ECOLOGICAL BASELINE STUDY OF THE INTERTIDAL ZONE
KAPOHO, HAWAII

A PRELIMINARY REPORT

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SEA GRANT PROGRAMS

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NOTE

John I. Ford attended the University of Hawaii, Hilo College from September, 1971 through August, 1972. During that time, he worked as a laboratory assistant for Dr. Albert C. Smith, Associate Professor of Biology, Hilo College, and was acknowledged for "excellent technical assistance" in the short communication, Lens Iso-precipitin in Yellowfin Tuna, *Thunnus albacares*. A.C. Smith. Comparative Biochemistry and Physiology. vol. 42b, pp. 497-499. 1972.

This ecological baseline study, an original undergraduate research project, was funded by Sea Grant through the Marine Option Program of the University of Hawaii in the summer of 1972.

At the present time, the author is completing his undergraduate requirements for a degree in zoology at the University of Hawaii, Honolulu.

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Finally, I owe a great deal to those who were, or are, residents of Kapoho who gave their support, specifically; Dr. Nicholas Steuermann, Mr. Arthur Lyman, Mr. Slim Holt, and the Crossett family.

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I. ABSTRACT: An Introduction

The geology of the Kapoho, Hawaii shoreline is unique in the Hawaiian Islands. Located 20 nautical miles south-south east of Hilo, it is sheltered from gusting trade winds and heavy seas by Cape Kumukahi. A 6,000 foot expanse of coastline approximately 200 yards wide adjacent to Kapoho Bay is dotted with clear, shallow tide pools and small coral reefs which support an abundance of marine life (Figures 1 and 2). As well as providing a source of revenue and sustenance for local fishermen, this area is a favorite spot for naturalists, diving enthusiasts and marine scientists. The convenient location of Kapoho has enabled life science classes from Hilo College to gain a first-hand insight into the intricate ecology of a living coral community, and to gain practical experience in observing, collecting and identifying species of fish and invertebrates.

For many years, the general public has taken advantage of the idyllic, secluded setting of Kapoho. Several private homes have been built along the shoreline under permit from the County of Hawaii (Figures 3 and 4). Lacking better facilities, raw sewage from these dwellings was, and still is, deposited in cesspools dug beneath each lot. The porous nature of the lava substrate allows considerable seepage of this waste to occur through fractures in the regolith, lava tubes and/or freshwater stream discharge. This problem, though perhaps negligible years ago, today threatens the swashes and tide pools of the intertidal zone, and all marine life therein, with harmful organic pollution.

Prompted by this increasing danger, the ecological baseline study was initiated in early June, 1972, in order to assess the present properties

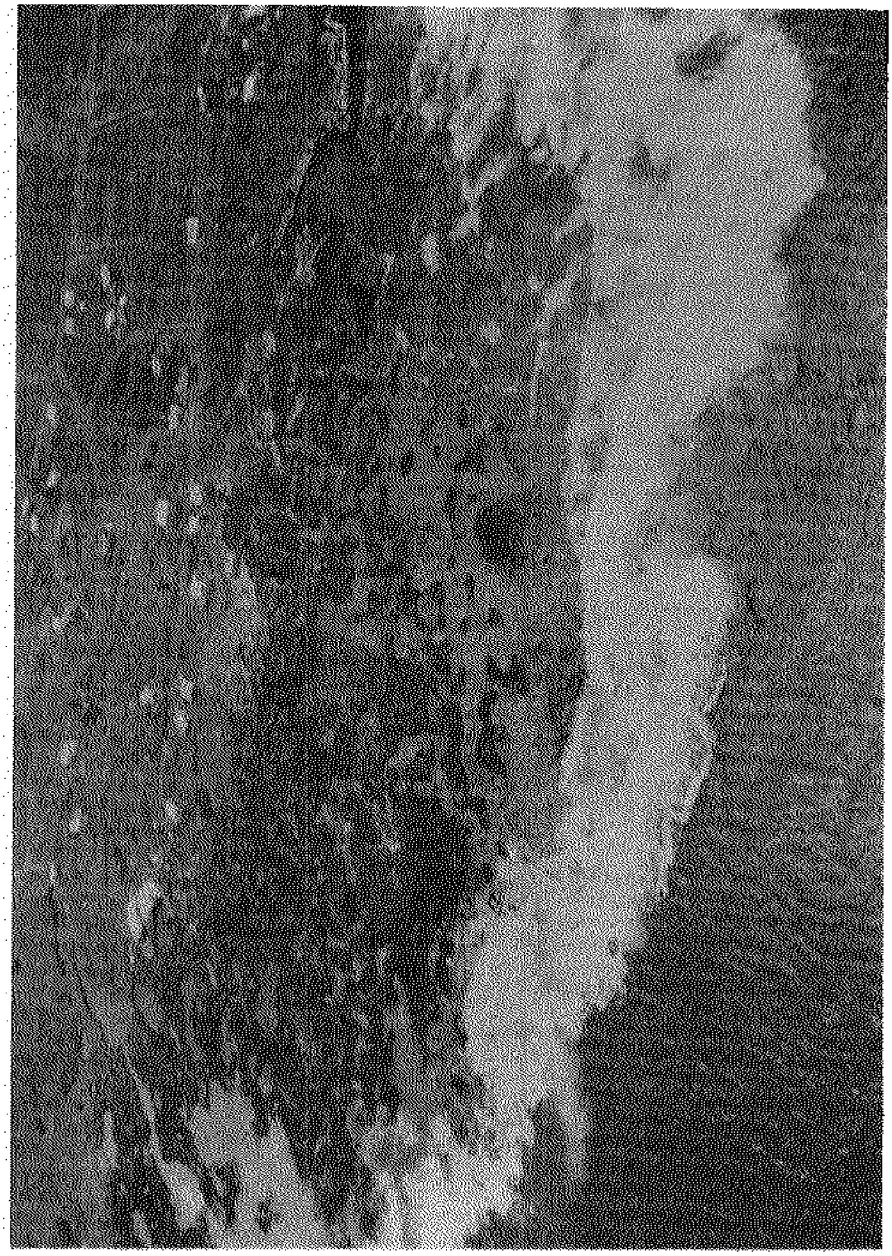


Figure 1. Kapoho Shoreline

Figure 2. Kapoho Bay

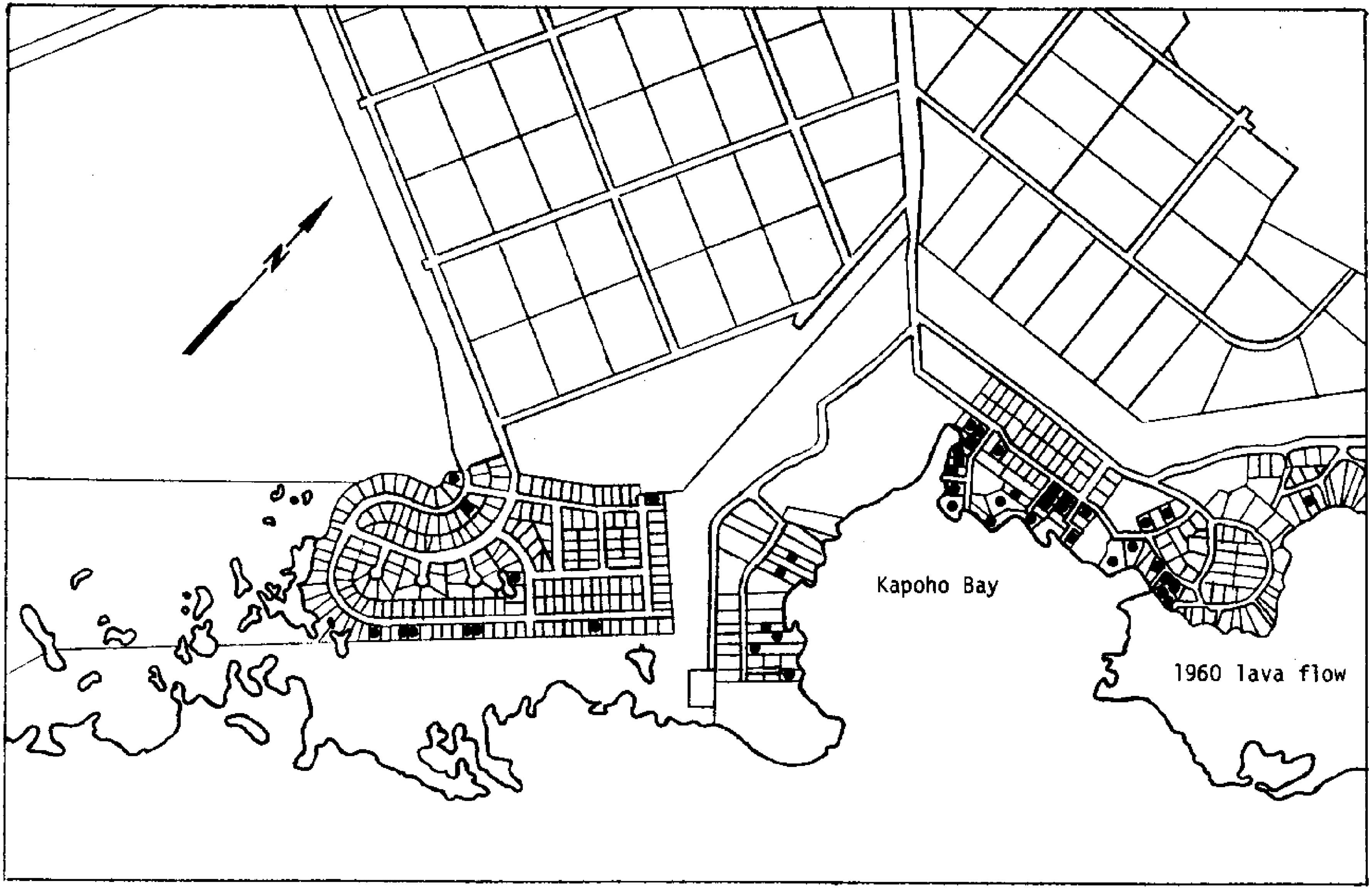


Figure 3. Kapoho Shoreline in 1965 (from Hawaii County tax map)

