to operate with foils retracted in the channel and turning basin then the depths can be reduced to 11 feet in the channel and 12-18 feet in the turning basin (Lee, 1975). These depths would drastically reduce the amount of initial dredging and maintenance dredging inside the entrance sandbar. Present channels are almost that deep and the depths in the mud basin exceed 11 feet. The shifting of the sandbar would still be a problem, but definitely of a reduced nature. This author offers no recommendation here because a judgement that must weigh the loss of operating efficiency due to foil retraction is beyond the scope of this report.

Summary and Conclusions

1. Maunalua Bay is at present a siltation-dominated environment. Inside the reef the water is almost perpetually turbid. Suction dredging during the construction phase of a Jetfoil terminal will not produce silt conditions worse than those already existing on a rainy day with a falling tide. Curtains should be added to the dredging hose if monitoring shows that intolerable conditions are developing during initial dredging operations.

2. Regardless of terminal location and channel depths, siltation will occur due to drainage from the urban areas and the marina. To determine the present rates of silt introduction into the Bay a specific study would be needed. Nevertheless, it appears, now, that siltation can be easily managed by maintenance dredging.

3. If the channel is dredged to a depth of 20 feet the sandbar extending across the gap in the reef may require continual dredging. Further study is strongly recommended to determine the rate of sand transport across this sandbar so that the sedimentation that will occur after dredging is completed can be estimated. It is necessary, further, to determine whether or not this sandbar is derived from material transported off Portlock Beach. If so, continual dredging could result in the destruction of Portlock Beach.

4. Calculations should be made to assure that the bow waves produced by the Jetfoil in the sheltered waters will not have a detrimental effect on the biological community and/or physical integrity of adjacent shorelines.

BIOLOGICAL STUDIES

Methods

A survey of the marine biota in Maunalua Bay in the vicinity of the existing small boat channel connecting Hawaii Kai Marina (Kuapa Pond) to the open ocean was conducted on July 1, 1975 and August 4 and 5, 1975. Due to a limited time in which to conduct this study, the survey of benthic organisms and fishes of the Maunalua Bay was accomplished by use of both qualitative[1] and semiquantitative[2] methods. The qualitative surveys (Fig. 3) involved observation dives in the back reef waters (area G), within or near the margin of the existing boat channel (area E, as indicated by the dotted line commencing at marker "5" and ending several hundred yards beyond marker "3"), perpendicular to the marked channel (observation dives shown as dotted lines that run across the channel as extensions of transects C, D and F), in the vicinity of buoy "1A" at the channel mouth (area B), and in a location about 600 yards seaward of buoy "1A" (area A). Semiquantitative surveys of fish and echinoderm populations (with estimations of coral coverage) were conducted along three transects perpendicular to the boat channel extending westward from channel markers "1", "3" and "7" (solid lines in Figs. 1 and 3). The transects at markers "1" and "3" began at the marker and extended 100 meters west across the reef flat. The transect at marker "7" was begun some 40 meters west of the marker and extended 100 meters westward from the starting point.

Coral and echinoderm populations were enumerated in square quadrats[3] two meters on a side centered at 10 meter intervals from the '0' to '100' meter marks

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[1]Qualitative methods - determine only presence or absence of organisms.
[2]Semiquantitative methods - an actual count is performed but the mobility and/or behavior of the organisms dictates that some error is unavoidable.
[3]Quadrat - rectangular sampling area used in biological counts of benthic organisms.

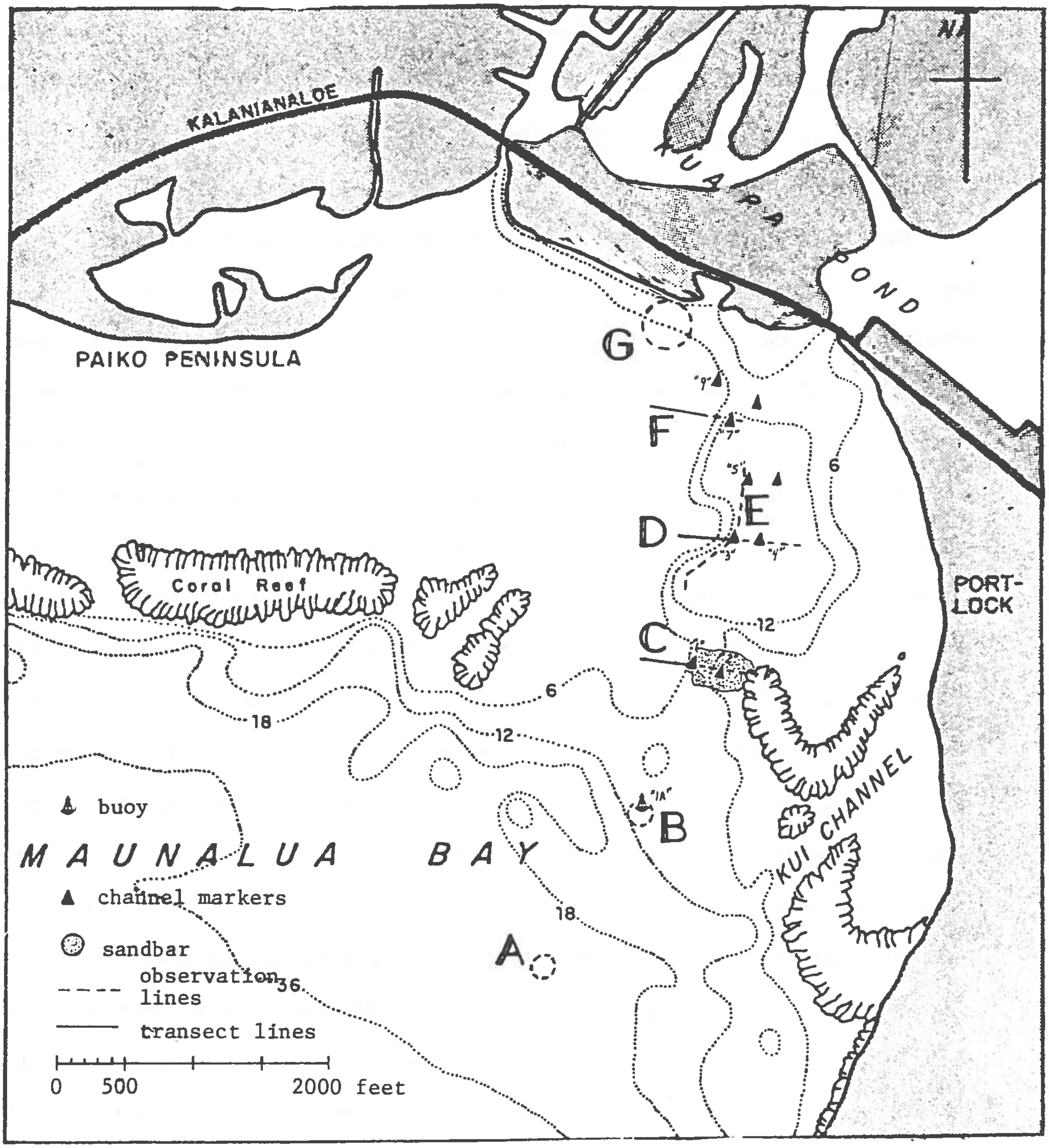

Figure 3: August 1975 survey sites for fishes and benthic biota in Maunalua Bay. (Soundings in feet; map from Marina Advisers, "Oceanographic Aspects - Kaiser Hawaii-Kai, Hawaii", 1961).

on the transect line. Results for the benthic surveys are given in Appendix A. Note that coral abundance is reported as percent of quadrat covered, while echinoderms are reported as number of individuals present per quadrat area (4 m^2). The coelenterate, Athelia (= Sarcothelia) edmondsoni, is listed only as present or absent.

The results of all fishes counted in the semiquantitative surveys at transects C, D and F as well as qualitative data from observations dives at areas A, B, E and G are given in Appendix B. In the semiquantitative visual surveys of fishes conducted at transects C, D and F, a 100 meter transect line was laid parallel to shore (solid line in Fig. 3). Following emplacement of the transect line a short wait in the boat prior to sampling was completed to reduce the "scare factor" (see below). All underwater observations in the semiquantitative surveys were made using SCUBA. To census fishes at a transect the method of Brock (1954) was used which consists of a diver carrying a slate (inscribed with the names of most species of fishes encountered), entering the water and slowly swimming along a transect line and tallying the numbers of each species seen within the area. The area censused was delimited by a four meter wide corridor running the length of the 100 meter transect line to the water's surface.

The qualitative visual fish surveys were carried out at areas A, B, E and G by noting all fish species present and their relative abundances. Time spent in the water during these surveys varied, e.g., area A - 20 minutes in the water, area B - 30 minutes, area E - 45 minutes, area G - 60 minutes. The time spent in the water is a reflection of the size of the area surveyed.

The method of visual censusing of fishes is subject to several observer errors. Secretive species are usually underestimated, e.g., the moray eels (Family Muraenidae) and the squirrelfishes (Family Holocentridae). Another source of error is failure to see cautious species which may leave the area of the transect before the counting has begun ("scare factor"). The "scare factor" may be minimized by reducing the amount of time spent in the water just prior to actual censusing. To accomplish this, the 100 meter transect lines were laid at sites C, D and F fifteen to twenty minutes before the censusing took place. The effectiveness of the visual method is reduced in turbid water (as was found at all sampling sites except area A) and species which move quickly and/or are very numerous make accurate counts difficult. In spite of these drawbacks, the visual census method is still useful and the most suitable in comparing relative abundance of diurnally active fishes in Maunalua Bay.

Finally, to gain insight on fish species present along the shoreline, a survey (by interview) was conducted of the fishermen in the area of Maunalua Beach Park on August 5, 1975. This method does not give one a complete list of species present but only an inventory of edible and commercially important species.

Results of Epibenthic and Fish Observations

Much of Maunalua Bay in the survey area is a shallow fringing reef (less than 3 feet deep) extending 1000 yards offshore. From the reef front the bottom drops gradually to a broad shelf reaching depths of 50 to 60 feet in line with Kawaihoa Point on Koko Head. Observations in about 25 feet of water approximately 500 yards seaward of buoy "1A" (area A) reveal a bottom of mixed sand flats and channels and eroded solid reef material (which underlies the sand deposits). In this area there is very little vertical relief, the difference between the sand bottom and the top of the solid substratum seldom exceeding 1 foot. No corals were observed in the area. Solid substratum was moderately covered with a red alga (*Rhodymenia* sp.), and this alga harbored the epiphytic blue-green alga, *Lyngbia* sp. Another alga, *Neomeris* sp., was also present. Only a few macro-invertebrates were noted. The most commonly encountered organism was the urchin, Echinothrix calamaris, but this species was not abundant. Also present in small numbers were Echinothrix diadema, Tripneustes gratilla (sea urchins), and Holothuria atra (sea cucumber). Since relief in area A is minimal, only 11 species and few individuals of fish were observed.

