COMMUNITY STRUCTURE OF FISH AND MACROBENTHOS AT SELECTED SITES FRONTING SAND ISLAND, O‘AHU, IN RELATION TO THE SAND ISLAND DEEP OCEAN OUTFALL, YEAR 3—1992

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Special Report 01.29:93

January 1993

PREPARED FOR

City and County of Honolulu
Department of Public Works

Project Completion Report
for
“The Assessment of the Impact of Ocean Outfalls on the Marine Environment off O‘ahu, Hawai‘i”

Project No.: C-59390

Project Period: 1 November 1992–31 January 1993

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ABSTRACT

This report constitutes the third year of an annual monitoring (carried out on 21–22 December 1992 and 25 January 1993) of shallow marine communities inshore of the Sand Island deep ocean outfall. This quantitative monitoring effort focuses on benthic and fish community structure and is designed to detect changes in these communities. Marine communities offshore of Honolulu have received considerable perturbation over the last 100 years. Raw sewage was dumped in shallow water until 1978; point and non-point sources of pollution from both urban sources and industry continue. All of these disturbances may serve to obscure any possible impacts from the deep ocean outfall discharge. The marine communities show a considerable range in development that is probably related to past (historical) impacts. Stations have been sited to take advantage of these gradients. Analysis of the first year's data showed that there had been no statistically significant change in the biological measures (i.e., percent coral cover, number of coral species, number of invertebrate species, total number of invertebrates counted, number of fish species, total number of fishes counted, and the biomass of fishes present at each station) quantified in the study during that period. Hurricane Iniki which occurred in September 1992 impacted marine communities along the south shore of O‘ahu. Considerable damage was incurred by the coral communities especially at the westernmost study site. Despite the considerable impact of this storm, statistical analysis of the most recent data show that the changes which have occurred are not statistically significant.

INTRODUCTION

Purpose

In recent years controversy has arisen regarding the impact that sewage effluent from the Sand Island Wastewater Treatment Plant may have on inshore coral reef species. Much of the geographical area of concern in this study was impacted by the release of 3 m^3/sec (62 mgd) of raw sewage in 10 m of water off Sand Island from 1955 to 1977. Starting in 1978 sewage received advanced primary treatment and was released further offshore of Sand Island from a deep ocean outfall (67–73 m depth). Despite studies that demonstrated the recovery of inshore benthic communities once the shallow sewage stress was removed (e.g., Dollar 1979), concern continues over the possible impact that the release of sewage from the deep ocean outfall may be having in the shallow (< 20 m) marine communities fronting Honolulu and Sand Island. Accordingly, this study was undertaken commencing in 1990 in an attempt to quantitatively ascertain the impacts that may be occurring. This document presents the results of the third annual survey carried out in 1992.

Strategy

Marine environmental surveys are usually performed to evaluate the feasibility of an ecosystem response to specific proposed activities. Appropriate survey methodologies reflect the nature of the proposed action(s). An acute potential impact (as channel dredging) demands a survey designed to determine the route of least harm and the projected rate and degree of ecosystem recovery. Impacts that are more chronic or progressive require different strategies for measurement. Management of chronic stress to a marine ecosystem demands identification of system perturbations which exceed boundaries of natural fluctuations. Thus a thorough understanding of normal ecosystem variability is required in order to separate the impact signal from background "noise." Infrequent natural events may add considerably to the variability or background "noise" measured in a marine community. In September 1992 Hurricane Iniki struck the Hawaiian Islands and impacted some marine communities along O'ahu's south shore. This rare event has provided this study with information on the possible extreme of such natural impacts.

Rare storm events not withstanding, the potential impacts confronting the marine ecosystem offshore of Sand Island and Honolulu Harbor are most probably those associated with chronic or progressive stresses. Because of the proximity of the population center and industry, marine communities fronting Honolulu Harbor are subjected to a wide array of impacts not usually occurring in other Hawaiian coral communities. Thus a sampling strategy must attempt to separate impacts due to wastewater treatment plant effluent on coral reef communities located at some distance shoreward from a host of other perturbations occurring in the waters fronting Honolulu.

Honolulu Harbor is the primary commercial port for the State of Hawaii and has been so since before the turn of the century (Scott 1968). The harbor is the result of dredging what was originally the drainage basin of Nu'uanu Stream. This dredging commenced before 1900 and periodic maintenance dredging occurs up to the present time; up until about 1960 spoils were dropped just outside of the harbor generally to the east of the Honolulu Sewer Outfall. Besides shipping, the harbor is ringed with industry; pineapple canneries, gas and oil storage, and numerous other businesses are operating or have operated in the past. Storm drainage into the harbor and nearby Ke‘ehi Lagoon carries runoff from Honolulu’s streets and suburbs into the ocean. Pollution is well-known in the harbor and Cox and Gordon (1970) cite references describing these conditions as early as 1920. Sewage has been pumped into the ocean offshore of Kewalo and Sand Island since the 1930’s. These early inputs were all raw sewage released in water not exceeding 20 m deep. The actual point of release varied through time as different pipes were constructed and used. The multitude of perturbations that have occurred or are still occurring in shallow water (< 20 m) up until the construction of the present deep water outfall in 1978 may serve to obscure the impacts of the present discharge.