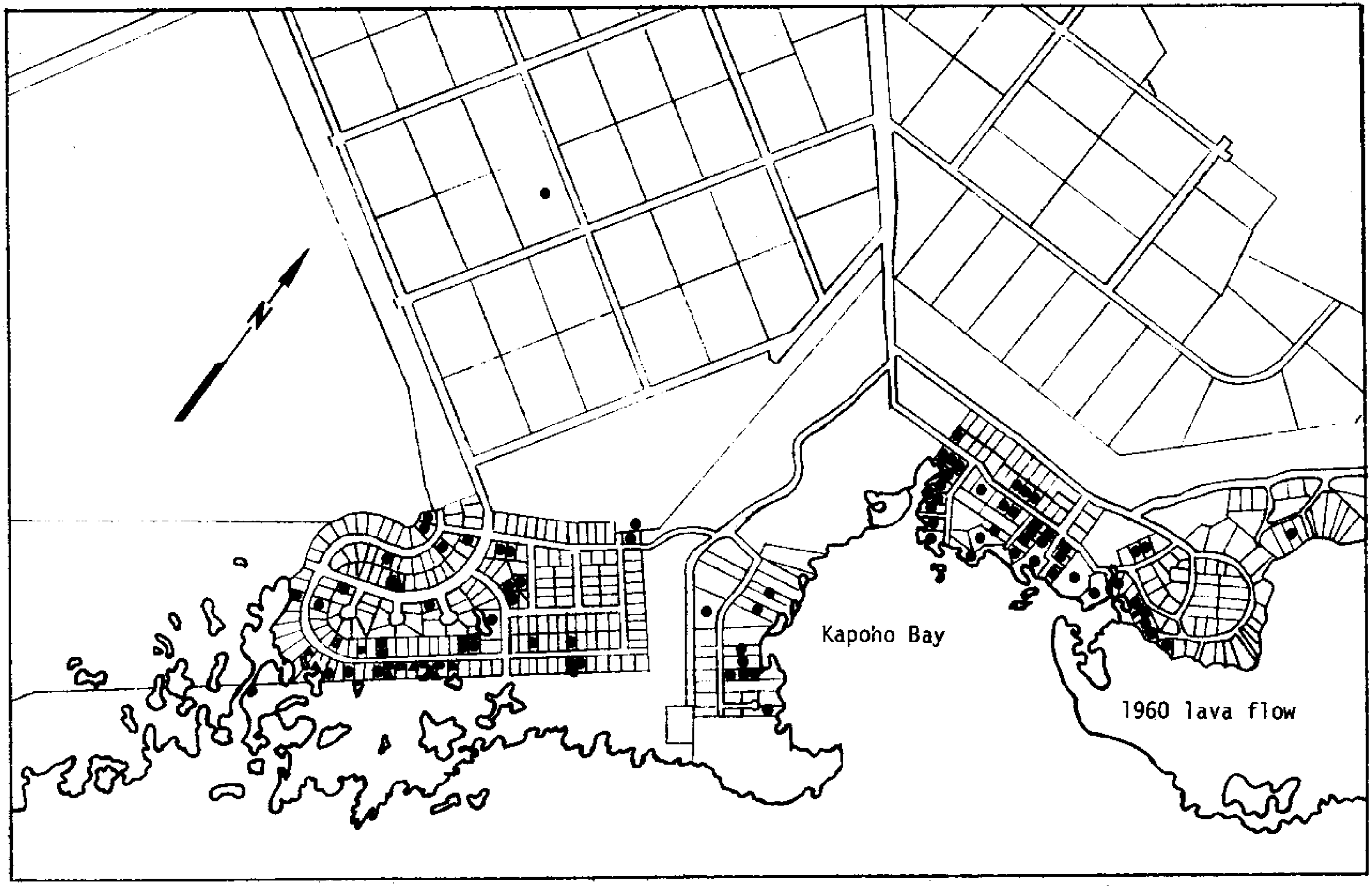


Figure 4. Kapoho Shoreline Today (from recent aerial photographs)

of the sea water, the extent of the pollution and related deleterious effects caused by the sewage outflow, and to determine community structures and compositions and their relationships to water quality. As set forth in the proposal for this research, specific aims of the project include: photographing and accurately re-mapping that portion of coastline under study; determining the primary introduction points of waste material into the tidal pools; establishing a water quality control station monitoring temperature, salinity, dissolved oxygen, pH, turbidity, fecal coliform bacteria; recording all species of marine animals within the intertidal zone, and determining the incidence of pathology in populations of these marine animals.

This information is intended to provide a practical and reliable key to resolving the effect of organic waste pollution upon the water quality and fauna of the Kapoho area over a period of time.

II. METHODS

1. Water Quality

Standard straight-line transects proved unfeasible in selecting sampling stations because of the unusual topography. Therefore, a certain degree of selectivity was allowed for, and stations were chosen in the surge area, the supra-surge zone, and at a considerable distance inland in the immediate vicinity of the housing subdivisions (Figure 5). These areas shall hereafter be referred to as the surge, supra-surge, and upper beach transect areas, respectively (Figure 6). The shoreline was further divided into six lateral divisions with respect to areas of like characteristics: Lava, Bay, Palm, Guava, Sword, and Crossett transect zones.

In order to minimize the deviations associated with monitoring a continually changing body of water such as this, all sampling techniques followed the guidelines established in Standard Methods, 1971. With one exception in the Lava transect zone, all water samples were collected during low tides to maintain uniformity, and to allow safe and easy access to a greater number of tidal pools. An effort was made to conduct as much analysis in the field as possible. All samples to be returned to the laboratory were hand collected in sterile 200 ml bottles, without rinse, cooled, and returned within three hours. Unfortunately, no tests for phosphate or nitrate nutrients or particulate matter were conducted.

Salinity was measured in the laboratory with an American Optical Company refractometer, and in the field with a YSI model 33 S-C-T salino-

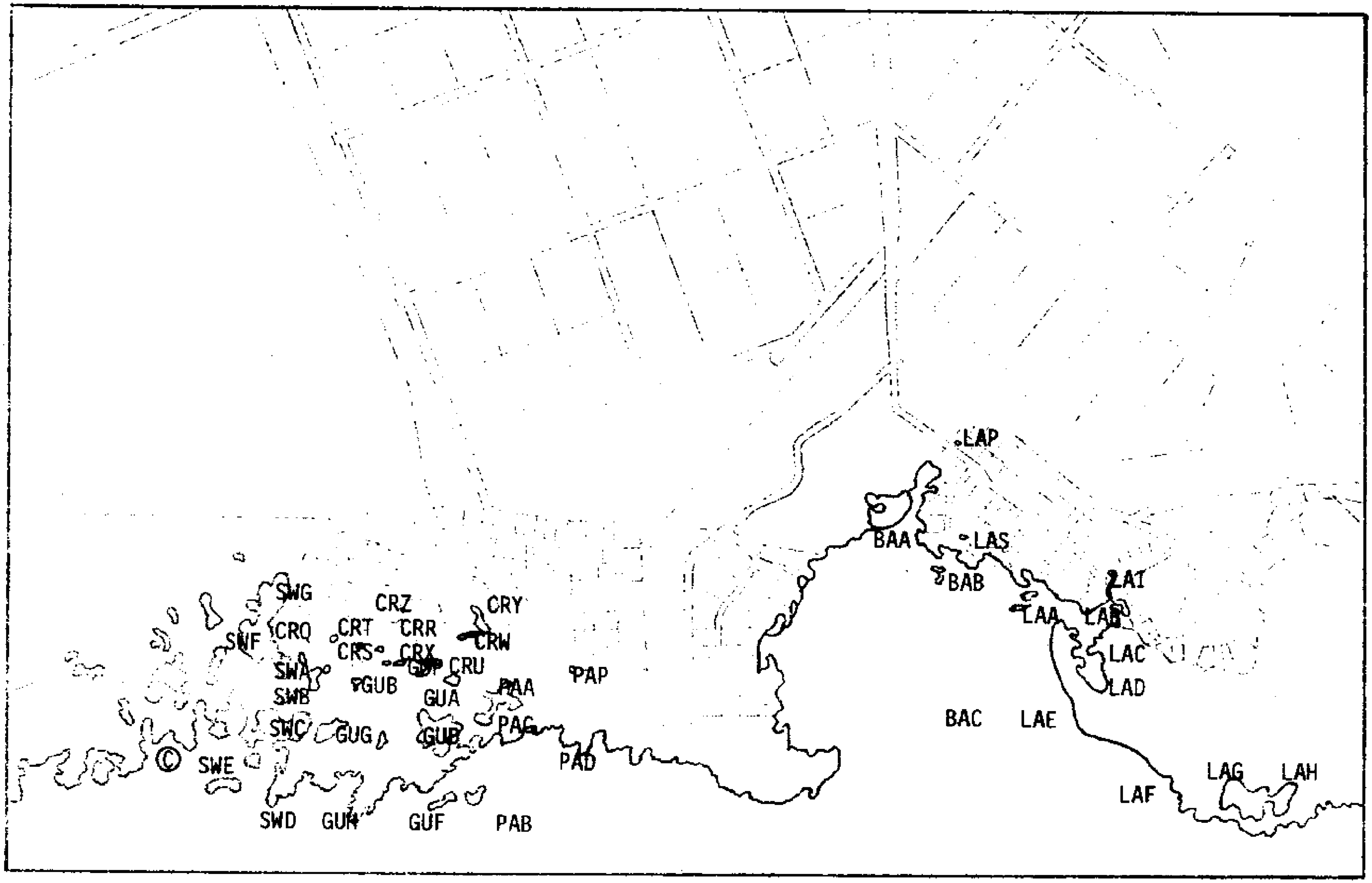


Figure 5. Water Quality Sampling Stations (Kapoho Intertidal Zone)