The small populations of epibenthic macro-invertebrates and absence of corals on first inspection might be considered atypical for a clear water environment with available hard substratum.[1] However, the low relief suggests that the exposed hard bottom is on occasion covered by shifting sand and therefore corals are unable to colonize the only periodically suitable substratum. Comparisons of the present data may be made with the results of a biological survey conducted in 1972 (Lau, 1973) off Kawaihoa Point (Koko Head, see Fig. 4) for the Quality of Coastal Waters project. Two stations, at depths of about 26 and 39 feet were surveyed. The bottom of the shallower station was abundantly covered with live coral (notably Porites lobata and some Pocillopora meandrina), and a large variety of invertebrates. Coral coverage approached 40 percent of available hard substratum (Dr. A. Reed, personal comm.). However, mounds of solid substratum in this area extended some 13-16 feet above the sand covered bottom. Occasional rock outcrops on the largely sand bottom of the deeper QCW station were described as being covered with the alga Dictyopteris. Mean cover by Dictyopteris sp. was estimated from photographic transects to be 63 percent. At our deepest sampling site (area A), algal cover was visually estimated to be less than 30 percent. Sea urchin density at the QCW stations are reported as follows: Tripneustes gratilla - $0.47/m^2$ and $3.55/m^2$ for the 26 and 39 foot stations respectively, and Echinothrix calamaris - $0.20/m^2$ and

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[1]Water clarity was exceptionally good during the observation dive conducted on a rising tide the morning of Aug. 5.

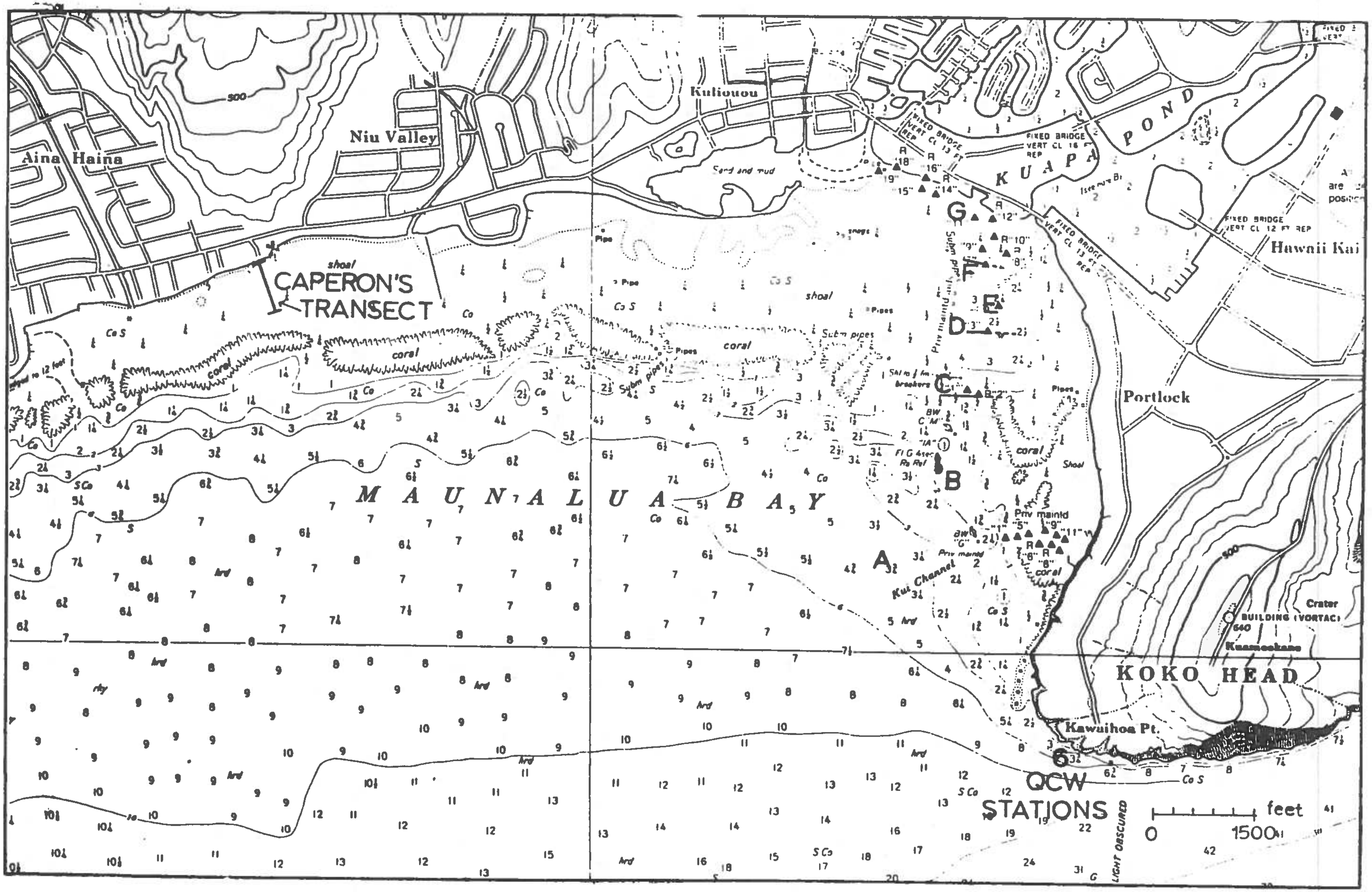

Figure 4: Location map of present and past biological survey sites in Maunalua Bay. (Soundings in fathoms at MLLW; figure taken from U.S.C. & G.S. Map #19358, "Southeast Coast of Oahu, Waimanalo to Diamond Head").

$0/m^2$ (absent) for these same stations. The results are somewhat at odds with our observations which indicate E. calamaris as more abundant than T. gratilla on the algal covered bottom. Neither species was as abundant in our area A as was reported for the 26 foot deep QCW station even though the two sampling sites are of the same depth. Additional biotic surveys by the QCW biologist (Dr. A. Reed) in Maunalua Bay are reportedly in progress.

Our area B was located adjacent to buoy "1A" marking the boat channel across the fringing reef. Area B depth was approximately 18 feet. Water clarity was considerably less than at area A, although observations were made at low tide on Aug. 4. However, unlike area A, a thin layer of silt covered the sand and calcium carbonate bottom. Substratum relief was low, but greater than at area A. Coral coverage was visually estimated at between 10 and 20 percent of available hard substratum. Most abundant were the species Pocillopora meandrina and Porites lobata, but Porites compressa, Montipora verrucosa, M. patula, M. flabellata, and Psammocora stellata were also present. Most colonies formed thin encrustations. Small heads of the coral, P. meandrina, on upright metal posts of a sunken barge (or dredge?) could provide an estimate of growth rate at this location if the sinking date of the vessel could be established.[1] The majority of 21 species of fishes seen were associated with the tangle of pipe and steel of this barge. The sea urchins, Tripneustes gratilla and Diadema paucispinum were common; Echinostrephus aciculatus was observed but was rare at this site. A small colony of the soft coral, Palythoa cf. tuberculosa and the sea cucumber, Holothuria atra, were noted. Algal species present were not recorded, except Neomeris sp. on the anchor chain of the buoy.

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[1]Determination of coral growth rates in this area would aid in estimating recovery time for the reef margins should dredging effect extensive coral destruction.

At the observation line extending from transect C a tongue of sand has partially filled in the channel between marker posts "1" and "2". To the west the sandbar ends abruptly on the rubble slope of the channel a little short of marker "1". Sand extends as a broad flat to the east at a depth of 3-4 feet. Because the sandbar is an unstable environment it harbors only a sparse population of infaunal organisms (occasional polychaete tubes and small crustacean burrows). Approximately 50 meters east of marker "2" the solid limestone of the reef edge projects less than a foot above the sand flat. This solid substratum is somewhat scoured by sand moving over the surface and no corals and only sparse macroalgae were observed. The reef here harbors beds of the small Hawaiian mussel, Hormomya crebristriatus. Shells of this species litter the surface of the sand flat. The urchins, Tripneustes gratilla, Echinometra mathaei, and Echinothrix diadema, and the sea cucumber, Holothuria atra, were observed.

At transect C the 100 meter line was laid parallel to the reef edge. The deeper end of this line (adjacent to the existing channel) began in 10 feet of water on a dredged rubble bottom and runs up onto a limestone reef platform at less than a 3 foot depth. The first 60 meters of the transect slopes gently from a depth of 10 feet to 3 feet. Small heads of the corals, Pocillopora damicornis and Porites lobata, and the urchin, Tripneustes gratilla, are scattered over the bottom. On channel marker "1" small heads of Pocillopora meandrina are found, broken but alive fragments of which are recorded in the "0 meter" quadrat. One specimen of the large pick urchin, Pseudoboletia indiana, was observed near the "20 meter" quadrat.

An abrupt change in the benthic biota occurs near the "60 meter" quadrat where the bottom shallows to 1 meter. Algal coverage, approaching 100 percent and dominated by Codium edule, Halimeda sp., and Enteromorpha sp., increases dramatically. Additional algae present include Dictyosphaeria versluysii, Turbinaria sp., Codium sp., (not Codium edule), and several species of calcareous algae. The remainder of the transect was similar, although algal coverage drops off somewhat as the "100 meter" quadrat is approached. The environment on this transect is representative of the reef flat directly behind the reef edge. The exceptionally high algal standing crop is largely limited to that portion of the transect adjacent to the channel where the waves break on the reef. Algal coverage appears to decline in all directions from this region, although the reef margin beyond the "100 meter" quadrat was not actually surveyed. Only 12 fish species were encountered on this transect due, probably, to the lack of cover and wave action present on the reef platform.

The channel behind transect C expands into a wide basin approximately 15 feet deep (the margins of which are delineated by the 12 foot depth contour surrounding the letter "E" in Figs. 1 and 3). The bottom of the basin is covered by a thick layer of mud. Numerous small burrows indicate the presence of infaunal crustaceans. Scattered large burrows are probably occupied by the crab, Macrophthalmus telescopicus.

At channel marker "3" (transect D) the basin deepens to more than 15 feet. The transect line began in the existing channel, crossed a short section of large live corals on the sloping edge of the channel, and coninued up and out across the reef flat at a 3 foot depth. Adjacent to the marker scattered large boulders occur on the bottom projecting above the silt. Small colonies of the coral, Pavona varians, occur on these deeper rocks. The channel edge is a rubble slope upon which extensive thickets of the branching coral, Porites compressa, are found in depths of 6-10 feet. The alcyonarian (small colonial sea anemone) Athelia (= Sarcothelia) edmondsoni, is very abundant in this area and along the transect to beyond the "30 meter" quadrat. Coral diversity is somewhat greater than at transect C, although coverage is approximately the same. Algal biomass is greatest between the "30 meter" quadrat and the "40 meter" quadrat where it is similar in character to that observed on transect C, although total biomass is less. Enteromorpha sp. is the most conspicuous alga along this segment, while Halimeda dominates the overall transect. About 80 meters across the reef from marker "3" sand begins to dominate the substratum. Tubes of a chaetopterid polychaete are evident. Epiphytic Lyngbia sp. covers much of the Halimeda. At the "90" and "100" meter quadrats the marine angiosperm, Halophila hawaiiana, is abundant on the silty-sand bottom; some Halimeda is present, as well. Most of the fish (23 species) observed on this transect were associated with the live coral probably because of the cover it provides and the associated community it harbors. Only four species of fish were observed in rubble and algae of the reef flat.