The waters fronting Sand Island into which the deep ocean outfall discharges may be considered in terms of gradients. There are numerous “gradients” due to point (storm drains, streams, etc.) and non-point inputs into Honolulu Harbor and environs from the above-mentioned activities. Because many of these inputs have been occurring for a considerable period of time, the species composition and functional relationships of the benthic and fish communities at any given location in the waters offshore of Honolulu are those that have evolved under the influence of these ongoing perturbations.

As noted above, if impacts are occurring in the shallow marine communities fronting Honolulu due to the deep ocean outfall, these are probably chronic in nature thus causing a slow decline in the communities so impacted. Gradients of “stress” or “impact” should be evident with distance from impact source(s). Thus to quantitatively define these impacts, one should monitor these communities through time in areas suspected of being impacted as well as in similar communities at varying distances away from the suspected source(s). This rationale has been used in developing the sampling strategy for this study.

MATERIALS AND METHODS

The quantitative sampling of macrofauna of marine communities presents a number of problems; many of these are related to the scale on which one wishes to quantitatively enumerate organism abundance. Marine communities in the waters fronting Sand Island may be spatially defined in a range on the order of a few hundred square centimeters (such as the community residing in a *Pocillopora meandrina* coral head) to major biotopes covering many hectares. Because considerable interest focuses on visually dominant corals, diurnally exposed macroinvertebrates, and fishes, we designed a sampling program to attempt to delineate changes that may be occurring in communities at this scale.

Three sites were selected for the monitoring of benthic and fish community response to possible sewage impacts. The approximate locations of these sites (shown in Fig. 1) are close to some stations used by Dollar (1979). The sites and the rationale for their selection are given below:

Site A (Kewalo Landfill) was utilized as a control area lying east of the present deep ocean outfall in about 16 m of water (Fig. 1). Prevailing currents create a westerly movement of sewage effluent (Dollar 1979) thus the shallow Kewalo Landfill area is probably not directly impacted. At this location, corals occur in areas of emergent limestone. Local coverage over short linear distances may exceed 30 percent. This station is in the vicinity of Dollar's (1979) Station 2.

Site B (Kalihi Channel) is located about 120 m east of the Kalihi Entrance channel in approximately 15 m of water. This station is about 900 m west of the bypass (old) outfall in an area heavily impacted by the old (1955–1977) shallow water discharge, and is very close to Dollar's (1979) Station 14. Again there is emergent limestone at this station but coral coverage is low (< 1%).

Site C (Reef Runway) is located in an area of complex limestone substratum, in water ranging from 7.5 to 12 m deep fronting Honolulu International Airport's Reef Runway. This station is close to Brock's (1986) station that was monitored quarterly in 1977–78 (AECOS, Inc. 1979) and again in 1986. It is close to Dollar's (1979) Station 19. This site was moderately impacted by the old shallow water sewage outfall (Dollar 1979).

At each site two transect lines have been permanently established using metal stakes and plastic coated no. 14 copper wire. Transects are 20 m in length and have an orientation perpendicular to shore. Two transects have been established at each location to provide some replication. Both sample approximately the same benthic community. On each transect there are five permanently marked locations (0 m, 5 m, 10 m, 15 m, and 20 m) for taking photographs of the benthic communities. Cover estimates were also made in the field with a 1 ∞ 1 m quadrat placed at the -1 to 0 m, 4 to 5 m, 9 to 10 m, 14 to 15 m, and 19 to 20 m marks on the transect line in each survey.

Fish abundance and diversity is often related to small-scale topographical relief over short linear distances. A long transect may bisect a number of topographical features (e.g., coral mounds, sand flats, and algal beds) thus sampling more than one community and obscuring distinctive features of individual communities. To alleviate this problem, a short transect (20 m in length) has proven adequate for sampling many Hawaiian benthic communities (see Brock 1982, Brock and Norris 1989).

Information collected at each transect location includes a visual assessment of fishes, benthic quadrats for cover estimates of sessile forms (algae, corals, and colonial invertebrates) and counts along the transect line for diurnally exposed motile macroinvertebrates. Fish censuses are conducted over a 20 ∞ 4 m corridor (the permanent transect line) and all fishes within this area to the water's surface are counted. A single diver equipped with SCUBA, and a slate and pencil enters the water, counts and notes all fishes in the prescribed area (method modified from Brock 1954). Besides counting the numbers of individuals of all fishes seen, the lengths of each is estimated; these length data are later used in the estimation of fish standing crop by linear regression techniques (Ricker 1975). Species specific regression coefficients have been developed over the last thirty years by the author and others at the University of Hawaii, Naval Undersea Center (see Evans 1974) and the Hawaii State Division of Aquatic Resources through capturing, weighing and measuring fishes; for many species the coefficients have been developed using sample sizes in excess of a hundred individuals. Two weeks were allowed to elapse from the time of station selection and marking to the time of the first fish census to reduce the bias caused by wary fishes. The same individual (R. Brock) performed all fish censuses to reduce bias.