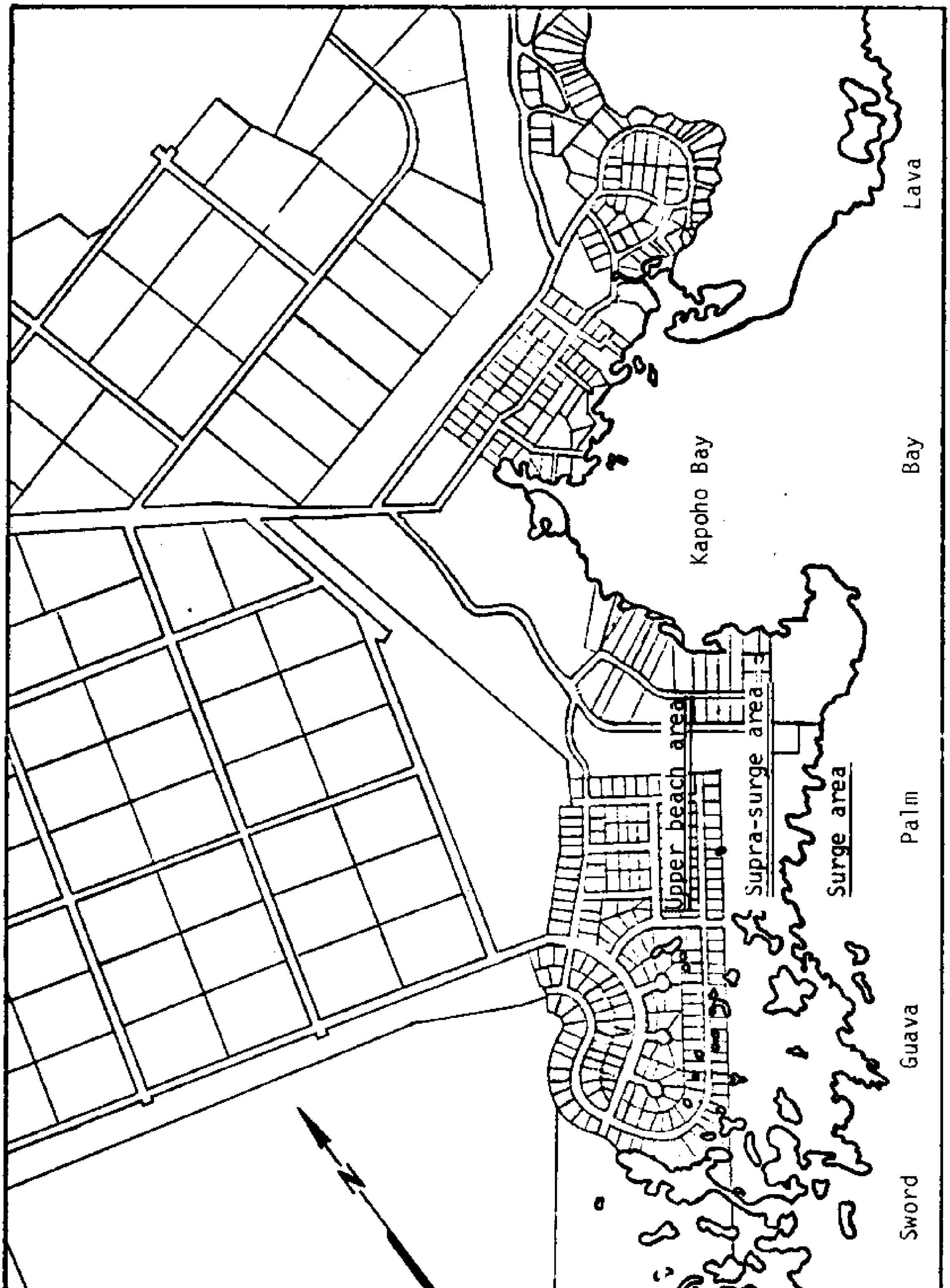


Figure 6. Shoreline Divisions (Kapoho Intertidal Zone)

meter. Dissolved oxygen was measured in the field by a Weston & Stack Oxygen Analyzer initially, and then by a YSI model 51-A oxygen meter. The use of oxygen meters was chosen over the more accurate Winkler titration method in the interest of time and available equipment. Temperatures were measured by precision thermometers within the submersible probes of the salinometer and oxygen meter. Turbidities were determined by line-of-sight. (See 5. Turbidity, page 17.) pH was measured in the laboratory with a Corning model 7 pH meter. Slight changes may have occurred in the pH of samples being returned to the laboratory. Unfortunately, these changes are not known.

Samples to be cultured for fecal coliform bacteria were collected as stated above. At the laboratory under sterile conditions, each sample was diluted to 1/10, 1/100, 1/1,000 and 1/10,000 of its original strength. One milliliter of each diluted sample was introduced into five culture tubes, per each dilution strength, containing 9 ml of lactose broth and inverted gas tubes. Those tubes showing gas after 48 hours incubation at 37°C were considered positive presumptive tests. Five culture tubes, per each positive test, containing 9 ml of EC medium and inverted gas tubes, were inoculated by sterile loop transfer. Tubes showing gas after 48 hours incubation at 48°C were considered positive fecal coliform tests, and used to determine fecal coliform count (fecal coliforms/100 ml water), in accordance with Standard Methods, 1971. The common practice of obtaining the total coliform count was not followed; however, the fecal coliform count is sufficient to determine the degree of waste pollution as set forth in the Water Quality Standards, Hawaii State Department of Health, Chapter 37-A.

Aerial photographs were taken of the entire area under examination on two separate occasions at altitudes ranging from 500' MSL to 3,500' MSL during low tide from a Cessna 150 aircraft. These color photographs were used to locate dwellings and isolated tidal and mixohaline pools, and to re-map the shoreline as it exists today.

2. Animal Populations

The emphasis in this area of research was placed primarily on determining the speciation and variation of marine life present at the time of the baseline study. Fish were observed randomly, and recorded by a diver on treated ASCOT paper (see Appendix). Care was taken to cause minimal disturbance while diving in smaller tidal pools in order to observe as many inhabitants as possible. To aid in this, the use of SCUBA was held to a minimum. The relative size of each population of fish was also noted.

Initially, a 1/2 meter square was used in observing bottom dwelling invertebrates; however, this method proved overly selective. A 1/4 meter square placed randomly along transects approximately 4 feet wide on the bottom of each pool produced more accurate results. In many cases, more information was gained by the diver as he swam the length of each transect and recorded all invertebrate life within 4 feet of either side of him.

Plankton communities were not sampled.

III. FIELD OBSERVATIONS

1. Temperature

All biochemical processes are extremely sensitive to temperature. The metabolism of poikilothermic animals will change as the temperature of their natural waters changes. Thus, their survival, reproduction, growth and behavior are ultimately dependent upon the constant temperature of their environment (Warren, 1971).

Surface temperature within the intertidal zone ranged from 25°C to 33.5°C. Along any given north-south transect, however, temperatures remained relatively constant between tides.

Stations within the surge area registered 25°C - 26.3°C. Those larger and deeper pools (and those small pools open to direct tidal ebb and flow) along the supra-surge transect area had temperatures between 26°C and 28°C. Shallow, stagnant pools in this area had temperatures of 28°C - 30°C. Temperatures between 27°C and 33.5°C were recorded at stations in the upper beach transect area.

During the course of one day, the surface temperatures were monitored at Lava transect zone stations during low and high tides to assess the degree of variation. Very little change in temperature was noticed with the incoming tide (Figure 7). Depending upon the depth (3 feet to 25 feet in this zone), bottom temperatures were characteristically 0.5°C - 1.0°C lower than surface temperatures.

2. Salinity

Due to the close proximity of the subterranean freshwater lens

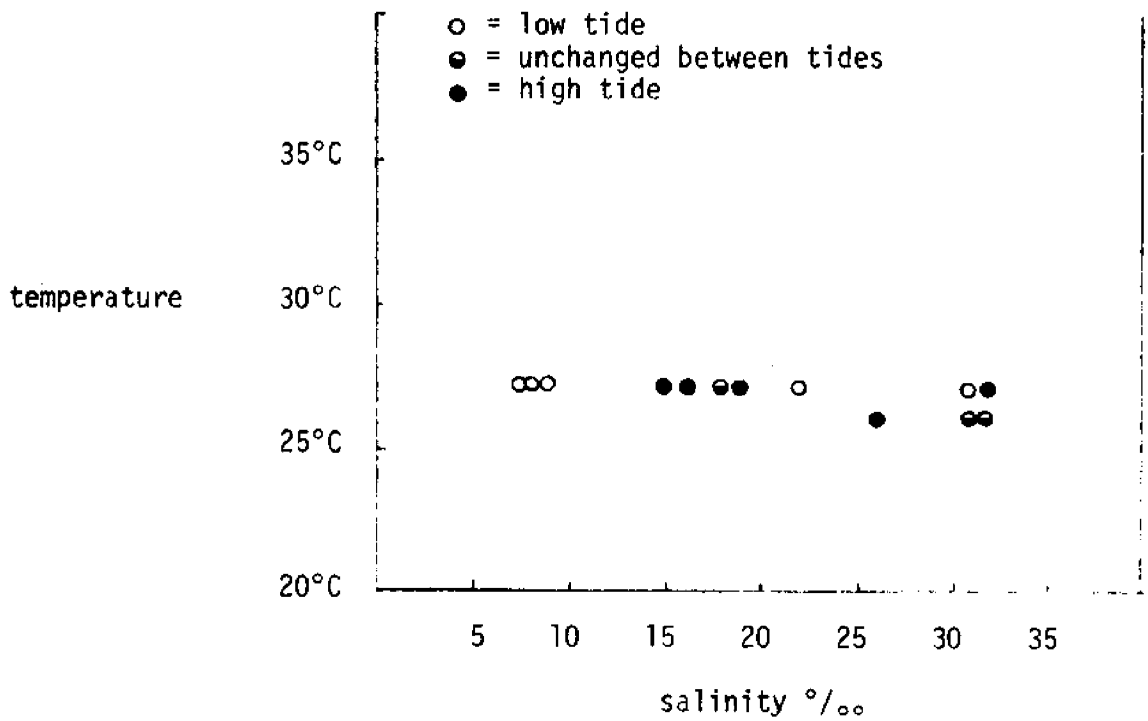


Figure 7. Temperature vs. Salinity Variation from Low to High Tide at All Lava Zone Stations