Large coral colonies were observed at the start of transects C and D Therefore an observation dive from midway between channel markers "1" and "3" to beyond channel marker "5" (area E) was conducted to establish the distribution of these corals along the west margin of the boat channel (dotted line running north and south in Fig. 3). Corals are most abundant in a zone between 3 and 6 feet deep. Below this depth, mud bottom predominates. In shallower water, only the coral, Pocillopora damicornis, is "abundant". The best coral development occurred on the seaward facing margin of the reef spur projecting toward marker "3". The corals are located on scattered large boulders or as massive colonies. Porites lobata heads in excess of 3 x 3 x 2 meters and thickets of P. compressa 7 meters across are present. Dictyosphaeria cavernosa growth occupies the lower portions of the P. compressa thickets. Beyond marker "3" these coral boulders become more scattered and only a few massive heads of Porites were observed in the vicinity of marker "5". Beyond "5" only small heads of Cyphastrea ocellina and Pocillopora damicornis were present. A single individual of the lobster, Panulirus penicillatus, was observed. Coral species observed in area E are listed in Appendix A. Colonies of the alcyonarian, Athelia edmondsoni, are abundant over much of site E.

Area E afforded the greatest footage surveyed, the most extensive live coral cover and the largest number of fish species (46) and individuals encountered in this study. The coral community and associated invertebrate fauna is probably responsible for the greater number of fish present. Certain species found only in this area are known to feed on live coral in small quantities, i.e., Chaetodon auriga, C. unimaculatas and C. trifasciatus (Randall, 1974). Many of the other species feed on invertebrates that are a part of reef communiies or simply use the corals for shelter.

Transect F was laid across the back reef flat just west of channel marker "7". The area between the marker and the start of the transect (about 40 meters) is a mud bottom as found elsewhere in the channel and basin. The "0 meter" quadrat was centered on several large boulders at the bottom edge of the channel margin in 6 feet of water. Small colonies of the coral Cyphastrea ocellina were scattered over the upper surface of these boulders. On the margin slope a band of Halophila hawaiiana occurs at a depth of about 4 feet marking the transition between mud bottom and silt over sand bottom. Some sponges occur in the area. Above the Halophila zone, Halimeda dominates but is not abundant. At the "30 meter" quadrat, the alga Acanthophora spicifera appears and the bottom is mostly rubble. A few heads of the coral, Pocillopora damicornis, were observed but none occurred in the quadrats. Acanthophora predominates over the area of the transect from the "60 meter" quadrat to the "100 meter" quadrat; Padina and Halimeda are also conspicuous here. Three individuals of Echinothrix diadema were noted on a large rock at the "95 meter" mark.

At transect F additional qualitative observations were limited to the boat channel and the immediate back reef environment adjacent to the channel (dotted line on Fig. 3 extending eastward from transect F). The channel bottom was covered with a layer of mud. In this area few epibenthic macroinvertebrates are evident even in shallow areas on the reef flat. The alga, Acanthophora spicifera, dominates the sparse benthic flora. Intertidal organisms observed include the shore crab, Metapograpsus thukuhar, and a small barnacle (Chthamalus sp.).

Transect F and area G both have little relief, are shallow (less than 6 feet deep), have little live coral, a large amount of sediment and detritus in the water and on the substratum, all creating a generally unfavorable environment for most fish species. These factors have probably been largely caused by human activities (dredging, hinterland construction and subsequent runoff). Species occasionally found in this environment include Mugil cephalus, Sphyraena barracuda and Asterropteryx semipunctatus. Echidna nebulosa was seen in the outer fringes of area G.

The results of the interviews with fishermen (n = 4) on the fish species present at Maunalua Beach Park are given in Table 1. Fish species seen outside the transects and sampling areas are listed in Table 2 along with the location of the sightings.

Discussion

The Quality of Coastal Waters project conducted surveys off Koko Head to "explore the biota of Maunalua Bay" (Lau, 1973, p. 90). Data reported from these transects have been compared with our offshore Station A in this report (p. 22). The shallowest of two QCW transects was located 100 meters offshore "...within a fairly persistent plume of turbid water...". Turbidity may be a factor influencing the biological community at Kawaihoa Point, but certainly not to the same degree as at our sampling areas B through G. Some of the silt flushing out of the marina area is carried around Koko Head close to the eastern shore of Maunalua Bay, but these fine sediments remain in suspension as they pass Kawaihoa Point (Dr. A. Reed, personal communication). The epibenthic biota of the reef flat midway between Aina Haina and Niu Valley

Table 1: Fishes said to be caught from the shoreline area at Maunalua Beach Park. No fish had been taken at the time of the interviews.

Species	Common Name	Frequency of Catch
Chanos chanos	Milkfish	rarely caught
Sphyraena barracuda	Barracuda	rarely caught
Mugil cephalus	Mullet	rarely caught

Table 2: Table of fish species encountered outside of transects and sampling areas that were not present within the nearest sampling site.

	Species	Common Name	Location
1.	*Psilogobius mainlandi*	-	in deeper parts of boat channel
2.	*Scorpaena ballieui*	-	on kokohead side of boat channel
	Arothron hispidus	Puffer	on reef crest
3.	*Cheilio inermis*	Kupoupou	on reef crest adjacent to transect C
	Chaetodon auriga	Butterfly fish	
	Dascyllus albisella	-	

was surveyed by Dr. John Caperon and Eric B. Guinther in 1973. The descriptions provided are relevant to obtaining a general overview of the biotic community on the fringing reef in Maunalua Bay, and therefore a portion of this report is included here as Appendix C.

Due to differences in the amount of relief in each of the three semi-quantitative surveys (transects C, D and F) it is impossible to equate surface areas. The amount of relief and hence surface area is an important agent in governing the numbers of fish within any one study area. For many inshore resident fish species the more relief that is present, the greater the number of individuals. In the case of those samplings where no transect was laid but rather a random swim was made, the size of area covered varied. It is to be expected that the greater the area surveyed, the greater will be the number of species encountered. The time spent in the water at sampling areas A, B, E and G reflect the size of the area sampled. Therefore, any comparisons of the absolute numbers of individuals between stations is not justified.

Our observations indicate a marked decrease in the fish and benthic fauna from the seaward face of the fringing reef to the shoreline. On leeward, fringing reef flats, biomass of benthic organisms decreases naturally inward across the reef. Decreasing water circulation and increasing distribution of soft substrata (sand, silt) create an environment largely unfavorable for corals, and the reduced bottom relief provides insufficient cover for high standing crops of reef fishes. Soft substrata are inherently unstable, and few epibenthic organisms colonize sand or mud flats; most of the biota present on these flats is infaunal.

In addition, the extreme back reef environment adjacent to Maunalua Beach Park appears to be stressed as a result of fine sediments carried out of the marina and deposited in part on the reef flat and in the boat channel. The impressive coral growth along the western margin of the boat channel (area E) undoubtedly developed in this area prior to the time at which present conditions were established. Shallowing of the boat channel by a sandbar at marker "1" combined with increased sediment load in the Bay waters from the marina has resulted in an unfavorable environment for those reef organisms normally associated with high quality nearshore waters. However, periodic shifting of the sandbar may temporarily improve conditions in the inshore reef basin.

Most fishes encountered in the nearshore sampling sites (transects C, D, F and areas E and G) were juveniles indicating either a high mortality of adults (possibly due to human fishing activities) or an unfavorable environment for adults. Areas offshore of the present Maunalua Beach Park boat channel (26 to 33 feet deep) appear not to support as high a diversity or biomass of fishes as would be expected for Hawaiian coastal waters (see Appendix B, area A). Comparative data taken in the recently dredged Honokohau Harbor (Kona, Hawaii; Brock, 1975) bear this point out. Twenty-five meter transect lines laid in the innermost parts of the harbor (comparable to transect F and area G) showed 25 species of fishes in an area only one-fourth the size of the present transects. The current study yielded only 5 to 6 species in similar habitats. Outside of Honokohau Harbor 73 species were found; the outermost sampling site in this study (area A) afforded only 11 species indicating that: (a) the fish populations of the area encompassed by this study are not representative of a diverse Hawaiian fish community; and (b) that the outer areas of the present study site do not provide many fishes for shoreward migration and colonization.

To obtain a rough picture of the dependence of fishes on available relief, the stations have been subjectively arranged in a descending order of relief present at each sampling site. This has been plotted in Figure 5 against the number of fish species present at each station. From this figure it is apparent that there is a decrease in the number of species with decreasing cover;

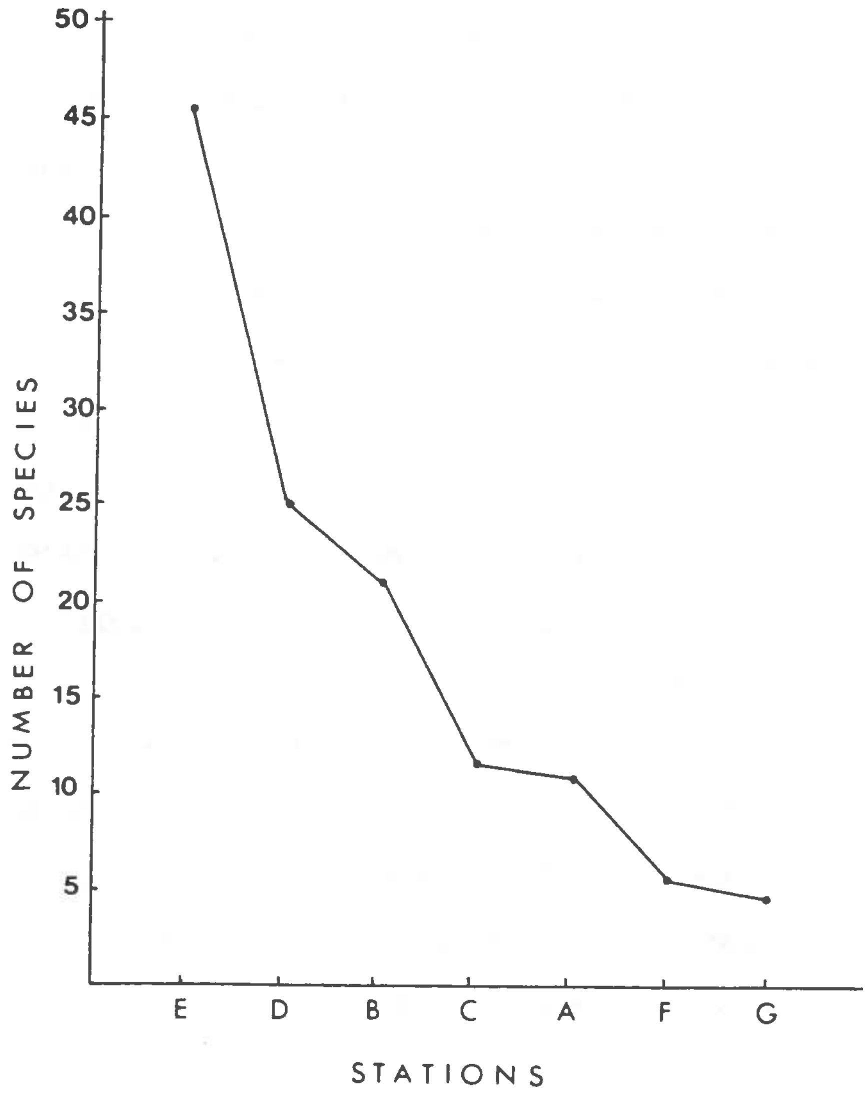

Figure 5: Plot of the number of species of fishes present at each of the stations. Sampling sites have been subjectively arranged in a sequence of decreasing coral and cover.