Besides frightening wary fishes, other problems with the visual census technique include the underestimation of cryptic species such as moray eels (Family Muraenidae) and nocturnal species, e.g., squirrelfishes (Family Holocentridae), bigeyes or aweoweos (Family Priacanthidae), etc. This problem is compounded in areas of high relief and coral coverage that affords numerous shelter sites. Species lists and abundance estimates are more accurate for areas of low relief, although some fishes with cryptic habits or protective coloration (e.g., the nohus, Family Scorpaenidae; the flatfishes, Family Bothidae) might still be missed. Obviously the effectiveness of the visual census technique is reduced in turbid water and species of fishes which move quickly and/or are very numerous may be difficult to count. Additionally, bias related to the experience of the diver conducting counts should be considered in making comparisons between surveys. In spite of these drawbacks, the visual census technique probably provides the most accurate nondestructive assessment of diurnally active fishes presently available (Brock 1982).

A number of methods were utilized to quantitatively assess benthic communities at each station; these methods included the use of photographs taken at locations marked for repeated sampling through time (each covering 0.67 m^2) and 1 ∞ 1 m quadrats also placed at marked locations for repeated measurements. The photographs and quadrats were both used to estimate coverage of corals and other sessile forms. Photographs provide a permanent record from which to estimate coverage and were used in 1991 and 1992; the 1 ∞ 1 m quadrats were used for an "in the field" appraisal of coverage in the three surveys. Cover estimates from photographs and quadrats were all recorded as percent cover. Diurnally exposed motile macroinvertebrates greater than 2 cm in some dimension were censused in the same 4 ∞ 20 m corridor used in the fish counts.

If macrothalloid algae were encountered in the 1 ∞ 1 m quadrats or photographs, they were quantitatively recorded as percent cover. Emphasis was placed on those species that were visually dominant and no attempt was made to quantitatively assess the multitude of microalgal species that constitute the “algal turf” so characteristic of many coral reef habitats.

As requested by permit agencies, simple physical measurements were made at the three sites while in the field. Measurements were made of percent oxygen concentration and temperature with a YSI Model 57 Oxygen meter, salinity was taken with a hand held refractometer and a 12-inch secchi disk was used to determine water clarity.

Data were subjected to simple non-parametric statistical procedures provided in the SAS Institute statistical package (SAS Institute 1985). Non-parametric methods were used to avoid meeting requirements of normal distribution and homogeneity of variance in the data. Data analysis utilized the Kruskal-Wallis one-way analysis of variance which was used to discern statistically significant differences among ranked means for each transect site and sample period; this procedure is outlined by Siegel (1956) and Sokal and Rohlf (1981). The a posteriori Student-Neuman-Keuls multiple range test (SAS Institute, Inc. 1985) was also used to elucidate differences between locations.

During the course of the fieldwork, an effort was made to note any green sea turtles (a threatened species) within or near the study sites.

RESULTS

Field sampling was first undertaken on 27–29 December 1990. Station locations were selected and marked in November 1990 The permanent pins were deployed about a week later. Figure 1 presents the approximate locations of the three stations, each with a pair of transects; Figures 2, 3, and 4 are sketches showing the orientation of the permanent photographic quadrats on each transect line. The 1991 data were collected on 5–6 December 1991, and the 1992 information was taken on 21–22 December 1992 as well as on 25 January 1993 from the same locations.

Malfunction of a new Nikonos V camera caused the loss of all photographic quadrat data for all stations in the first (1990) field effort. Subsequently, the annual photography effort has been carried out by Mr. A. Muranaka (City and County of Honolulu). However, the 1990 visually assessed square meter quadrat data provided information on benthic coverage in this first annual effort. Subsequent surveys have used both photographic and quadrat methods to assess the benthic communities. It should be noted that the numbering of photoquadrats has changed from the 1991 and 1992 surveys but the locations are the same.

The results are presented below by station. All transects have an orientation that is perpendicular to shore.

Site A – Kewalo Landfill Station

This station is located 600 m offshore of the old Kewalo Landfill in water ranging from 17 to 18 m deep on a substratum dominated by limestone with moderate coral community development. The two transects are 35 m apart out of visual range of one another (see Fig. 2). Water clarity at this station is usually in the range from 15 to 20 m.

A summary of the data collected at Transect 1 in December 1992 is presented in Table 1. In the quadrat survey, six coral species were encountered having a mean estimated coverage of 18 percent; the dominant species are *Porites lobata* and *Pocillopora meandrina*. One algal species (*Amansia glomerata*) was noted in the quadrats. The macroinvertebrate census noted one cone shell (*Conus lividus*), two polychaetes (the Christmas tree worm - *Spirobrachus giganteus corniculatus* and the featherduster worm - *Sabellastarte sanctijosephi*), and three echinoderms (the long-spined sea urchin or wana - *Echinothrix diadema*, the sea star - *Linckia diplax,* and the boring sea urchin - *Echinostrephus aciculatum*). The results of the fish census carried out at Transect 1 are given in Appendix Table A. Table 2 presents the results of the photographic survey carried out on 3 August 1992. The mean coral coverage in the photographic survey was estimated to be 12.9 percent with *Porites lobata* being the dominant coral. Interestingly, in this survey an adult helmet shell (*Cassius cornuta*) was present in the 20 m quadrat occupying about 3 percent of the substratum.

In total 36 species of fishes and 312 individuals were encountered on Transect 1. The most common species include the yellowstripe goatfish or weke (*Mulloides flavolineatus*), the damselfishes (*Chromis ovalis* and *C. vanderbilti*) as well as the sleek unicornfish or kala holo (*Naso hexacanthus*). The standing crop of fishes on this transect was estimated to be 736 g/m^2 and the species contributing most heavily to this biomass were the weke (*Mulloides flavolineatus* - 78% of the total biomass) and the kala holo (*Naso hexacanthus* - 7% of the total biomass).