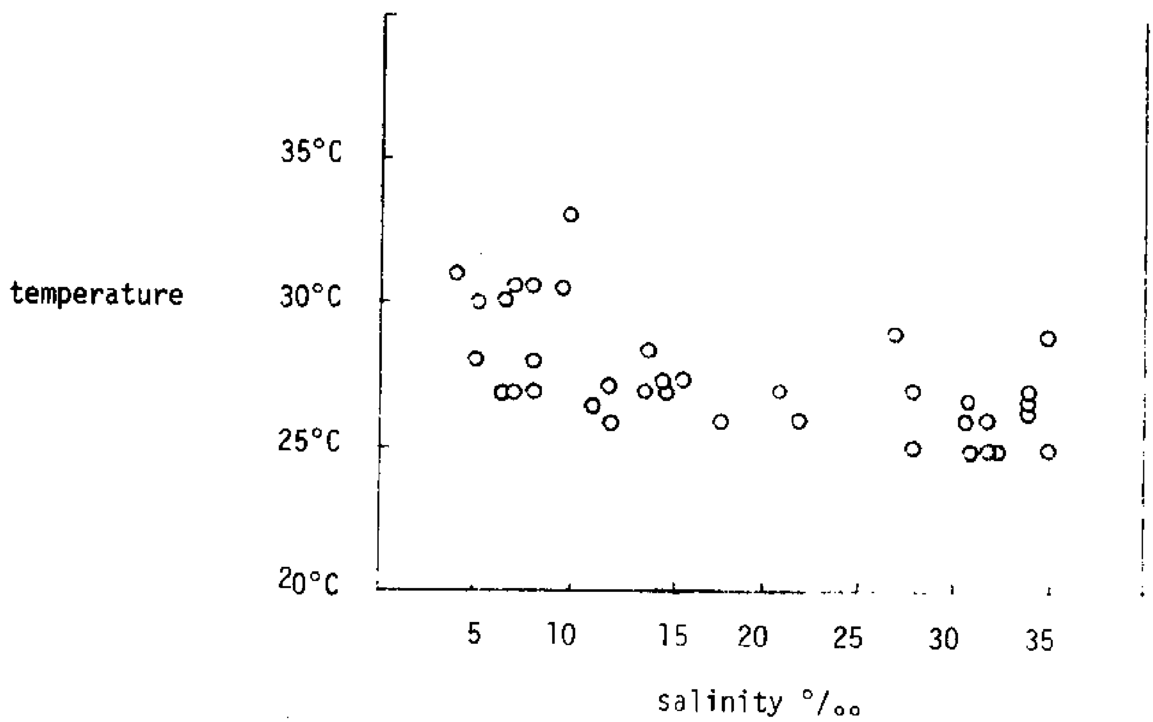


Figure 8. Temperature vs. Salinity During Low Tide for All Stations

to the surface, and to the distance of many tide pools from the ocean, a great variation in salinity was expected. The overall salinity range was 5 °/oo - 35.2 °/oo (Figure 8).

All supra-surge area stations had a surface layer of fresh water varying in depth from six inches to three feet, depending upon the amount of freshwater runoff in the immediate area. During high tide, as observed at stations in the Lava transect zone, surface salinities rose as much as 3.5 °/oo, and the surface layers became unclear and poorly defined. At stations exposed to strong currents (all Bay stations, PAA and SWF), these layers became thoroughly mixed.

Surge area stations had salinities of 31 °/oo - 35.2 °/oo. As the average salinity of open ocean water is approximately 35 °/oo, it is apparent that a significant amount of fresh water is present in certain parts of the surge area, although it is not immediately evident to the diver. (See 5. Turbidity, page 17.) This is most apparent in the Palm transect zone.

Salinities ranged from 17.5 °/oo to 32 °/oo within the supra-surge area. Stations in the upper beach area registered 5.1 °/oo - 12.8 °/oo.

3. Dissolved Oxygen

Depletion of oxygen in natural waters may be either directly or indirectly deleterious to fish and invertebrate populations. Whenever it is, pollution may be said to occur. High concentrations of putrescible organic matter, such as untreated domestic waste, are the major cause of such reduction and subsequent pollution (Warren, 1971).

The Weston & Stack Oxygen Analyzer could not be calibrated to compensate for salinity and consistently gave inaccurate readings. A YSI model 51-A oxygen meter was substituted and proved very satisfactory.

Saturated and super-saturated readings were obtained at all surge area stations due to surf action. These readings ranged from 8.0 mg/l to 10 mg/l. Supra-surge area stations registered 4.7 mg/l - 8.5 mg/l, and upper beach area stations varied between 4.8 mg/l and 7.6 mg/l. All values are within State limitations for dissolved oxygen in Class A waters (Department of Health, State of Hawaii), with the exception of stations CRU (4.8 mg/l), GUA (3.8 mg/l), GUB (4.7 mg/l), GUC (4.8 mg/l), GUG (4.8 mg/l), and GUP (4.8 mg/l) (Figure 9). These stations vary slightly from the State minimum value of 5.0 mg/l.

4. pH

The buffering capacity of sea water is of importance to marine organisms because the stability of the environment is maintained to a high degree (Quan, 1969). The normal pH range of sea water is 7.5 - 8.4, with higher values expected near the surface (Sverdrup, 1942). Higher values may also occur in waters where greater photosynthetic activity of plants takes place. The pH sometimes exceeds the range of 8.1 - 8.3 in tide pools, bays, and estuaries. In areas where great dilution with fresh water occurs, the pH may reach 7.0 or even fall into the acid range (Sverdrup, 1942).

Overall pH measurements were 6.9 - 8.6, and averaged 8.2 to 8.4 (Figure 10). These values are within State limitations.

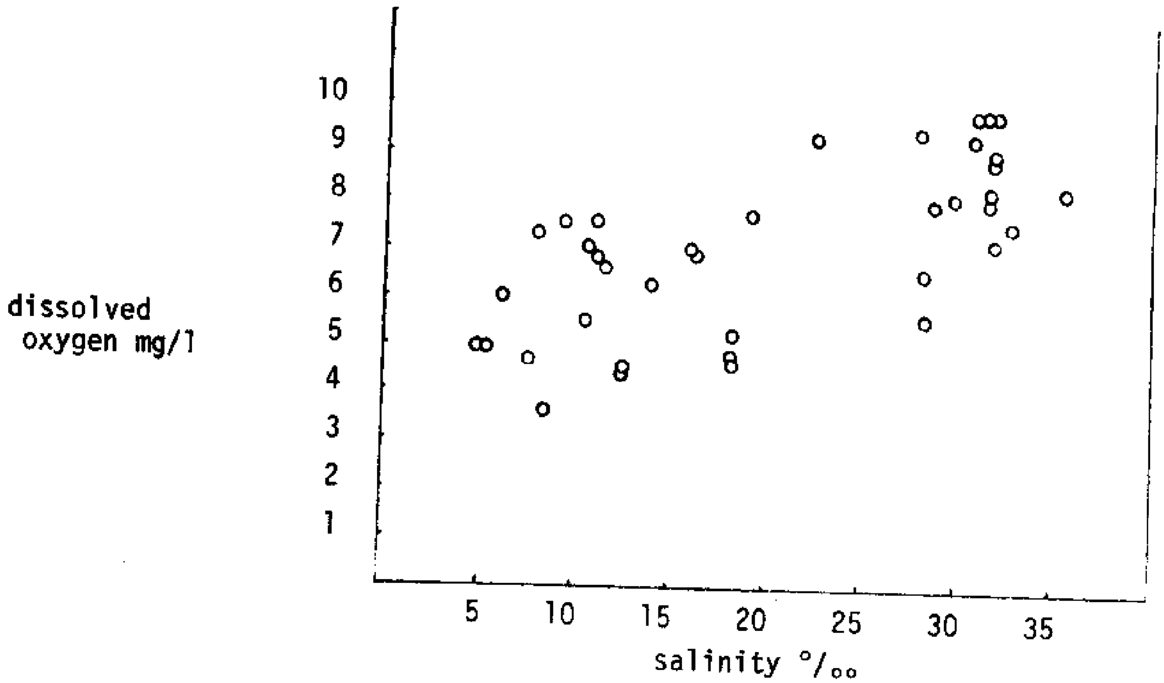


Figure 9. Dissolved Oxygen vs. Salinity for All Stations

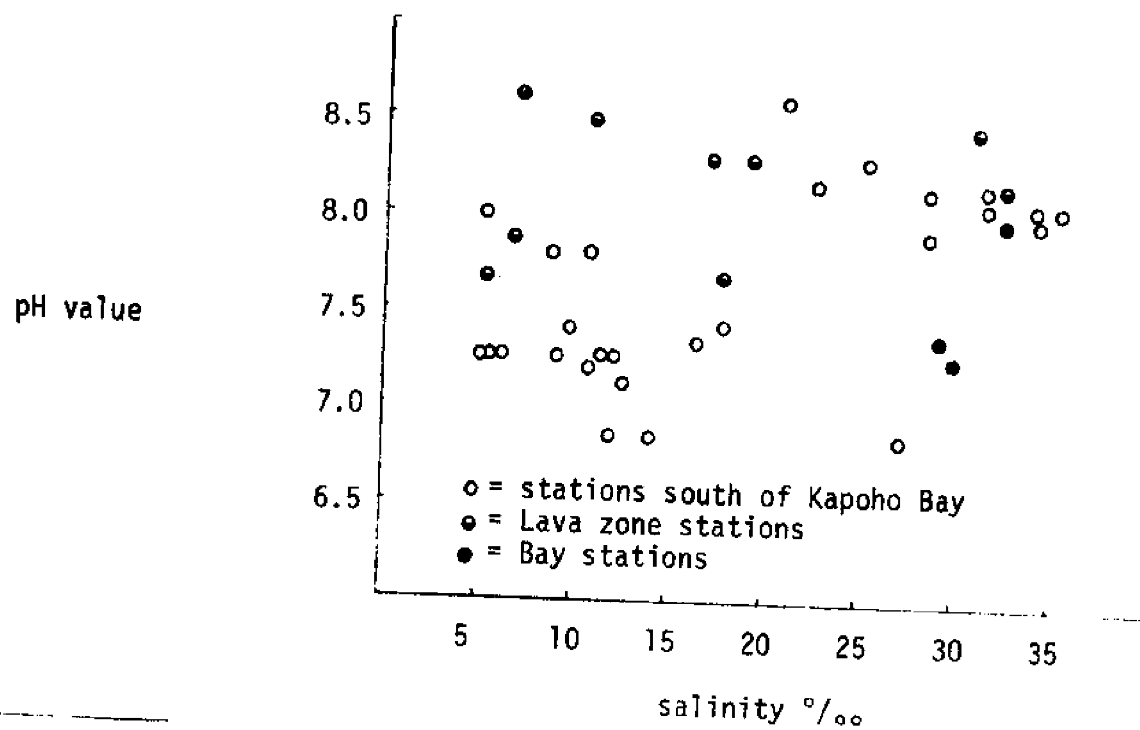


Figure 10. pH vs. Salinity for All Stations

5. Turbidity

Due to the configuration of the tidal pools, turbidity was measured by line-of-sight, and not by the standard Secchi disk. In most instances the transparency of the water was greater in number than the dimensions of the tidal pool. In such cases of unrestricted visibility the turbidity was recorded as clear (clr). In pools unaccessible to the diver, turbidities were estimated or recorded as a blank (-). The major factors influencing the clarity of the water proved to be the amount of fresh water present, silt and suspended solids, surf, high tides and rainfall. Bagasse also presents another problem with respect to turbid conditions at Kapoho.