deleting the two sampling sites (transect D and area E) with the large amount of coral cover (relative to other stations) and plotting those remaining against the number of species yields the curve shown in Figure 6. This plot indicates that there is a decrease in the number of species present at each station moving from just outside the reef (area B) shoreward to area G. This is probably indicative of the nearshore areas not being suitable for most fish species (except transect D and area E with high coral cover).

Besides the previously mentioned observer errors in the semiquantitative counts, other factors that are not apparent from the data operate to change the counts. One of these is encountering roving and schooling fishes. An encounter with a school can considerably increase the number of individuals counted and, further, the presence of a school is a random event. Species encountered that fall into this category are Scomberoides lysan, Caranx melampygus (area B) and juvenile scarids (transect D and areas B and E).

Interviews with fishermen present at Maunalua Beach Park yielded the results shown in Table 1. These fish species have all been taken near area G. The only fishes observed by the author in this area were Mugil cephalus, Asterropteryx semipunctatus and Echidna nebulosa. The beach park is presently serving as a recreational site for casual net and line fishing.

Impact Assessment

Relative to other sites the fish fauna adjacent to the boat channel appears to be low in species diversity and biomass. This is probably due to the lack of cover and high turbidity. The only area examined in this survey in which a near normal community of fishes exists was area E. The inshore sites near Maunalua Beach Park (transect F and area G) are essentially devoid of fishes. In view of the already stressed conditions which exist in the back reef area and the heavy layer of silt which presently covers the bottom of the basin and

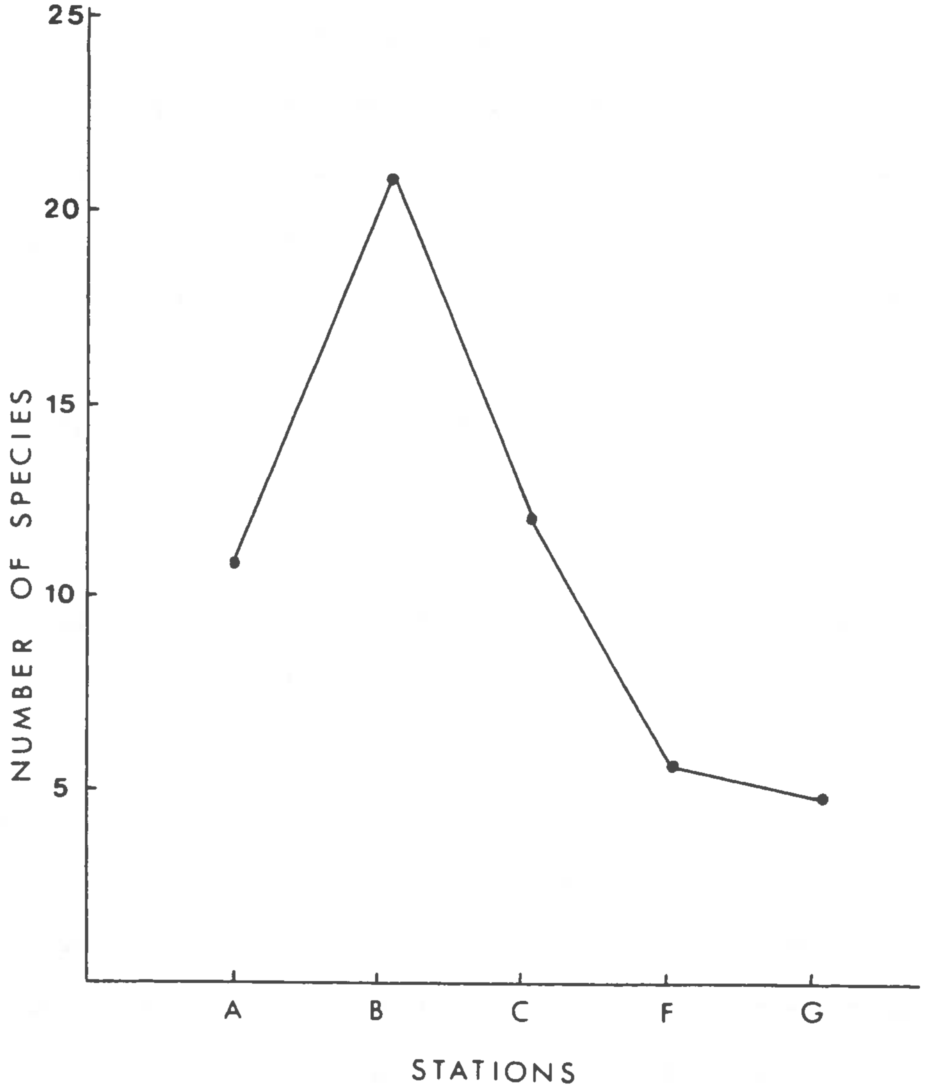

Figure 6: Plot of the number of species of fishes against sampling sites moving from the sea towards shore. Sampling sites D and E have been omitted from this figure (see text).

existing channels, little direct environmental damage will result from dredging in these areas. After construction of the turning basin, the type of community found in the boat channels will be reestablished in the bottom mud layer of the basin. Indirect damage to adjacent areas from sediments stirred up by the dredging operation would be minimal and temporary on the back reef flat. The same general conclusions can be drawn concerning the area between survey sites F and D. However, environmental degradation of the flourishing coral area near channel marker "3" would be minimized if the center line for the proposed deeper channel were placed slightly to the east of the existing channel markers (see Fig. 1, p. 4). Displacing the proposed channel should be a viable option in view of the fact that the present marked channel follows the western edge of a wide basin.

The biological community on the bottom near channel marker "1" and seaward to the 20 foot depth contour will suffer the greatest direct damage from channel enlargement. In general, this area harbors an impoverished reef fauna and recovery to the present status of coral development could occur within a few years. An additional survey of the organisms on the seaward reef edge may be required if our recommendation of channel realignment involves creating an additional opening in the reef some distance eastward of the present boat channel.

The offshore community (beyond the 20 foot depth contour) will be affected only by suspended sediments from dredging. This area is already influenced both by silt transported from the inner reef areas and the marina and by shifting locally derived sand. Silt presently does not collect in this area (our station A) but presumably moves into deeper waters. Consequently, sediments stirred up by dredging operations would have a minimal effect on the offshore benthic communities.

The operation of the Jetfoil will have little dirrect affect upon the existing benthic biological community. However, the Jetfoil turbines - coupled through reduction gearboxes to centrifugal water pumps - pump large quantities of sea water (up to 40,000 gallons per minute) which can be expected to have impact upon the pelagic (water-borne) biological community (e.g., phytoplankton, zooplankton, larval fish, larval stages of benthic invertebrates) not only within the Maunalua Bay area, but over the entire track of Jetfoil operation. This impact will likely be manifested in a high mortality for those organisms pumped through the Jetfoil turbines. Both reef fishes and benthic invertebrates have evolved large reproductive potentials to compensate for the extemely high natural mortalities for larval organisms in the marine environment. Typically, high larval fish mortality is due to a lack of sufficient quantity or quality of food whereas the distribution of benthic invertebrates is generally limited by the ability of the larval forms to settle out on suitable substrates where they metamorphose and grow to adult, reproductive organisms. The elimination of a fraction of the larval fish and invertebrate populations by Jetfoil operation should increase the survival rates of the remainder of the population by reducing competition for limiting food and substrate resources and thereby at least partially offset the negative effects of the Jetfoil. The generation time for the zooplankton and expecially the phytoplankton is so short that these populations are not likely to be adversely affected over the long term by the Jetfoil operation. Furthermore, any changes in the pelagic community are likely to be masked by natural fluctuations of these dynamic populations due to seasonal, climatic, and circulation changes within the areas of operation such that a clear separation of anthropogenic as opposed to natural population variations will be impossible to effect. It can be assumed, then, that the operation of the Jetfoil will not have a measurable effect on the pelagic community.

Summary and Conclusions

1. Moving from east to west at transect C (Fig. 3), the bottom rises gradually from a 10 foot depth to a shallower limestone reef platform for approximately the first half of the transect along which small coral heads are found. The remainder of the transect lies in a 3 foot deep wave washed area with little coral but extensive benthic algae coverage. Few fish were observed at this transect because of the lack of cover and wave action present on the reef platform.

2. The east side of transect D starts at approximately a 15 foot water depth in the boat channel, leads to the reef edge, and up across the reef flat in 3 feet of water. Extensive coral coverage is found on the steep areas of the channel margin. The greatest numbers of both species and individuals of fish were found on this transect but, nevertheless, the populations fall far short of a diverse Hawaiian community becuase of generally low coral coverage and poor water quality.

3. Transect F covered an area about 5 feet deep with little live coral, substantial sediment and detritus, and abundant benthic algae. The least numbers of both fish species and individuals were found at this transect, again, because of virtually non-existent coral coverage and poor water quality.

4. There appears to be a gradient of decreasing species diversity of fish from the offshore sampling sites to the marina entrance. The abundance of fish in Maunalua Bay correlates directly with cover and live coral distribution.

5. The existing environment along the shoreline in the areas proposed for construction of a turning basin is poor in terms of the biota presently found there (sampling area G). Damage to the reef flat community, as a result of dredging, will be temporary in adjacent areas and the new environment created after terminal and channel construction will resemble the present basin near the east entrance to Hawaii Kai Marina.