Transect 2 was also established offshore of the Kewalo Landfill approximately 35 m west of Transect 1 in water ranging from 17 to 18.2 m deep. Table 3 presents a summary of the biological information collected at this transect site. The quadrat survey noted two macroalgal species (*Amansia glomerata* and *Botryocladia scottsbergii*) and six coral species (*Porites lobata*, *P. compressa*, *Pocillopora meandrina*, *P. eydouxi*, *Leptastrea purpurea,* and *Montipora verrucosa*) having an average coverage of 20.7 percent. The largest contributor to this coverage was *Porites lobata*. The estimated coral coverage has decreased approximately 8 percent since the 1991 survey, probably due to Hurricane Iniki which impacted the Hawaiian Islands on 11 September 1992. There were numerous broken coral fragments in the quadrats and elsewhere. The invertebrate census counted two polychaete species (the Christmas tree worm - *Spirobranchus giganteus corniculatus* and the featherduster worm - *Sabellastarte sanctijopsephi*), the pearl oyster (*Pinctado marginifera*), hermit crab (*Aniculus strigatus*), and one sea urchin species (*Echinothrix diadema*). The photographic quadrat survey carried out on 3 August 1992 (before the hurricane) noted three algal species (mean coverage 2%), an unidentified red sponge, and four coral species with a mean coverage of 27.8 percent (Table 2).

The results of the fish census are presented in Appendix Table A. Twenty-six fish species were identified (240 individuals) on this transect; the most abundant species included the yellowstripe goatfish or weke (*Mulloides flavolineatus*) and the damselfish (*Chromis vanderbilti*). The standing crop of fishes was estimated to be 247 g/m^2. The species that contributed the most to this estimated weight was the yellowstripe goatfish or weke (*Mulloides flavolineatus* - 93% of the total biomass).

Site B – Kalihi Entrance Channel

Two transects (numbers 3 and 4) were established on a limestone substratum about 120 m east of the Kalihi Entrance Channel in 13.7 to 15 m of water. This station is located about 2.2 km seaward of Mokauea Island situated in Keʻehi Lagoon, and about 900 m west of the old outfall which is now used as an emergency bypass. Much of the substratum in the vicinity of this station is comprised of sand and rubble. An area of low emergent limestone approximately 60 m wide and 110 m in length with the long axis oriented perpendicular to shore is present. Transect 3 is located on the deeper end of this hard substratum area. Transect 4 parallels Transect 3 but is shoreward of this and approximately 8 m to the west (see Fig. 3). During the 1992 survey water clarity at this station ranged from 10 to 27 m during our visits. The lack of appropriate hard substratum necessitated establishing the two transects at this station on an "end to end" fashion relatively close to one another (8 m apart). Because of the close proximity, the fish censuses at these stations were carried out on both transects prior to any other data collection.

Transect 3 has an orientation perpendicular to shore on the limestone substratum in water 14.6 to 15 m deep. Table 4 presents a summary of the biological observations made at Transect 3. The quadrat survey noted two algal species (*Desmia hornemannii* and limu kohu or *Asparagopsis taxiformis* together having a mean coverage of 0.1%), the red encrusting sponge (*Spirastrella coccinea*), one soft coral (*Palythoa tuberculosa*), and four coral species (*Porites lobata, Pocillopora meandrina, Montipora verrucosa,* and *M. patula*) having a mean estimated coverage of 2 percent (a decrease of 2% over previous surveys). The invertebrate census noted one rock oyster (*Spondylus tenebrosus*), octopus or he‘e (*Octopus cyanea*), and three sea urchin species (*Echinostrephus aciculatum*, *Echinometra mathaei* and *Echinothrix diadema*) as well as the starfish (*Linckia diplax*). The photographic quadrat survey found an unidentified red sponge species and four coral species (*Porites lobata, Pocillopora meandrina, Montipora verrucosa?,* and *Fungia scutaria*) having a mean coverage of 4 percent.

The fish census (App. Table A) found 15 species, 33 individuals and an estimated standing crop of 30 g/m^2. The most abundant fishes at Transect 3 included the manybar goatfish or moano (*Parupeneus multifasciatus*) and the lei triggerfish or humuhumu lei (*Sufflamen bursa*). The fish species contributing heavily to the biomass on Transect 3 included a single tableboss or a‘awa (*Bodianus bilunulatus* making up 38% of the biomass), an orangebar surgeonfish or na‘ena‘e (*Acanthurus olivaceus* - 19% of the total), a rockmover (*Novaculichthys taeniourus* - 14%), and five humuhumu lei (*Sufflamen bursa* - 14% of the total weight).