Underwater visibility is greatly reduced in all areas during high tides. The pressure of the incoming tide acts on the subterranean water lens to force greater amounts of fresh water into the pools, and the strong currents associated with the tide serve to mix these waters and carry suspended matter produced by heavy surf into the area, thus causing poor transparency. Visibility is reduced as much as 5 meters under such conditions.

Similar conditions are produced during low tides after a heavy rainfall. Rainwater runoff contributes a great amount of suspended matter and fresh water resulting in reduced visibility. Samples collected after heavy rains show a rise in fecal coliform bacteria which is associated with increased freshwater runoff. (See 6. Biological Indicators, page 18.) Extreme turbidity, often the result of human activity whether direct or indirect, can result in the almost complete cessation of photosynthesis in aquatic environments and can in other ways endanger life (Warren,1971).

6. Biological Indicators

Coliform bacteria, normally found in the intestinal flora of humans, were used as the primary indicator of potential waste pollution and contamination with enteric pathogens. Surface samples collected were cultured for Escherichia coli.

Microbiological requirements for Class A waters, as stated in Water Quality Standards, Hawaii State Department of Health, Chapter 37-A, maintain that, "Fecal coliform content shall not exceed an arithmetic average of 200/100 ml during any 30-day period, and not more than 10% of the samples shall exceed 400/100 ml over the same time period."

During the past two years, fecal coliform levels in Kapoho Bay have been monitored twice a month by the State Department of Health. Samples taken from the vicinity of station BAB by the State have not been less than 3/100 ml and have not exceeded 240/100 ml over this time.

Culture tests for this research yielded negative presumptive and fecal results for all surge area stations. Limitations allowed only single samples to be taken from each station; however, several stations showed values much higher than the average allowed by the State regulations. Fecal coliform counts in the Lava transect zone ranged from 50/100 ml to 230/100 ml. In Kapoho Bay, station BAA registered 490/100 ml. Other high fecal coliform levels were observed at stations GUP, GUG, GUB, GUA, SWA, CRT, and CRQ. These stations had values between 330/100 ml and 2,200/100 ml (Figure 11).

In pools with a count of greater than 940/100 ml, further culture tests were performed for Salmonella, Shigella, Pseudomonas, and Leptospira

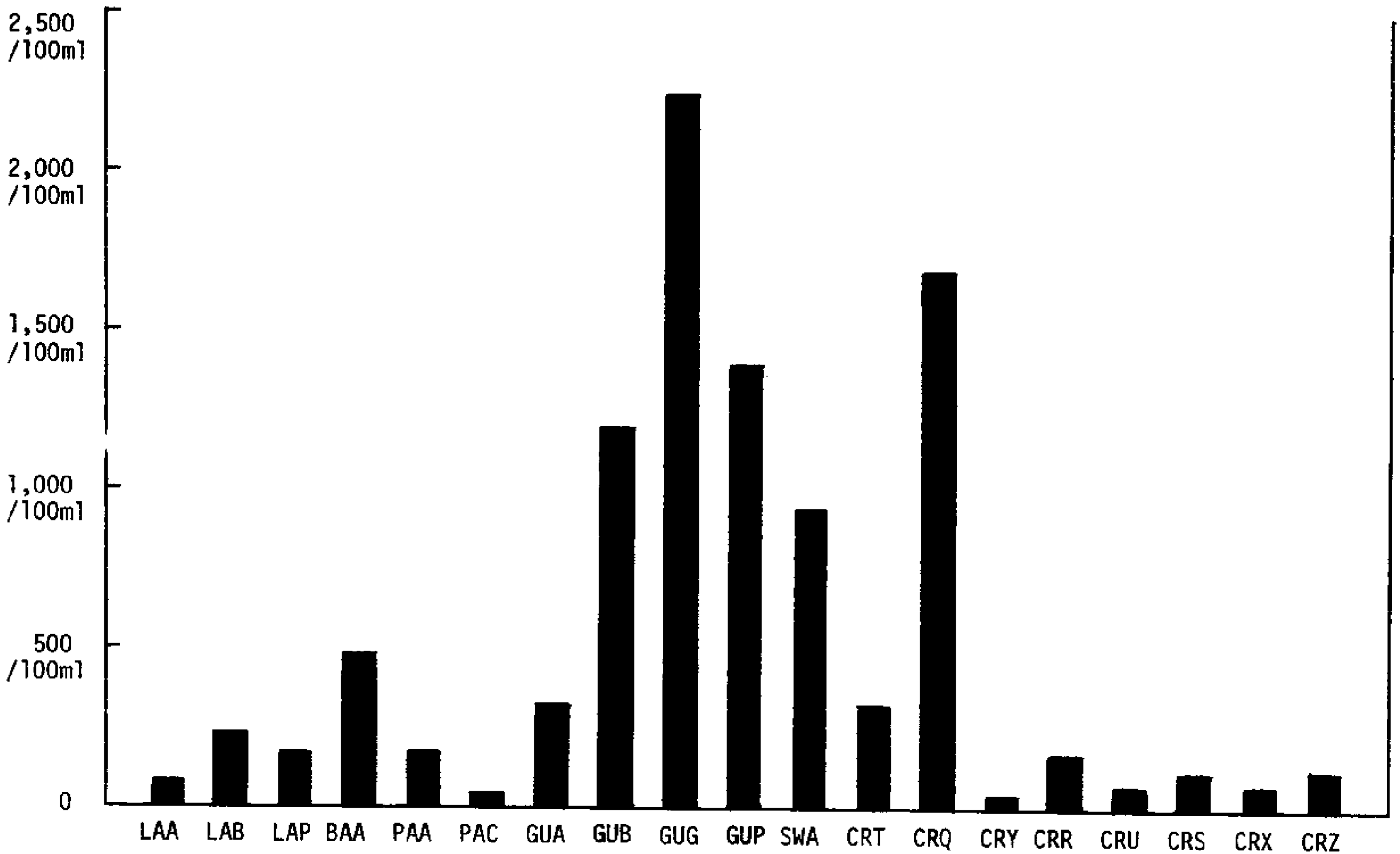


Figure 11. Fecal Coliform Counts by Station

organisms. These tests produced negative results with the exception of station GUB, which was positive for Pseudomonas; however, it was not determined if the organism was pathogenic.

In general, those pools which were open to tidal ebb and flow had little or no fecal coliform bacteria present or detectable. Although areas of contamination are relatively defined, it is difficult to determine any definite direction or pattern of seepage from any given cesspool. Many of the dwellings were not occupied during the time of study, and some were occupied only on weekends or holidays, yet high fecal coliform counts were recorded from pools within a 25-foot radius, such as the case of station GUB (see Appendix). In such circumstances, it is remotely possible that fish infected with E. coli in polluted areas could transfer the bacteria to uncontaminated waters (Janssen, 1970). As well, some pools had negative results although they were within the same radius of a home which was occupied year-round, such as the case of station CRW. During the three months of study, only 10 of the 34 dwellings to the south of Kapoho Bay, and only about 20 of the 48 homes around the Bay, were occupied at any time.

Other biological indicators used to detect the presence of organic pollution included algae tolerant to various degrees of organic pollution (Palmer, 1968), and macroscopic animals particular to brackish or eutrophicated waters. All the indicators used in this research are not intended to present proof positive of contamination; however, the presence of such organisms and their relative numbers should suggest the probable existence of a condition which could be deleterious to the normal flora and fauna of a given area.

Utilizing the key prepared by Palmer, 1968, algae samples were collected and identified with regard to their preference of habitat and water properties. Stations with high fecal-coliform counts were observed to foster the growth of such genera as Oscillatoria, Chlamydomonas, Nitzschia, Melosira (the most common form), Cyclotella, Microcystis, Fragilaria, and Diatoma. Stations exhibiting extensive growth of one or more of these algae include LAB, LAD, GUG, CRQ, and GUP. Station GUD was the only station observed to have a covering of Hydroclathrus on the bottom.

Marine animals associated with brackish waters commonly found in the upper beach transect area at Kapoho include the mollusc Neritina cariosa, isopods of the genus Gammarus, and the small shrimp Palaemon debilis.

7. Marine Animal Life

Interviews with residents of Kapoho provided information on the ecology of the area prior to the catastrophic lava flow of 1960. A large coral reef extended from the apex of Kapoho Bay along the eastern coastline and supported a sizable climax community. The Bay was at one time a haven for sea turtles, Chelonia mydas, and large Manta rays, Manta birostris, were often seen near the surface just beyond the surf. Small sharks, particularly hammerheads, Sphyrna lewini, and greys, probably Carcharhinus menisorrah, used to frequent the Bay. The overall visibility was reported to be infinitely clearer than today, with conditions being reduced only during periods of heavy surf. After the 1960 lava flow, early studies of the colonization of the intertidal area in the vicinity of station LAG at Kapoho were conducted by Townsley, et al., 1962.

Extensive observations were conducted on the fish and invertebrate populations for this project. Due to the position of many tide pools in relation to the ocean, and to the slight species variation along the length of the shoreline, dominant organisms were placed into three categories in relation to their preferred habitat and its distance from the surf. A fourth category describes those species observed in Kapoho Bay. Although each station within a transect area may not contain each species listed for that area at one time, the list represents the full compliment of species which are commonly found in each zone. An exception to this is station LAB, which was observed to have only Acanthurus sandvicensis, Abudefduf abdominalis, Muraena pardalis, Kuhlia taenuria, and Neritina cariosa. Many of the artificial pools within the housing subdivisions had been stocked with large carp, Cyprinus sp. Many of these pools had also been stocked with animals caught in the surge area or in deep water such as Acanthurus dussumieri, A. leucopareius, Rhinecanthus rectangulus, Caranx sexfasciatus (juv.), and Chelonia mydas. These animals seemed to have adjusted well to the low salinity of some of these pools.

The dominant species of fish observed belonged to the family Acanthuridae. The Acanthurids, Labrids, Pomacentrids, and Chaetodontids are the most abundant families represented in the tidal pools at Kapoho. The most abundant invertebrates appear to be Echinometra mathei, and members of the genera Actinopyga and Holothuria, as well as the omnipresent black rock crab Metapograpsus messor, and the mollusc Nerita picea. The most common coral species was undoubtedly Porites lobata.