6. Dredging a deeper channel in the mud bottom of the existing basin will only temporarily disturb the impoverished fauna found there (the 12 foot depth contour surrounding the letter "E" in Fig. 3 delineates the basin margins). If dredging proceeds in a seaward to landward direction, much of the silt in the basin may be resuspended by increased wave action once the sandbar at marker "1" is removed. The offshore environment (seaward of sampling area A) can easily handle moderate amounts of suspended material without damage to the existing biotic community should silt be carried out to sea. These fine sediments will not remain long on the bottom directly offshore and the character of this area will be unchanged.

7. An area of impressive coral bottom, developed prior to present day poor water quality, is found along the western margin of the boat channel in the general area of marker "3" (sampling area E, which is represented by a dotted line on Fig. 3 commencing at marker "5" and running at or near the reef margin to a point several hundred yards beyond marker "3"). Destruction of this area can be avoided by displacing the proposed channel eastward of the present boat channel (see Fig. 3 for recommended location). The reef margin east of channel marker "2" is scoured by shifting sand and should be sacrificed in preference to dredging activities along the western margin of the existing boat channel and basin.

8. The greatest damage to existing biotic communities as a result of the proposed dredging will occur at the reef edge (area between buoy "1A" and channel marker "1"). The coral community in this area is not flourishing, and appears stressed.

9. It is predicted that the pumping system of the Jetfoil will adversely affect entrained pelagic organisms (i.e., phytoplankton, zooplankton, larval fish, larval stages of benthic organisms) over the entire track of operation. It is estimated, however, that the long term effects of this entrainment will be

minor if not undetectable. An effort to actually quantify the effect of the Jetfoil pumping system on the pelagic community would be prohibitively costly to the point that further efforts in this area are impractical.

WATER QUALITY STUDY

No field sampling or laboratory analyses were carried out for this phase of the study. The assessment for the Jetfoil impact upon water quality in Maunalua Bay is based on data from the Water Resources Research Center (Lau, 1972 and Lau, 1973). During the first year of the Quality of Coastal Waters study (1972) waters were sampled and analyzed from two stations in Maunalua Bay and from three stations during the following year. Analyses during the first year of sampling included pH, total solids, total nitrogen, total phosphorus, potassium, chlorides, turbidity, total organic carbon, total inorganic carbon, heavy metals (Pb, Cu, Zn, Cd, Hg) and pesticides (lindane, dieldrin, DDT, PCP). The analyses conducted during the second year included, in addition to those listed above, suspended solids, volatile suspended solids, total volatile solids, conductivity, chromium, nickel, alpha chlordane, and gamma chlordane. Many of these analyses are of no value for defining water quality in surface waters of a coastal marine environment as they pertain to the Jetfoil program (i.e., pH, total solids, potassium, chlorides, total organic cargon, total inorganic carbon, total volatile solids). Some of the other parameters measured have values reported that are clearly suspect, especially the heavy metals results. Mercury was not detected in any of the 1973 samplings even in the innermost areas of the lagoon and all of the metals are listed as not detectable in many of the samples.[1]

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[1]It appears as though an acid preservative was not added to the water upon collection so that the metals were either plated out on the walls of the sample containers (i.e., Pb, Cu, Zn, Cd, Cr, Ni) or were volatilized (i.d., Hg).

Characterization of Present Water Quality

Those parameters of most value in defining the quality of coastal waters for the purpose of the present assessment are the inorganic nutrients (i.e., PO_4, NH_3, NO_2, NO_3) and light penetration. Inorganic nutrients are usually the limiting factor in phytoplankton and benthic algae growth in the marine environment and since these plants are the base of the food web nutrient analyses figure prominently in defining water quality. Light penetration (in which turbidity is a factor) is also important in that sunlight is the primary energy input into littoral[1] marine ecosystems and thus highly turbid water is detrimental to the extent that it reduces sunlight penetration of the water column. High turbidities are also detrimental in that they are often accompanied by heavy silting of the substrate which reduces attachment sites for sessile invertebrates and generally stresses the benthic community.

Unfortunately, the nutrient data from Maunalua Bay in the QCW study is reported only as total nitrogen and total phosphorus. This data, then, does not partition the nutrient supply into those fractions that can and cannot be readily utilized by marine plants.[2] The 1972 report states that nitrogen and phosphorus concentrations form a positive gradient leading out of the marina into the Bay. This is not clear from the data presented and, furthermore, such a gradient is improbable. In a long term average sense, the marina waters should be higher in nutrients since the area has poor circulation and is subject to inputs from runoff and urban activities. The apparently spurious results of the 1972 QCW study may be due to the fact that data was collected on only four dates. In spite of these limitations in the available nutrient data, it is clear that the values for the waters of Maunalua Bay are quite high. The

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[1]Shallow, nearshore environment characterized by light penetration to the bottom.
[2]Furthermore, these samples were not filtered prior to the inorganic nutrient analyses which introduces error on top of uncertainty.

1973 QCW report gives average total nitrogen and total phosphorus values cf 1.38 mg N/l and 0.33 mg P/l, respectively. Class A waters (Maunalua Bay), according to state water quality standards, are not to exceed 0.025 mg P/l. Hence the Bay now exceeds state water quality standards for phosphorus (i.e., QCW stations 5 and 7, Fig. 7). Station 6 has an average value of 0.027 mg P/l listed and thus also exceeds the phosphorus standard. No QCW water samples were taken from the area of the boat channel but the QCW station 3 is close to the probable location of the Jetfoil terminal. The average nitrogen value at station 3 (0.15 mg N/l) equals the standard while phosphorus (0.41 mg P/l) again exceeds, and nearly doubles, the legal level.

The turbidity values given in the QCW studies appear reliable and need not be suspect if for no other reason than the measurement of turbidity is extremely easy. The turbidities for Class A waters are not supposed to exceed a value 10 percent greater than those found under natural conditions. A comparison of turbidity values between Maunalua and Kahana Bay is informative because the latter is not subject to urban runoff and therefore serves as a good control. The average turbidity value for Kahana Bay reported in the 1973 QCW study is 2.27 FTU (Formazin Turbidity Units) whereas the average value for stations 5 and 7 in Maunalua Bay is 4 FTU, for station 6 is 2 FTU, and for station 3 is 11.5 FTU. The turbidity value for station 3 approximates a five-fold increase in turbidity over background levels. These turbidity values underscore the dominant influence of waters flushing out of the marina on water quality in Maunalua Bay.

The nutrient and turbidity data alone suggest that the water quality of Maunalua Bay does not meet Class A standards. Further, the QCW stations within the Bay (i.e., stations 5, 6 and 7) were not placed in areas where the worst water quality would be found. Since the boat channel contains tidal currents flushing water and silt in and out of the marina this area probably

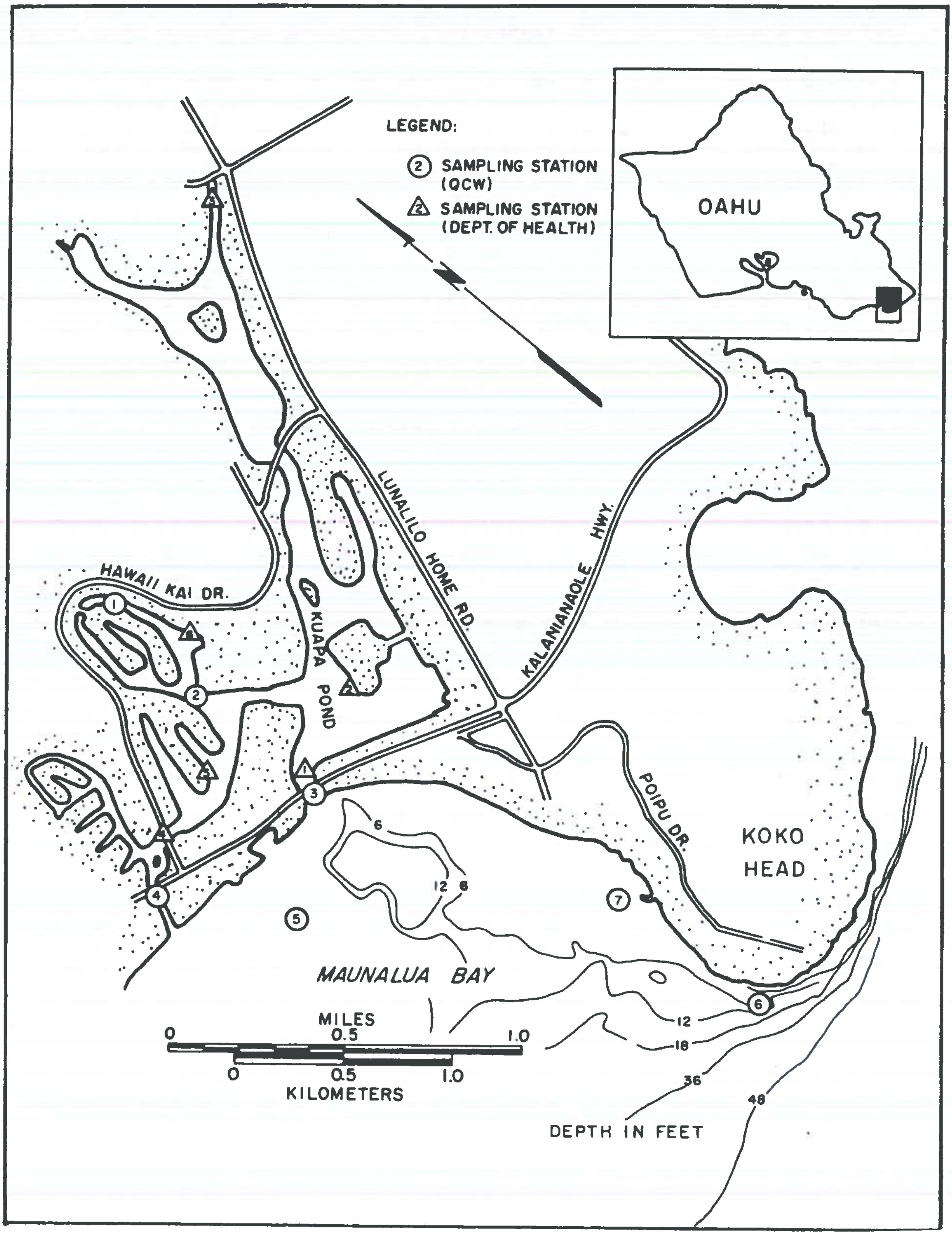

Figure 7: Location of QCW water qauality sampling stations in Maunalua Bay during 1972 and 1973. (Map from WRRC, the Quality of Coastal Waters: Second Annual Progress Report, 1973.)

has the poorest water quality of the entire Bay. The nutrient and turbidity values for water in the channel are probably far higher than those reported in either QCW annual report and presumably increase with proximity to the marina.