Transect 4 also sampled the benthic and fish community present in the vicinity of the Kalihi Entrance Channel. As with the previous transect, Transect 4 sampled the limestone substratum at a depth ranging from 13.7 to 14 m. Table 5 presents a summary of the biological data collected on Transect 4. The quadrat survey noted two algal species (*Desmia hornemannii* and limu kohu or *Asparagopsis taxiformis*), the red sponge (*Spirastrella coccinea*), and four coral species (*Porites lobata, Pocillopora meandrina, Montipora verrucosa,* and *M. patula*). Coral coverage was estimated to be 3.2 percent and both *Porites lobata* as well as *Pocillopora meandrina* were the major contributors to this coverage. The invertebrate census noted one small cone shell (*Conus lividus*), four sea urchin species (the boring urchin - *Echinostrephus aciculatum,* the green urchin *Echinometra mathaei,* and long spined urchin or wana - *Echinothrix diadema*) as well as the starfish *Linckia diplax*. In the photographic quadrat survey an unidentified red sponge species was seen and two corals (*Porites lobata* and *Pocillopora meandrina*) having a mean coverage of 6.3 percent.

The fish census noted 27 individual fishes among 9 species (App. Table A). The most common fishes present on this transect include the twospot wrasse (*Cheilinus bimaculatus*) and the lei triggerfish or humuhumu lei (*Sufflamen bursa*). The standing crop of fishes on Transect 4 is estimated to be 14 g/m^2 and the important contributors to this biomass include a stripebelly puffer or keke (*Arthron hispidus* - 46% of the total) and the lei triggerfish or humuhumu lei (*Sufflamen bursa*) which contributed 30 percent of the total weight present at this transect site.

Site C – Reef Runway

Two transects (numbers 5 and 6) were established on limestone substratum offshore of the Honolulu International Airport Reef Runway. This station lies between 760 and 840 m seaward of the runway in water ranging from 9.1 to 11.6 m deep. The substratum of this area is a mosaic of emergent limestone spur and groove formations grading seaward into a series of low limestone mounds. The general orientation of the spur and groove formations is perpendicular to the shoreline and direction of usual wave impact. The spurs are from 5 to 40 m in width, 30 to 80 m in length and are spaced from 10 to 100 m apart. Sand is the dominant substratum in the intervening areas. The maximum topographical relief formed by these spurs is about 3.5 m. Just seaward of the spurs and grooves is a zone of low emergent limestone; these "patches" of hard bottom are from 5 ∞ 10 m to several hundred square meters in size; spacing of these limestone areas is between 10 to 50 m and sand is again found in the interven-ing areas. Corals are restricted to the areas of hard substratum. Water clarity at this station ranged from 7 to 20 m during our 1992 visits; usually the clarity did not exceed 12 m. Hurricane Iniki caused considerable damage to the benthic communities at Station C. A large (approximately 60 m in diameter) sand patch located between Transects 5 and 6 has disappeared and has been replaced by coral rubble. Much of the hard substratum on both transects was broken and the underlying limestone rock exposed and crevices and holes were filled with coral rubble. The result of this has been a change in the abundance of both invertebrates and fishes at this location.

Both transects were established on spurs or ridges of limestone (see Fig. 4). Transect 5 was established on a limestone ridge at a depth of 9.1 to 11 m. Table 6 presents the results of the biological survey carried out at Station 5. The quadrat survey noted the coralline algal species (*Porolithon onkodes*), two soft corals (*Anthelia edmondsoni* and *Palythoa tuberculosa*), and four coral species (*Porites lobata, P. compressa, Pocillopora meandrina,* and *Pavona duerdeni*) having a mean coverage of 0.4 percent. This coverage is down from the previous survey (2.1%). The invertebrate census found one hermit crab (*Calcinus herbstii*) and two sea urchin species, the green sea urchin (*Echinometra mathaei*) and the black sea urchin (*Tripneustes gratilla*). The photographic quadrat survey completed after Hurricane Iniki noted the encrusting coralline algae (*Porolithon onkodes*), soft coral (*Palythoa tuberculosa*), and two coral species (*Porites lobata* and *Pocillopora meandrina*) having a mean estimated coverage of 0.2 percent (down 2% from the previous year).

The fish census (App. Table A) counted 136 individuals amongst 23 species. The most common species included the manybar goatfish or moano (*Parupeneus multifasciatus*), the brown surgeonfish or ma'i'i'i (*Acanthurus nigrofuscus*), and the goldring surgeonfish or kole (*Ctenochaetus strigosus*). The standing crop of fishes on Transect 5 was estimated to be 69 g/m^2; the most important contributors to the estimated standing crop include the moano

(*Parupeneus multifasciatus* - 19% of the total), the kole (*Ctenochaetus strigosus* - 36% of the biomass), the ma‘i‘i‘i (*Acanthurus nigrofuscus* - 9%), and the black triggerfish or humuhumu ‘ele‘ele (*Melichthys niger* - 9%).

Transect 6 was established approximately 80 m seaward of Transect 5. The substratum at Transect 6 was similar to Transect 5 and is situated on a limestone spur that is about 40 m wide and 80 m long. Water depth at this site varies between 10.7 to 11.6 m. A summary of the biological observations made on Transect 6 is given in Table 7. The quadrat survey found two algal species (*Porolithon onkodes* and *Cladymenia pacifica* having a mean coverage of 6.5%), one soft coral (*Anthelia edmondsoni*), and six coral species (*Porites lobata, P. compressa, Pocillopora meandrina, Montipora patula, M. verrucosa,* and *Pavona duerdeni*) having a mean coverage of 3.1 percent. This coral coverage estimate is down 3.6 percent from last year's survey. The census of macroinvertebrates noted three species: the terebellid polychaete worm (*Loimia medusa*), the green sea urchin (*Echinometra mathaei*), and the black sea urchin (*Tripneustes gratilla).* The photo quadrat survey noted coralline algae (*Porolithon onkodes*) with a mean coverage of 15 percent as well as three coral species (*Porites compressa, P. lobata,* and *Pocillopora meandrina*) with a mean coverage of 5 percent.