A LIST OF THE DOMINANT MARINE ANIMALS OF THE KAPOHO INTERTIDAL ZONE

I. Surge area

A. Coelenterates

- Porites lobata
- P. compressa
- P. puboensis
- Pocillopora meandrina
- P. damicornis
- Psammocora stellata
- Pavona varians
- Montipora verrucosa
- Lepastrea bottae
- Fungia scutaria

B. Molluscs

- Trochus intextus
- Nerita picea
- Barbarita hawaia
- Chama iostoma
- Conus miliaris
- C. leopardus
- C. spiceri
- C. quercinus

C. Crustaceans

- Metapograpsus messor
- Atya sp.

D. Echinoderms

- Actinopyga mauritiana
- A. obesa
- Holothuria atra
- H. fuscorubra
- Stichopus tropicalis
- Linckia multiflora
- Echinometra mathei
- Tripneustes gratilla
- Diadema setosum
- Chondreocidaris gigantea
- Heterocentrotus mammilatus
- Acanthastar planci

E. Fishes

Acanthurus dussumieri

A. leucopareius

A. sandvicensis

Zebrasoma flavescens

Dascyllus albisella

Pomacentrus jenkinsi

Chaetodon lunula

C. miliaris

C. quadrimaculatus

C. unimaculatus

Kuhlia sandvicensis

K. taenuria

Gymnothorax flavimarginatus

Coris gaimardi

C. venusta

Gomphosus varius (juv.)

Labroides phthirophagus

Thalassoma duperreyi

Paracirrhites forsteri

Canthigastor jactator

Aulostomus chinensis

Fistularia petimba

Hemiramphus depauperatus

Hyporamphus pacificus

Apogon menesamus

II. Supra-surge area

A. Coelenterates

Porites lobata

Pocillopora meandrina

P. damicornis

Pavona varians

Montipora verucosa

Fungia scutaria

B. Molluscs

Trochus intextus

Nerita picea

Isognomon incisum

I. costellatum

Chama iostoma

Drupa ricina

Dolabella varigata

Hydatina amplustre

Balcis aciculata

Diodora granifera

Conus ebraus

C. distans

C. leopardus

C. Crustaceans

Metapograpsus messor

D. Echinoderms

Actinopyga mauritiana
A. obesa
Holothuria atra
H. fuscorubra
Stichopus tropicalis
Echinometra mathei
Tripneustes gratilla
Heterocentrotus mammilatus
Chondreocidaris gigantea
Linckia multiflora

E. Fishes

Acanthurus dussumieri
A. leucopareius
A. sandvicensis
Naso hexacanthus
Zebrasoma flavescens
Abudefduf abdominalis
Chromis leucurus
Dascyllus albisella
Pomacentrus jenkinsi
Chaetodon lunula
C. miliaris
C. ornatissimus
C. quadrimaculatus
C. unimaculatus
Kuhlia sandvicensis
K. taenuria
Zanclus canescens
Coris venusta
Gomphosus varius (juv.)
Thalassoma ballieui
T. duperreyi
Fistularia petimba
Cirripectus lineopunctatus
C. obscurus
Echnida nebulosa
Muraena pardalis
Gymnothorax eurostus
G. meleagris
G. undulatus

III. Upper beach area

A. Molluscs

Nerita picea
Neritina cariosa
Isognomon incisum
I. costellatum

B. Crustaceans

Metpograpsus messor
Palaemon debilis
Gammarus sp.

C. Fishes

Acanthurus sandvicensis

Kuhlia sandvicensis

K. taenuria

Cyprinus sp.

IV. Kapoho Bay

A. Coelenterates

Fungia scutaria

Montipora verucosa

B. Molluscs

Nerita picea

C. Fishes

Acanthurus dussumieri

A. leucopareius

A. sandvicensis

Pomacentrus jenkinsi

Rhinecanthus rectangulus

Gymnothorax meleagris

G. undulatus

D. Other

Chelonia mydas

8. Pathology

The search for pathological specimens concentrated on the Echinoderms, as this phylum represents the most abundant form of marine invertebrate life present in the intertidal zone.

The animals collected were examined in the field for external anomalies, autopsied, and checked for internal macroscopic abnormalities. Only animals showing such visible pathology were to be returned to the laboratory for further microscopic analysis. No animals, however, other than those listed, were found to have any deleterious pathology. The number of specimens examined is relative to the total population of each species.

Of the specimens listed, only one possible anomaly was discovered. One specimen of Holothuria fuscorubra had a dark reddish inflammation near the anterior portion of one respiratory tree branch. This sample was fixed and submitted for analysis; however, the cause of the inflammation has not yet been determined. This specimen was collected at station LAD.

A relatively high incidence of parasitism was observed among the populations of Linckia multiflora and Actinopyga obesa examined. In the case of the Hawaiian starfish Linckia, the comparatively large gastropod Hydatina amplustre had bored through the epidermis and was situated well within the lumen of the arm so that only the apex of its shell protruded from the swollen lip of epidermis. In all affected specimens, the parasite appeared to cause great damage to local tissues. Three of these animals were submitted for examination. The brown sea cucumber Actinopyga obesa was parasitized by the tiny gastropod Balcis cummingii. This small mollusc caused a similar epidermal reaction, however, it did not appear to cause such severe damage to the surrounding tissue.

No fish were collected for pathological examination; however, from general observation, no external anomalies were immediately evident on any of the fish observed.

Research in this field has shown that some human enteric pathogens may be pathogenic to freshwater and saltwater fish and invertebrates. Most bacterial pathogens of fish belong to the genera Aeromonas, Pseudomonas, and Vibrio (Bullock, 1964). Janssen, 1970, reports that Salmonella parathyphi B, S. typhosa, and Shigella dysenteriae have also been found to actively infect fish, and in some cases, occur naturally in their gastro-intestinal tract. Furthermore, there is evidence that Pseudomonas enteritis, P. aeruginosa, and Vibrio parahaemolyticus (the latter two being human pathogens,) are pathogenic to fish. In tests conducted on the east coast of the United States, these same bacteria were able to survive for two weeks in brackish water from the Chesapeake Bay, and for at least two months in ocean water from the Delaware coast (Janssen, 1970). These tests suggest that perhaps man has placed too much confidence in the ability of natural waters to destroy such bacteria in a short period of time.

ECHINODERMS EXAMINED FOR PATHOLOGY

1. Asteroidea

   Of 12 specimens of Linckia multiflora, 6 were parasitized.
   Of 1 specimen of Acanthastar planci, it proved normal.

2. Echinodea

   Of 12 specimens of Echinometra mathei, all proved normal.
   Of 8 specimens of Tripneustes gratilla, all proved normal.
   Of 3 specimens of Heterocentrotus mammilatus, all proved normal.
   Of 2 specimens of Chondreocidaris gigantea, all proved normal.

3. Holothuroidea

   Of 15 specimens of Actinopyga mauritiana, all proved normal.
   Of 10 specimens of Holothuria fuscorubra, one demonstrated pathology.

Of 8 specimens of *Actinopyga obesa*, 3 were parasitized.

Of 2 specimens of *Holothuria atra*, both proved normal.

Of 2 specimens of *Stichopus tropicalis*, both proved normal.

IV. CONCLUSIONS

From the data presented, it is apparent that the waters of the intertidal zone south of Kapoho Bay support a healthy, growing sub-littoral community. The observations, however, have also exposed certain conditions which have previously gone undetected, or have been ignored. These conditions, which will be further discussed in this chapter, include the surprising inability of Kapoho Bay's coral community to recolonize after its virtual sterilization by the lava flow of 1960, and the extent of pollution caused by untreated domestic waste in the vicinity of the housing subdivisions south of the Bay. The causes of these two related problems will clearly illustrate the dangerous trends associated with poor solid-waste management in the construction of shoreline housing developments.

The control station for the baseline study was chosen to the south of station SWE (marked C, Figure 5). The initial site was to be at least 1/4 mile south of Kapoho, near Kalapana Beach, where no housing areas were situated; however, this area proved inaccessible by land and was too dangerous to permit a shore entry by a diver.

Water quality properties at the control station were identical to those at station SWE. The substratum between C and SWE varied in depth between one foot and 12 feet, and was composed primarily of live coral (*Porites* sp. being the most dominant,) which covered approximately 80% of the bottom at any given point. All species of marine animal life recorded for the surge area were observed here in addition to *Carangoides ferdau*, *Mulloidichthys samoensis*, and *Chaetodon trifasciatus*. All surge area stations show similar characteristics, as they have not been influenced by large amounts of fresh water high in organic nutrients and coliform bacteria. In the Palm transect zone, however, a considerable amount of freshwater runoff does occur; yet only two dwellings presently occupied in this area actively contribute untreated wastes. Therefore, the fresh water present in this surge area has not contributed deleterious amounts of organic pollutants. This condition is expected to deteriorate as more dwellings are constructed.

One year after the 1960 lava flow had entered the sea at Kapoho, no coral growth was found in Kapoho Bay or in the vicinity of station LAG (which was formed by the flow itself), despite the fact that coral formations flourished along the shoreline south of the Bay (Townsley, et al. 1962). The dominant fauna which recolonized this area was, and is today, composed primarily of herbivorous fish and invertebrate populations. Today, almost 13 years later, the coral communities to the south of the Bay continue to grow, while the Lava transect zone and Kapoho Bay remain almost totally void of corals. Altogether, only four small heads of Montipora sp. and scattered groups of Fungia scutaria were observed in the Bay, and only one live Pocillopora meandrina and one Porites lobata were discovered at station LAG.

Several reasons for absence of coral growth, as stated in Edmondson, 1928, 1929, are: excessive fresh water, such as after heavy rainfall, causing significant alterations in salinity; excessive silt, sand, and debris; and temperature change. Dissolved oxygen and temperature are not considered to play an important role here. Corals adapted to shallow pools are particularly resistant to changes in the oxygen content of the water (Edmondson, 1929); and field observations have shown that temperatures at a given station remain relatively constant.

The following are considered to be the specific causes in the particular case of Kapoho, as observed during this research:

1. Turbid conditions produced by excessive bagasse and other debris washed ashore at station LAG, has suffocated coral growth at this station.

2. Excessive suspended matter produced by surf action and affected by strong currents creates overly turbid and abrasive conditions deleterious to the growth of coral in Kapoho Bay. Photosynthesis and productivity in the Bay are believed to be hindered by turbid conditions.