Impact Assessment

Consideration of the impact of the Jetfoil upon water quality in Maunalua Bay should be divided into the construction phase versus the operation phase. Impact upon water quality during the construction phase will be manifested by the suspension of sediments in the water column as a result of dredging operations. This suspension, while it obviously increases the turbidity, will probably also stimulate the release of nutrients from the sediments into the water column. Both of these impacts are detrimental as discussed above and hence the need to minimize the suspension of sediment with the use of suction hose dredging (possibly with curtains) as discussed previously in the physical studies of this report. If proper care and attention are taken during the dredging operation the increase in turbidity can be controlled and relatively localized. Furthermore, the perturbations in water quality effected by the dredging will be short term and probably will not produce water quality worse that found on a rainy day with a falling tide. However, the generally poor water quality of Maunalua Bay should not be construed as license to dredge and suspend sediments with impunity in that, should this be done, the remaining coral communities in the Bay would like be adversely affected.

The impact upon water quality during the operation phase of the Jetfoil should be minimal. The only possible impact of the Jetfoil itself might be a slight suspension of the sediments by the action of the high powered turbines. This sediment suspension would be more pronounced if a shallow channel is opted for rather than the deeper alternative (see physical studies section). The effect of the Jetfoil turbines in suspending sediment should be minimal, in any case, and would not likely be discernable from the onslaught of silt flushing out of the marina. Maunalua Bay already has water quality problems far worse than any that could possibly be associated with the operation of the Jetfoil.

Summary and Conclusions

1. Water quality in Maunalua Bay is heavily influenced by the Hawaii Kai Marina and hence some areas of the Bay have high nutrient and turbidity levels, exceeding state standards for Class A waters.

2. The impact of dredging a deeper channel on water quality will be a temporary and localized increase in nutrient and turbidity levels. If proper care is taken during the dredging operation this impact can be minimized.

3. The only impact on water quality of the Jetfoil operation could be a small increase in turbidity due to the resuspension of bottom sediments. This impact will not only be minor but would be difficult to measure since the effect would be heavily masked by water and silt flushing out of the marina.

APPENDIX A

PRESENCE/ABSENCE OF SPECIES IN SURVEY AREAS (SUMMARY TABLE)

	AREA:	A	B	C	D	E	F
	Coelenterata						
	Athelia edmondsoni				P	P	
corals	*Psammocora stellata*		P	P	P	P	
corals	*Psammocora* cf. *nierstraszi*					P	
corals	*Pocillopora damicornis*			P	P	P	P
corals	*Pocillopora meandrina*		P	P	P	P	
corals	*Montipora verrucosa*		P			P	
corals	*Montipora patula*		P				
corals	*Montipora flabellata*		P	P		P	
corals	*Pavona varians*				P	P	
corals	*Porites compressa*		P	P	P	P	
corals	*Porites lobata*		P	P		P	
corals	*Leptastrea bottae*				P	P	
corals	*Leptastrea purpurea*					P	
corals	*Cyphastrea ocellina*					P	P
	Palythoa ?tuberculosa						
	Echinodermata						
sea urchins	*Echinothrix calamaris*	P					
sea urchins	*Echinothrix diadema*	P	P	P	P		P
sea urchins	*Diadema paucispinum*						
sea urchins	*Echinostrephus aciculatus*		P				
sea urchins	*Pseudobolatia indiana*			P			
sea urchins	*Tripneustes gratilla*	P	P	P	P	P	
sea urchins	*Echinometra mathaei*			P	P		
sea urchins	*Echinometra mathaei oblongata*			P			
	Holothuria atra	P		P			

coral abundance as percent of 4 m^2; echinoderm abundance as no./4 m^2; p - present or coverage $<0.5\%$

APPENDIX A

TRANSECT C (CHANNEL MARKER "1" TO 100 METERS WEST)

	QUADRAT:	0	10	20	30	40	50	60	70	80	90	100 METER
	Coelenterata											
	Athelia edmondsoni											
corals	*Psammocora stellata*						p			p		
corals	*Psammocora* cf. *nierstraszi*											
corals	*Pocillopora damicornis*			p		p	p	p		p		
corals	*Pocillopora meandrina*	1									p	
corals	*Montipora verrucosa*											
corals	*Montipora patula*											
corals	*Montipora flabellata*										p	
corals	*Pavona varians*											
corals	*Porites compressa*				p							p
corals	*Porites lobata*					p	0.5	p	p		p	p
corals	*Leptastrea bottae*											
corals	*Leptastrea purpurea*									p		
corals	*Cyphastrea ocellina*											
	Palythoa ?tuberculosa											
	Echinodermata											
sea urchins	*Echinothrix calamaris*											
sea urchins	*Echinothrix diadema*					1						
sea urchins	*Diadema paucispinum*											
sea urchins	*Echinostrephus aciculatus*											
sea urchins	*Pseudobolatia indiana*											
sea urchins	*Tripneustes gratilla*			3	3	9	2	2		1		1
sea urchins	*Echinometra mathaei*				3	1	2			2	1	1
sea urchins	*Echinometra mathaei oblongata*									1		
	Holothuria atra										2	1

coral abundance as percent of 4 m^2; echinoderm abundance as no./4 m^2; p - present or coverage $<0.5\%$

APPENDIX A

TRANSECT D (CHANNEL MARKER "3" TO 100 METERS WEST)

	QUADRAT:	0	10	20	30	40	50	60	70	80	90	100 METERS
	Coelenterata	"0 meter" quadrat not quantified										
	Athelia edmondsoni		p	p	p							
corals	*Psammocora stellata*				p							
corals	*Psammocora* cf. *nierstraszi*											
corals	*Pocillopora damicornis*		p	p	0.5				p			
corals	*Pocillopora meandrina*											
corals	*Montipora verrucosa*											
corals	*Montipora patula*											
corals	*Montipora flabellata*											
corals	*Pavona varians*											
corals	*Porites compressa*		3									
corals	*Porites lobata*											
corals	*Leptastrea bottae*		p									
corals	*Leptastrea purpurea*											
corals	*Cyphastrea ocellina*											
	Palythoa ?tuberculosa											
	Echinodermata											
sea urchins	*Echinothrix calamaris*											
sea urchins	*Echinothrix diadema*											
sea urchins	*Diadema paucispinum*											
sea urchins	*Echinostrephus aciculatus*											
sea urchins	*Pseudobolatia indiana*											
sea urchins	*Tripneustes gratilla*		2	1								
sea urchins	*Echinometra mathaei*									1		
sea urchins	*Echinometra mathaei oblongata*											
	Holothuria atra											

coral abundance as percent of 4 m^2; echinoderm abundance as no./4 m^2; p - present or coverage $<0.5\%$

APPENDIX A

TRANSECT F (40 METERS WEST TO 140 METERS WEST OF CHANNEL MARKER "7")

	QUADRAT	0	10	20	30	40	50	60	70	80	90	100 METERS
	Coelenterata											
	Athelia edmondsoni											
corals	Psammocora stellata											
corals	Psammocora cf. nierstraszi											
corals	Pocillopora damicornis											
corals	Pocillopora meandrina											
corals	Montipora verrucosa											
corals	Montipora patula											
corals	Montipora flabellata											
corals	Pavona varians											
corals	Porites compressa											
corals	Porites lobata											
corals	Leptastrea bottae											
corals	Leptastrea purpurea											
corals	Cyphastrea ocellina	1										
	Palythoa ?tuberculosa											
	Echinodermata											
sea urchins	Echinothrix calamaris											
sea urchins	Echinothrix diadema											
sea urchins	Diadema paucispinum											
sea urchins	Echinostrephus aciculatus											
sea urchins	Pseudobolatia indiana											
sea urchins	Tripneustes gratilla											
sea urchins	Echinometra mathaei											
sea urchins	Echinometra mathaei oblongata											
	Holothuria atra											

coral abundance as percent of 4 m^2; echinoderm abundance as no./4 m^2; p - present or coverage $<0.5\%$

APPENDIX B: List of species and the numbers of each seen in transects C, D and F. Qualitative surveys were carried out at all other sampling sites. Relative abundances are given by: A = abundanct, more than 10 individuals seen; C = common, 5-10 individuals seen; adn R = rare, less than 5 fish seen.

Family and Species	Stations						
	A	B	C	D	E	F	G
CHANIDAE							
Chanos chanos							R
MURAENIDAE							
Gymnothorax meleagris					R		
Echidna nebulosa							R
AULOSTOMIDAE							
Aulostomus chinensis					R		
HOLOCENTRIDAE							
Adioryx lacteoguttatus					A		
SPHYRAENIDAE							
Sphyraena barracuda							R
MUGILIDAE							
Mugil cephalus							R
APOGONIDAE							
Apogon brachygrammus					R		
Apogon maculiferus					A	1	
CARANGIDAE							
Scomberoides lysan		A			R		
Caranx melampyrus		A					
LUTJANIDAE							
Lutjanus kasmira					R		
MULLIDAE							
Mulloidichthys flavolineatus					R		
Parupeneus multifasciatus		R		3	C		
P. pleurostigma		R					
P. porphyreus				3	A		
CHAETODONTIDAE							
Centropyge potteri					R		
Chaetodon auriga					C		
C. lunula		R		1	R		
C. miliaris		R			C		
C. multicinctus					C		
C. trifasciatus					A		
C. unimaculatus				1	C		
CIRRHITIDAE							
Cirrhitus pinnulatus				1			
C. fasciatus				2			
Paracirrhites forsteri				1			
POMACENTRIDAE							
Dascyllus albisella					A	2	
Abudefduf sordidus					C		
A. abdominalis	A	A	1	17	A		
A. imparipennis			4	1	C		
Chromis hanui	C		6				
C. ovalis		C			A		
Pomacentrus jenkensi		A	2		A		

APPENDIX B

Family and Species	Stations A	B	C	D	E	F	G
LABRIDAE							
Cheilio inermis	R				R		
Labroides phthirophagus					C		
Thalassoma ballieui					R		
T. duperryi		A	24	66	A	1	
T. umbrostigma			1				
Gomphosus varius				4			
Coris gaimardi	R			1			
C. venusta	R			2			
Stethojulis balteata	C	A	32	101	A	13	
Macropharyngodon geoffroyi				2	R		
SCARIDAE							
Scarus perspicillatus					R		
S. sordidus	R	C		3			
juvenile scarids		A	3	96	A		
ZANCLIDAE							
Zanclus cornutus		C		3	C		
ACANTHURIDAE							
Acanthurus achilles					R		
A. nigrofuscus	R	A		9	A	1	
A. nigroris		R		1	C		
A. sandvicensis	A	C	4	18	A		
A. xanthopterus					R		
Ctenochaetus strigosus				23	A		
Naso unicornis					R		
Zebrasoma flavescens		R		2	R		
Z. veliferum		R			C		
ELEOTRIDAE							
Asterropteryx semipunctatus					R	3	C
BLENNIDAE							
Cirripectus lineopunctatus					R		
BALISTIDAE							
Rhinecanthus rectangulus	R						
MONOCANTHIDAE							
Pervagor spilosoma	C	R	1	7	C		
OSTRACIONTIDAE							
Ostracion meleagris		R	1				
TETRADONTIDAE							
Arothron hispidus					R		
CANTHIGASTERIDAE							
Canthigaster jactator			1	3	R		
total number of species	11	21	12	25	46	6	5
total number of individuals (transects only)			80	371		21	

APPENDIX C

The enclosed description of the biota on the reef flat between Aina Haina and Niu Valley was obtained from a report by Dr. John Caperon (1974, "Environmental Impact on the Marine Ecosystem of a Storm Drain Outlet for the Hawaii Loa Development"). Dr. Caperon was aided in this effort by E.B. Guinther of Environmental Consultants, Inc. The reef flat investigated in 1973 is similar in character to that located off Hawaii Kai, particularly the area west of the existing boat channel and in the vicinity of Paiko Peninsula. The report is not generally available and therefore the sections covering biotic observations are included here as supplementary material. The emphasis of Dr. Caperon's report is on effects of fresh water and discussions of organisms in the areas influenced by natural fresh water springs along the shore may not be directly applicable to the coastline near Hawaii Kai. However, his description of organisms along a transect crossing the reef applies reasonably well to conditions generally in Maunalua Bay. (See Fig. 4 for site location.)