The fish census found 247 individuals belonging to 36 species in the 4 ∞ 20 m census area. The most abundant fishes on Transect 6 included the damselfish (*Chromis vanderbilti*), the brown surgeonfish or ma‘i‘i‘i (*Acanthurus nigrofuscus*), the goldring surgeonfish or kole (*Ctenochaetus strigosus*), and the plankton feeding surgeonfish (*Acanthurus thompsoni*). The standing crop of fishes on this transect was estimated to be 108 g/m^2; the largest contributors to this biomass included the bullethead parrotfish or uhu (*Scarus sordidus* - 22% of the total), the goldring surgeonfish or kole (*Ctenochaetus strigosus* - 17%), the black triggerfish or humuhumu ‘ele‘ele (*Melichthys niger* - 11%), and the brown surgeonfish or ma‘i‘i‘i (*Acanthurus nigrofuscus* - 8%).

There were from one to three green sea turtles (*Chelonia mydas*) usually present at Transect 6 in the past. No green turtles were seen during the 1992 survey work in the vicinity of Transects 5 and 6. A short underwater reconnaissance of the usual resting area (a small ledge under a large *Porites lobata* colony) revealed that the resting site had been completely covered with coral rubble from the hurricane (as had most of the depressions in the surrounding area).

Physical measurements were made on the morning of 22 December 1992. These data are presented in Table 8. Little variation was noted in temperature (22.6 to 22.8°C), percent oxygen saturation (102 to 105%) or salinity (all 34‰) despite the fact that measurements for oxygen and temperature were made both at the surface and about 1 m above the bottom. In all cases the secchi disk measurements did not yield an extinction value; water clarity was such that the disk was still plainly visible on the bottom from the surface. As has been suggested previously, a better method of determining water clarity might be to collect water samples and measure turbidity with a nephalometer in the laboratory.

The biological data for all three surveys (1990, 1991, and 1992) are summarized as means for each transect in Table 9. The 1990 and 1991 data are from Brock (1992*a*, 1992*b*). Differences are apparent for some of the parameters between the three years. Some change is evident in the benthic measures (such as coral cover) between the 1991 and 1992 (pre- and post-hurricane) surveys and this is to be expected. Despite these changes the Kruskal-Wallis ANOVA shows that there are no statistically significant changes from the 1990 survey to the most recent 1992 field effort for the mean coral cover at a sample site ($P > 0.69$, df = 2, N.S.), mean number of coral species at each site ($P > 0.28$, df = 2, N.S.), mean number of invertebrate species on a transect ($P > 0.52$, df = 2, N.S.), mean number of individual invertebrates at each location ($P > 0.74$, df = 2, N.S.), mean number of fish species on a transect ($P > 0.36$, df = 2, N.S.), mean number of individual fish at a sample site ($P > 0.16$, df = 2, N.S.), and mean standing crop at a station ($P > 0.44$, df = 2, N.S.). The Student-Neuman-Keuls multiple range test likewise demonstrated that there are no statistically significant differences among these parameters between the six stations and three sample periods.

The biological parameters measured in the three surveys (i.e., number of coral species, percent cover, number of macroinvertebrate species, number of fish species, number of individual fish and biomass of fishes), point to the fact that the Kewalo Landfill site has the most diverse communities, followed by the Reef Runway. The least diverse appears to be the Kalihi Entrance Channel site; this ranking has not changed over the three surveys. The low biological diversity at the Kalihi Entrance Channel site is not surprising in view of the fact that this station was heavily impacted by the old shallow water outfall until 1978.

From a commercial fisheries standpoint, a number of important species have been encountered in the vicinity of the Kewalo Landfill transects and Reef Runway sites including goatfishes (weke - *Mulloides flavolineatus* and weke‘ula - *M. vanicolensis*), amberjack or kahala (*Seriola dumerili*), emperor or mu (*Monotaxis grandoculis*), uku (*Aprion virescens*), and the squirrelfish or menpachi (*Myripristes amaenus*).

DISCUSSION

Since their delineation in December 1990, the six transects have been visited on a number of occasions to insure that permanent markers are remaining in place, etc. During these visits reconnaissance surveys have been carried out in the areas surrounding the selected stations.

At a minimum, these qualitative surveys have covered about 4 hectares around each of the three sites. These qualitative observations suggest that the marine communities sampled at the three stations are representative of those found in the surrounding areas.

The working hypothesis is that all three study sites, being situated in relatively shallow water, are outside of the zone of influence of the present deep water outfall. However if impacts from the present deep ocean outfall are occurring to the shallow water coral reef areas shoreward of the outfall, our monitoring should be able to quantitatively discern these impacts. Because of bottom time constraints, potential dangers with deep diving and the fact that coral community development is usually greatest in water less than 30 m of depth, the placement of biological monitoring stations was restricted to waters 20 m or less in depth in this study. Monitoring the shallow water stations provides additional information regarding the recovery of these communities to the perturbation of raw sewage released from the old shallow water outfall that was terminated in 1977–78. Dollar's (1979) study showed that the Kewalo Landfill station was not directly impacted by the old outfall but the Kalihi Entrance Channel station was "acutely" perturbed and the station offshore of the Reef Runway received an "intermediate" level of disturbance. Additionally in the mid-1970's the reef runway was constructed which must have contributed to the disturbance of benthic communities at this station (Chapman 1979). The results of these impacts are still evident in the average coral cover estimates made at these stations: the mean coverage offshore of the Kalihi Entrance Channel is only 3 percent, at the Reef Runway station it is 4 percent, and offshore of the Kewalo Landfill it is 23 percent.