3. At stations LAA - LAD, excessive freshwater runoff and associated changes in salinity, combined with the suspected abundance of nitrate and phosphate nutrients from the seepage of raw sewage, have fostered the extensive growth of filamentous algae on the substratum to the extent that no coral growth is possible. Only at station LAD is a small segment of the once-living coral reef of Kapoho Bay visible, and its remains are blanketed with algal growth.

The discovery of a small area of fecal contamination in the upper beach and supra-surge areas has brought to light the inability of the State Health Department's bi-monthly bacterial tests to monitor environmental changes over the entire housing development. Of particular concern are those pools having a fecal coliform count of greater than 940/100 ml, specifically stations CRQ, SWA, GUB, GUG, and GUP. These five polluted pools are grouped together along the southeastern boundary of the housing area (Figure 5). The primary source of the raw sewage entering these stations is probably from one or more of six dwellings (marked ▲ on Figure 4) which were occupied during the three months of research. Other contributing factors, such as the age, type and condition of the cesspools, and the approximate rate of waste disposal, were not obtained.

The dangers presented by such organic waste pollution affect both marine life (see pages 27-28) and man. Tidal and brackish pools at Kapoho provide a natural playground for children. Many local residents collect shellfish and fish for consumption from these pools. Bacterial analysis of water samples has proven the ease with which domestic wastes diffuse into nearby waters through the lava rock. The possibility of acquiring a serious infection through open wounds, ingestion of water, or by eating uncooked or steamed fish and shellfish contaminated with enteric pathogens, must not be overlooked in such circumstances. While the author was conducting field studies at station GUG, his foot became infected and required treatment with Ampicillin.

Without appropriate action by the proper State and County offices, the pollution of the intertidal zone at Kapoho should be expected to continue unimpeded as it has done in the past. Prompt attention must be afforded this problem before further construction is initiated, as only 82 of the more than 300 subdivisions currently have dwellings erected on them.

It is hoped that the results of this preliminary research project will promote further studies of the problems associated with growth and development of shoreline housing projects and their effect on the neighboring marine and freshwater ecosystems. For the protection of the intertidal marine communities and of the human inhabitants of the coastal area, it is strongly suggested that research be initiated in the following:

1. Improved methods of solid-waste disposal for the Kapoho Beach Lot and Vacationland homes.

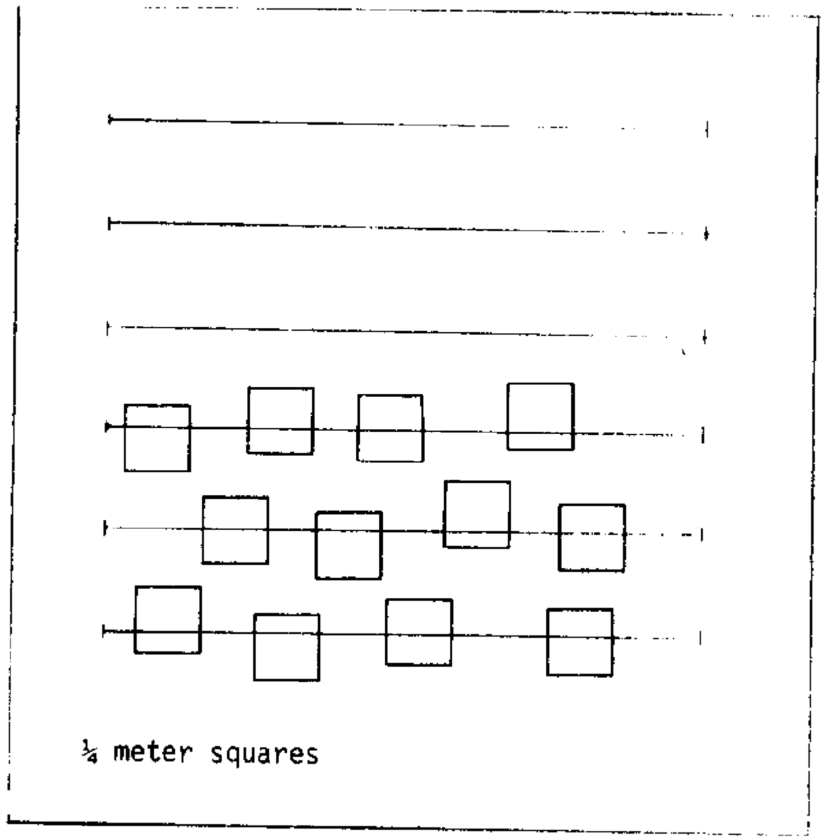
2. Education of the local residents on the problems associated with waste contamination of natural waters and of the marine life therein.

3. More frequent monitoring of environmental changes within the residential areas by State and County Health Department personnel, and coordinated and precise follow-up research into areas of below-acceptable minimums.

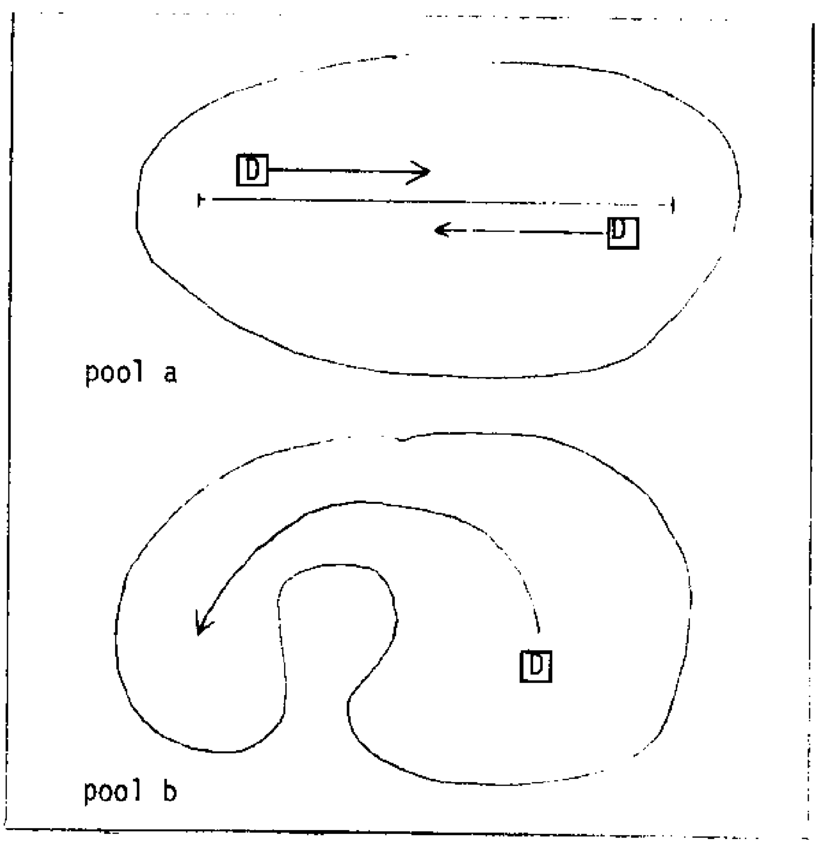
4. In-depth research of the ecology of the intertidal zone, including examination of phyto- and zooplankton productivity and nitrate/phosphate nutrient balances, over a long period of time to assess and differentiate natural and man-induced changes.