BIOLOGICAL ENVIRONMENT

General Description

A general ecological reconnaissance of the beach and nearshore flora and fauna was made on 1 December 1973 and sediment samples were collected and sieved to examine the infauna in the region of the fresh water springs (see Figure 3 for location) and at the mouth of the Wailupe Canal. On 15 December 1973 a detailed survey of the marine organisms along the 750 foot transect shown in Figure 1 was made. A more general survey was continued beyond the end of the transect to the deeper water outside the surf zone. Organisms that could not be identified in the field were brought to the laboratory for specific identification wherever possible. Tables 3 and 4 give flora and fauna species lists respectively.

The reef flat is essentially a single community of organisms that exhibits a gradient of relative abundances in the principal components. At the surf line there is a relatively distinct break in the species composition that can be distinguished as a different community of organisms. The first 100 feet adjacent to the shore line is also distinctive and there are also quite distinct differences along the shoreline reflecting the influence of fresh water in localized areas.

Infauna

The dominant organism in the sediment close to shore is the eunicid tube worm, *Diopatra* sp. Somewhere around 150 feet offshore it is replaced by a second unidentified species of Polychaet worm in the Family Chaetopteridea. In a number of nearshore areas *Diopatra* occurs in dense beds where they consolidate very fine silty sediments into beds that are often elevated three to four inches above the surrounding sandy bottom. (See photographs 1, 2, 3, and 4).

The series of sediment samples collected in the fresh water springs area, A through F, were also dominated by polychaet worms. Sample C, closest to the source of fresh water, contained no macroscopic organisms. Samples A and B, next closest to the spring, contained three individuals of Marphysa sanguinea. This apparently fresh water tolerant organism was the only individual contained in a sediment sample of the mouth of the Wailupe Canal. A second polychaet showing tolerance to depressed salinity was Malacoceros indicus. Six specimens were found in sample A and numerous individuals were found in sample B. Samples A, D and E, more removed from the springs than B and C contained the soft coral Palythoa psammophyla. Diversity increased with distance from the spring with the acorn worm, Ptychodera flava, the chiton Ischnochiton petaloides, the holothurians Holothuria monocaria and Chirodota rigida and the crustacean Etisus electra. Sample F which is quite well out of the region of depressed salinity contained 43 specimens of Diopatra (not found at all in samples A through E). Also present were C. rigida, H. monocaria, P. psammophyla and the molluscs Gualteriana natica and Hormomya crebristriatus. This assemblage of infauna species now represented a complete shift from the sequence of species beginning at the fresh water spring.

Reef flat plants

On the solid substrate portions of the reef flat (dark areas in Figure 1) the dominant plant is Acanthophora spicifera, with Halimeda discoidea, Sargassum sp. and Ulva reticulata also abundant. Acanthophora is found on all solid substrate over the reef flat, at 75 feet offshore of

the transect start it covers 75 to 85% of the substrate. By the 225 foot mark Sargassum has become relatively abundant, about 10% of total substrate, with Acanthophora accounting for 70%. At 375 feet the reef flat is covered by about 40% Acanthophora and 40% Halimeda discoidea with Ulva reticulata and Dictyosphaeria cavernosa also present. By 450 feet Acanthophora is down to 20% with Halimeda at 50% and Ulva reticulata at 5 to 10% of substrate cover. At 525 feet, Acanthophora is still less abundant than it was closer to shore but plants are lush and larger; Ulva, Halimeda and Acanthophora are about equally abundant here. At 550 feet a relatively dense stand of Lyngbya sp. occurs. This species is found epiphytically on other algae over much of the reef. By 600 feet Acanthophora is quite abundant again (about 70% of cover) with Dictyosphaeria verslusyi and Codium edule also present. Beyond about 650 feet more and more encrusting calcareous algae are found along with Halimeda and scattered fleshy algae.

On the sediment covered recesses between the platform structures (light colored area in Figure 1) the dominant macroscopic plant is Halimeda. It is rarely found close to shore but becomes quite abundant in the recesses, covering 20 to 30% of the substrate from 225 to 375 feet offshore. By 600 feet the distinction between reef flat top and recess is less desirable floristically.

Beyond the end of the transect the bottom flora becomes much more diverse. The vertical relief increased to 4 or 5 feet at the point where the surf breaks. Coraline algae, Codium sp. and D. verslusyi are present.

Reef Flat Animals

Near the shore the proportion of sediment-rubble-filled recess area is larger than farther offshore. The dominant animal in these recesses is

Diopatra sp. with the soft coral Palythoa psammophyla also abundant, the latter also occurring among the plants on the reef top. These organisms remain dominant out to about 150 feet along the transect line, with relatively few and cryptic other invertebrates. The sea anemone Aiptasia diaphana is found here. At 225 feet a blue sponge, Halichondria sp. is frequently encountered and Palythoa remains abundant. The mollusc Plakobrachus oscellatus occurs here also. The most commonly noted fish in the first 450 feet is Asterropteryx semipunctatus. Between 300 and 450 feet a small parrot fish (Scaridae sp.) and manini (Acanthurus triostegus) were noted. At 450 feet a small overhanging ledge offered some cover and the maomao, Abudefduf abdominalis, the goatfishes, Mulloidechthys samoensis and Parupeneus porphyreus, and the wrasses, Thalassoma duperreyi, Gomphosus varius and Stethojulis balteata were also noted. From 400 feet to beyond the end of the transect the sea cucumber Holothuria atra was abundant on the sandy areas, joined by a second species, Actinopyga mauritiana, on the reef flat at about 550 feet.

Beyond the end of the transect occasional small isolated coral colonies were noted. Porites lobata was noted first, followed by a small colony of Pavona sp. before reaching the surf zone. Beyond the surf zone P. lobata, Pocillopora meandrina and Montipora flabellata were frequently encountered as small colonies, but total coral coverage of the bottom was less than 1%.

Outside the transect area and the offshore reef special attention was paid to flora and fauna that were indicative of fresh water influence. In addition to the differences noted under the infauna section the area of the shoreline under fresh water spring influences showed other adaptations to persistent fresh water suppression of salinities. *Theodoxus vessertinus* is a fresh water estuarine snail while its congener *T. neglectus* is marine. The specimens found in this area appear to span the characteristics of these two species. At least it can be said that this is not the typical marine or estuarine species. Likely this question does not have a definitive answer. Some fresh water influence seems evident at least. The mollusc *Isognomon californicum* and the small shrimp *Palaemon pacificus* are typical of marine environments with depressed salinities as is the alga *Cladophora fascicularis*. All three of these species were found in this area but in the adjacent waters upcoast or downcoast.