The shallow marine ecosystem fronting Sand Island and Honolulu has received considerable perturbation from human activity over the last 100 years. Among the disturbing influences was the disposal of raw sewage effluent in shallow water between the 1930's and 1977–78 when the deep ocean outfall became operational. In the period from 1955 through 1977 the shallow outfall released 3 m^3/sec (62 mgd). Dollar (1979) noted two distinct zones of impact to marine communities: the area of "acute" perturbation was an ellipse 500 m to the east and 1000 m to the west of the outfall. Outside of this area the impacts were evident in a decreasing gradient with distance from the outfall. The maximal extent of impact attributed to this sewage input was 1.9 km to the east and 5.8 km to the west of the outfall. The ellipsoid shape of the zone of influence was attributed to the predominant westerly direction of current flow.

The Kewalo Landfill station is 4.75 km east and inshore of the terminus of the deep ocean outfall, the Kalihi Entrance Channel station is about 2.1 km east and inshore of the terminus and the Reef Runway station is about 3.25 km inshore and west of the deep ocean outfall terminus (Fig. 1). Presumably the present outfall releases the sewage below the thermocline and little interaction occurs with the inshore biota. If however the material was carried into inshore waters, impacts to shallow marine communities would occur in those communities situated primarily to the west of the outfall based on Dollar's (1979) findings.

The Kewalo Landfill station served as a "control" site in this study. Despite the fact that coral coverage and fish community development is greater at this location, the Kewalo Landfill station has received perturbations in the past. The two transects (T-1 and T-2) that sample the Kewalo Landfill site are situated close to an old, non-operable sewage discharge pipe. Operations utilizing this pipe ceased sometime prior to 1955, and the pipe was probably used sometime in the 1940's (Mr. A. Muranaka, Oceanographic Team, Division of Wastewater Management, City and County of Honolulu). The development of Kewalo Basin and the entrance channel in the mid-1930's would have created considerable turbidity that probably impacted this site, some 200 m to the west. From the historical perspective, human induced perturbations have occurred in probably all marine communities situated in shallow waters fronting Honolulu over the last 100 years. The Kewalo Landfill site was selected as the "control" site for this study because of relatively diverse coral and fish communities present as well as its location well to the east of the present deep ocean outfall (presumably out of the zone of influence).

On 11 September 1992 the Hawaiian Islands were struck by Hurricane Iniki. The hurricane passed directly over Kaua‘i with sustained winds of 144 mph and gusts to 172 mph resulting in considerable damage to improvements and forests of that island and the west (leeward) coast of O‘ahu. To a lesser extent, high surf caused damage to marine communities along the south, east and west shores of O‘ahu, Kaua‘i, Maui, Lo(¯,a)na‘i and Hawai‘i; this damage was primarily to coral communities. In many areas a large amount of sand and other loose material was moved and/or advected out of the shallow areas (i.e., depths of less than 27 m) into deeper waters. On O‘ahu, storm waves emanating from the southeast were estimated to exceed 6 to 7 m in height and were breaking in water at least 20 m deep (personal observations).

Storm damage to benthic and fish communities is frequently patchy resulting in a mosaic of destruction (personal observations, Walsh 1983) and occasional storm events generating high surf are important factors in determining the structure of Hawaiian coral communities (Dollar 1982). Numerous studies have shown that storm generated surf may keep coral reefs in a non-equilibrium or sub-climax state (Grigg and Maragos 1974; Connell 1978; Woodley *et al.* 1981; Grigg 1983). Indeed, the large expanses of near-featureless lava or limestone substratum present around much of the Hawaiian Islands at depths less than 30 m attest to the force and frequency of these events (Brock and Norris 1989). These same wave forces also impact fish communities (Walsh 1983).

Hurricane Iniki caused damage to coral communities at all three study sites; the greatest impact occurred to the benthic communities at Station C (Reef Runway) where areas of the *Porolithon* covered substratum (up to 1 ∞ 2 m in area and up to 0.75 m in depth) were completely removed; other sites were entirely covered with coral rubble at scales from 10 m^2 to over 30 m^2. In some cases a "blanket" up to 0.5 m deep of rubble buried coral colonies or has killed the lower portions of larger colonies. The hurricane broke many coral colonies into pieces; some of these have survived where they have lodged into the substratum. These live fragments are responsible for the increase in the number of coral species seen in some quadrats between the pre- (1991) and post-hurricane (present) surveys. This same phenomenon (i.e., live fragments) has also served to lessen the decrease in coral cover encountered in some of the quadrats where coverage was low prior to the storm. Despite these large changes, many of the benthic components survived as shown in the results above. However, since Hawaiian corals are relatively slow growing, it will be years before the impact of this large storm will no longer be evident in the benthic communities of the study sites.