5. Detailed analysis of pathology in vertebrate populations.

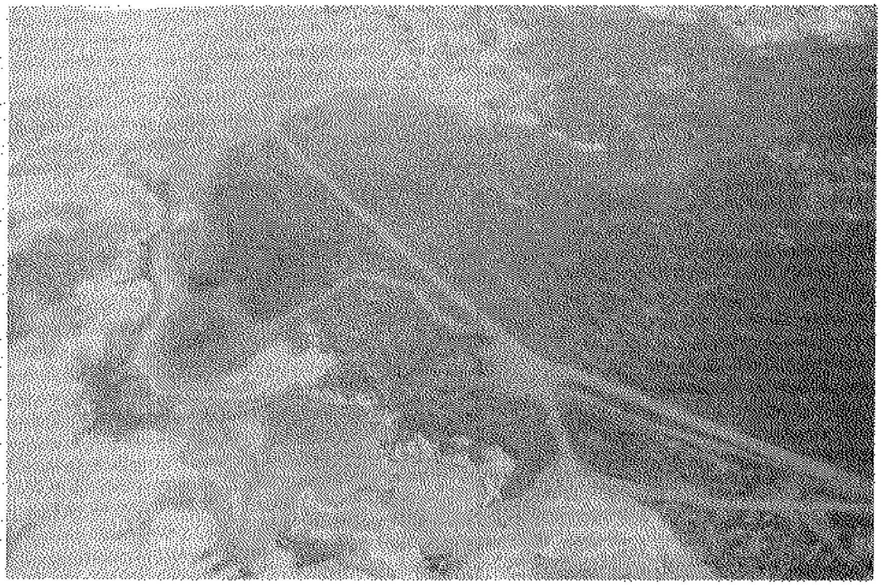
V. APPENDIX



Invertebrate transect methods

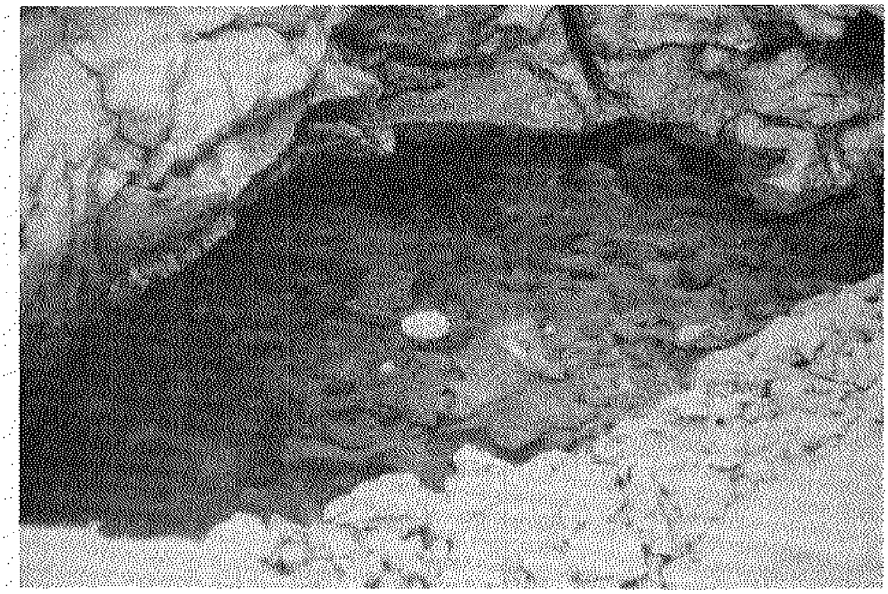


Vertebrate transect methods

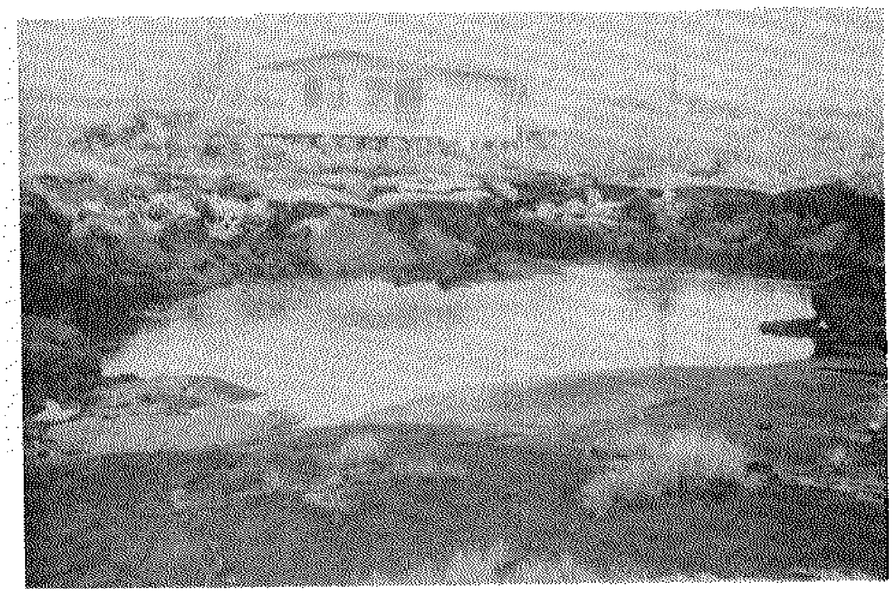


The 1960 lava flow (Lava zone). Pool in foreground (stn. LAD) was studied in 1961 by Townsley, et al. Note quantity of bagasse which has washed ashore.

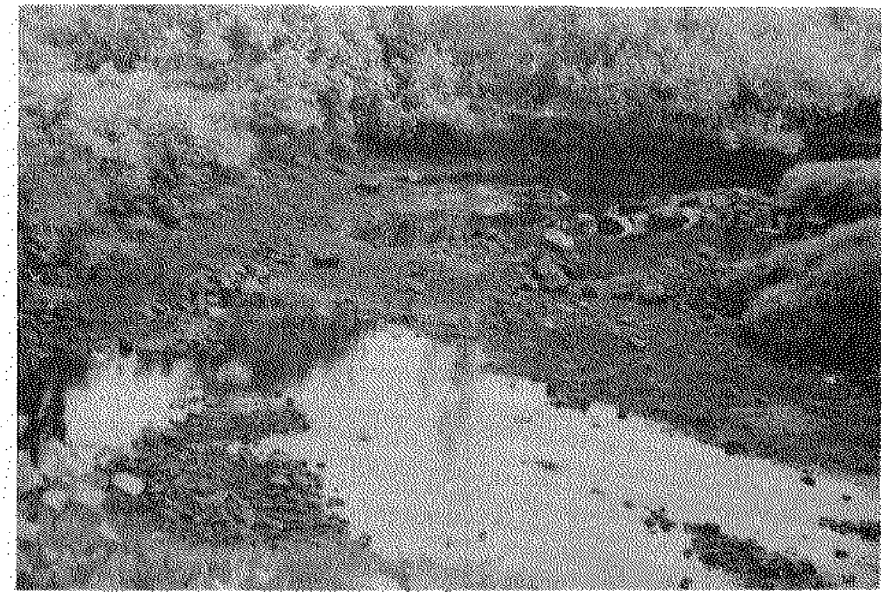
Station GUD is located in the supra-surge area. As it is open to tidal ebb and flow, it is free of detectable waste pollution. All species of animals listed for this area may be found here.



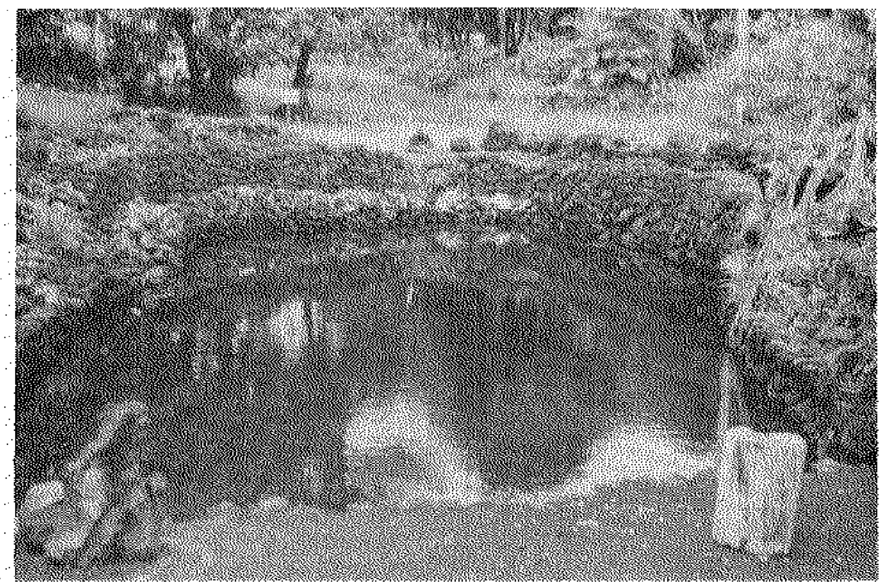
Station GUG, which is located in the supra-surge area, is shallow, stagnant, and can be considered polluted.



Note station GUB's proximity to the vacant dwelling. Also located in the supra-surge area, this pool is contaminated with fecal coliform bacteria.



Station GUP at low tide. This upper beach area pool, adjacent to two occupied homes, is also polluted.



Station LAP is an example of an artificial pool stocked with open ocean species. Despite a low salinity of 5.6 °/₀₀, two active juvenile *Caranx* sp. were observed here.

OBSERVED WATER QUALITY DATA

KAPOHO INTERTIDAL ZONE

CROSSETT TRANSECT ZONE

	stations								
	CRQ	CRR	CRS	CRT	CRU	CRW	CRX	CRY	CRZ
temperature °C	30.7	31.2	30.7	33.5	27.0	33.0	31.5	30.3	30.8
salinity °/₀₀	9.8	6.9	12.7	10.7	8.2	6.1	11.5	5.8	11.5
pH	7.4	7.3	7.1	7.2	7.3	7.3	7.3	7.1	7.3
dissolved oxygen gm/l	7.6	-	6.6	7.0	4.8	-	7.6	-	-
turbidity meters	1/2	1/2	1/4	1/2	1/2	-	-	-	-
Coliform count fecal/100ml H_2O	1,700	170	130	330	70	-	70	50	90

OBSERVED WATER QUALITY DATA

KAPOHO INTERTIDAL ZONE

SWORD TRANSECT ZONE

	stations						
	SWA	SWB	SWC	SWD	SWE	SWF	SWG
temperature °C	27.5	27.9	28.0	25.8	26.3	27.1	28.0
salinity °/₀₀	16.5	27.0	34.0	35.2	34.3	28.0	14.2
pH	7.4	6.9	8.1	8.1	8.0	7.9	6.9
dissolved oxygen gm/l	7.0	5.6	8.4	7.4	7.8	6.8	6.5
turbidity meters	5	7	8	8	clr	7	5
Coliform count fecal/100ml H_2O	940	-	-	-	-	-	20

OBSERVED WATER QUALITY DATA
KAPOHO INTERTIDAL ZONE

GUAVA TRANSECT ZONE

stations

	GUA	GUB	GUC	GUD	GUF	GUG	GUH	GUP
temperature °C	27.8	29.2	26.0	26.0	25.0	27.4	25.0	28.5
salinity °/₀₀	8.4	13.5	17.5	32.0	32.0	17.5	32.0	13.5
pH	7.8	7.3	7.5	8.1	8.2	8.6	-	6.9
dissolved oxygen gm/l	3.8	4.7	4.8	8.1	8.3	4.8	>10	4.8
turbidity meters	3	3	6	clr	clr	6	5	1/2
Coliform count fecal/100ml H_2O	330	1,400	-	-	-	1,100	-	2,200

OBSERVED WATER QUALITY DATA
KAPOHO INTERTIDAL ZONE

PALM TRANSECT ZONE

stations

	PAA	PAB	PAC	PAD	PAP
temperature °C	26.5	25.0	26.0	25.0	28.1
salinity °/₀₀	11.0	28.0	23.0	31.0	5.1
pH	7.8	8.3	8.3	8.4	8.0
dissolved oxygen gm/l	5.8	9.8	9.6	9.7	5.0
turbidity meters	-	-	5	5	-
Coliform count fecal/100ml H_2O	170	-	50	-	-

OBSERVED WATER QUALITY DATA
KAPOHO INTERTIDAL ZONE

KAPOHO BAY

stations

	-	-	-	-	BAA	BAB	BAC	-	-	-	-
temperature °C					26.4	25.8	25.0				
salinity °/oo					30.0	29.5	33.1				
pH					7.3	7.4	6.5				
dissolved oxygen gm/l					8.5	8.4	>10				
turbidity meters					3	4	5				
Coliform count fecal/100ml H_2O					490	50	-				

OBSERVED WATER QUALITY DATA
KAPOHO INTERTIDAL ZONE

LAVA TRANSECT ZONE

stations

	LAA	LAB	LAC	LAD	LAE	LAF	LAG	LAH	LAI	LAP	LAS
temperature °C	26.8	27.5	27.7	27.0	25.0	25.0	26.0	26.0	27.0	27.6	29.1
salinity °/oo	19.1	7.7	11.5	16.7	31.0	31.0	32.0	32.0	18.1	5.6	6.6
pH	8.3	8.6	8.5	8.3	8.5	8.5	8.3	8.3	7.7	7.6	6.9
dissolved oxygen gm/l	7.9	7.5	7.0	7.1	>10	>10	9.1	9.0	5.6	5.0	6.1
turbidity meters	7	7	9	8	4	4	7	7	6	5	-
Coliform count fecal/100ml H_2O	70	230	20	-	-	-	-	-	50	170	-

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