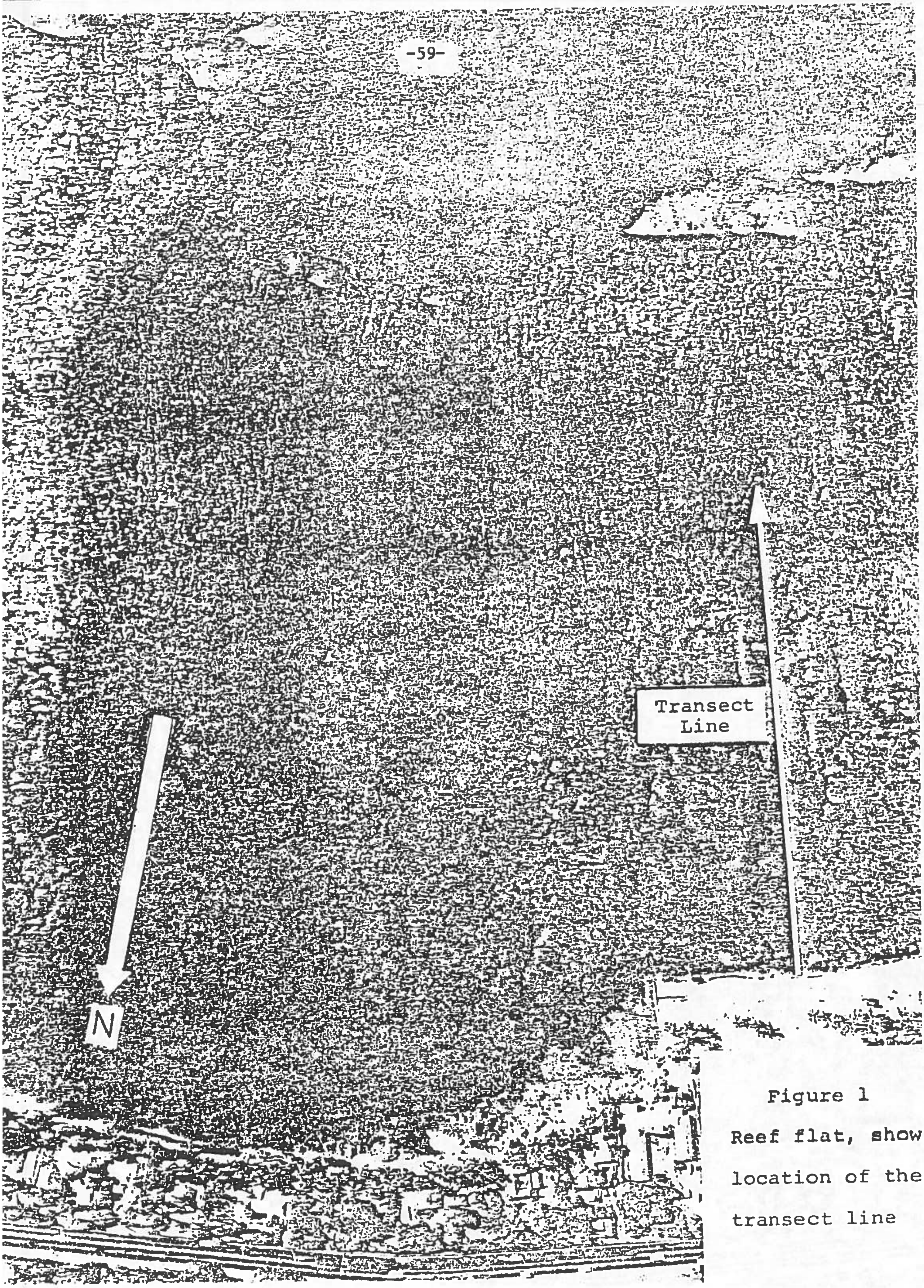

Figure 1

Reef flat, show location of the transect line

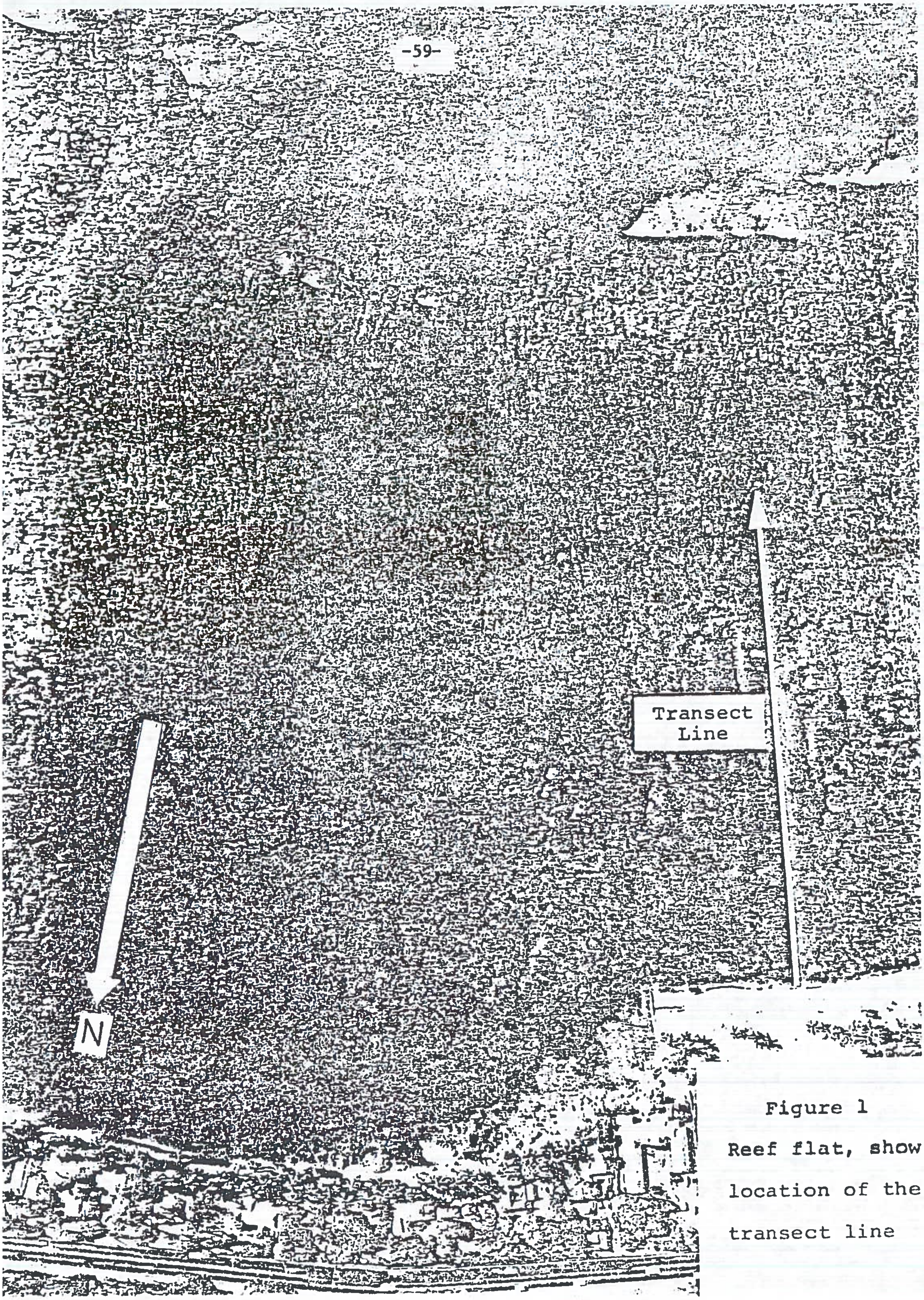

Figure 1
Reef flat, show location of the transect line

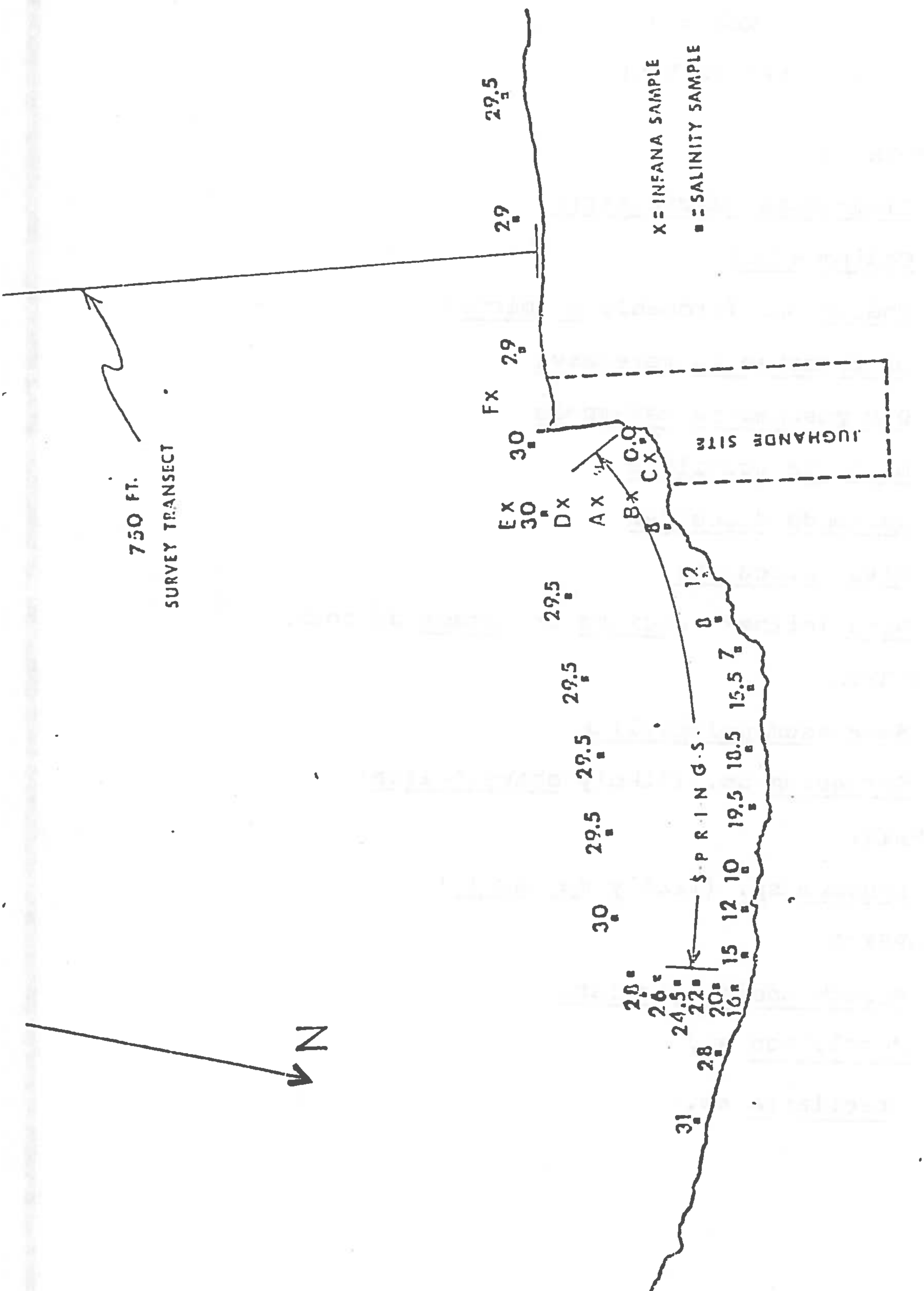
750 FT.
SURVEY TRANSECT
X = INFANA SAMPLE
■ = SALINITY SAMPLE
JUGHANDE SITE
SPRINGS
N
A X
B X
C X
D X
E X
F X
G O
29.5
29
30
12
0
7
15.5
18.5
19.5
10
15
28
26
24.5
22
20
16
31

FIGURE 3

Table 3

Plant Species List

CHLOROPHYTA

Cladophora fascicularis

Codium edule

Codium sp. (probably *arabicum*)

Dictyosphaeria verslusyi

Dictyosphaeria cavernosa

Dictyota acutiloba

Halimeda discoidea

Ulva reticulata

Ulva (either *fasciata* or *latuca* or both).

PHAEOPHYTA

Sargassum polyphyllum

Sargassum sp. (likely *obtusifolium*)

MYXOPHYTA

Lyngbya sp. (likely *majuscula*)

RHODOPHYTA

Acanthophora spicifera

Porolithon sp.

Gracilaria sp.

Table 4

Animal Species List

PORIFERA

Halichondria sp.

COELENTERA (Zoantharia)

Aiptasia diaphana

Anthopleura nigrescens

Palythoa psammophyla

Porites lobata

Montipora flabellata

Pocillopora meandrina

Pavona sp.

ANNELIDA

Malacoceros indicus

Marphysa sanguinea

Eurythoa complanata

Diopatra sp.

Chaetoperids

Cirratulids

ECHINODERMATA

Echinometra mathaei

Holothuria monocaria

Holothuria atra

Chirodota rigida

Actinopyga mauritiana

Table 4 (Cont.)

MOLLUSCA

Theodoxus (*neglectus* and/or *vespertinus*)

Conus lividus

Gualteriana natica

Hormomya crebristriatus

Isognomon californicum

Ruditapes philippinarum

Ischnochiton petaloides

Plakobrachus ocellatus

ARTHROPODA (Crustacea)

Etisus monocaria

Palaemon pacificus

Thalamita sp.

Gonodactylus falcatus

Alphaeid shrimp

CHORDATA

Ptychodera flava

VERTEBRATA

Acanthurus triostegus

Mulloidichthys samoensis

Parupeneus porphyreus

Apogon snyderi

Chaetodon auriga

Thalassoma duperreyi

Stethojulis balteata

Table 4 (Cont.)

Gomphosus varius

Scaridae spp.

Asterropteryx semipunctatus

Zanclus canescens

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