The hurricane also impacted the fish communities at the sample sites. Coral rubble deposited in depressions serves to lessen the rugosity of the submarine topography (i.e., shelter available to fishes). The loss of local shelter causes fishes to move and take up residence elsewhere; at Stations 5 and 6 (Reef Runway) where considerable rubble was present, many of the resident fishes (such as a school of emperor or mu (*Monotaxis grandoculis*) were no longer on Transect 6 but had moved about 100 m east to an area where the coral and benthic community remained relatively intact.

Despite the impact of Hurricane Iniki, the summary data in Table 9 which spans three years (December 1990 and December 1992) shows that there has been no statistically significant change in the biological parameters measured in this study. The most variable parameters through time have been the number of fish censused and the estimated standing crop of fish; these changes have been greatest at the Kewalo Landfill site. Relative to many other locations in the Hawaiian Islands, the fish community is well developed at the Kewalo Landfill station. The high standing crop estimates in 1990 and 1992 are much greater than found on most coral reefs; the maximum fish standing crop encountered on natural coral reefs is about 200 g/m^2 (Goldman and Talbot 1975; Brock *et al.* 1979). There are two explanations for the high biomass of fishes at the Kewalo Landfill site; these are (1) the shelter created by the old sewer pipe locally enhances the fish community and (2) chance encounters with roving predators or planktivorous and/or other schooling species during censuses.

Space and cover are important agents governing the distribution of coral reef fishes (Risk 1972; Sale 1977; Gladfelter and Gladfelter 1978; Brock *et al.* 1979; Ogden and Ebersole 1981; Anderson *et al.* 1981; Shulman *et al.* 1983; Shulman 1984; Eckert 1985; Walsh 1985; Alevizon *et al.* 1985). Similarly, the standing crop of fishes on a reef is correlated with the degree of vertical relief of the substratum. Thus Brock (1954) using visual techniques on Hawaiian reefs estimated the standing crop of fishes to range from 4 g/m^2 on sand flats to a maximum of 186 g/m^2 in an area of considerable vertical relief. If structural complexity or topographical relief is important to coral reef fish communities, then the addition of materials to increase this relief in otherwise barren areas may serve to locally increase the biomass of fish. The additional topographical relief is usually in the form of artificial reefs but any underwater construction activity (such as the deployment of a sewer line) will have a similar effect. The old sewer discharge pipe is set above the seafloor creating considerable local topographical relief (about 2 m high) in an area where the maximum natural vertical relief does not exceed 25 cm. The shelter and high topographical relief must foster greater development of the fish community (see Brock and Norris 1989).

Chance encounters with large roving predators (such as uku, *Aprion virescens*; mu, *Monotaxis grandoculis*; kahala, *Seriola dumerili*; papio, *Caranx melampygus* or *C. orthrogrammus*) or schools of planktivorous fishes (opelu, *Decapterus macarellus*; kala holo, *Naso hexacanthus*; kala lolo, *N. brevirostris*; lauwiliwili, *Chaetodon miliaris*; mamo, *Abudefduf abdominalis*) or other schooling species (weke, *Mulloides flavolineatus*) may greatly increase the counts and biomass of a particular transect. The presence of the sewer pipe serves to focus numerous predators and schooling fishes in the vicinity of the two transects at the Kewalo Landfill site and an encounter with these fishes during a census will result in high biomass estimates. Chance encounters with a small school of mu or emperor (*Monotaxis grandoculis*) at Station 6 (Reef Runway) accounts for 51 percent of the biomass at that station in 1990; on Transect 2 (Kewalo Landfill) the two planktivorous surgeonfishes (kala holo and kala lolo - *Naso hexacanthus* and *N. brevirostris*) accounted for 40 percent of the biomass and the two roving predators the kahala (*Seriola dumerili*) as well as the papio (*Caranx orthogrammus*) contributed 21 percent to the biomass estimate for that transect in 1990. In 1991 these planktivorous surgeonfishes and some predators were present around Transects 1 and 2 at the Kewalo Landfill site but did not enter the actual census area while the counts were proceeding, thus do not appear in the data. In 1992 the large school of yellowstripe goatfish or weke (*Mulloides flavolineatus*) that are resident to the old sewer pipe made up 78 percent of the biomass of Transect 1 and 93 percent of the standing crop present on Transect 2.

Making biological measurements underwater can often be a time-consuming process; use of the photographic technique lessens bottom time in measuring coral and other benthic species coverage. However as noted by Brock (1992*b*) inspection of the results of the coral coverage data from visual appraisal of quadrats in the field relative to the data from the photographic method points out several things. First, mean coral coverage estimates are in reasonable agreement by either method and the regression of visual versus the photographic coverage data show a statistically significant relationship. However, the photo quadrat technique does not discern small coral colonies or other small colonial benthic species such as the soft coral *Anthelia edmondsoni*; these are easily seen in the field using the visual assessment method. Both methods work but the technique selected should be done so keeping the objectives of the study in mind. This study will continue to use both methods.

In the present survey the photographs for Transects 1–4 were collected in August 1992 and for Transects 5 and 6 in late September. The hurricane struck on 11 September thus the photo quadrat data from stations 5 and 6 represent post-hurricane conditions. The visually assessed (field) quadrat data were all collected after the hurricane. Thus the photo and field quadrat data are not all directly comparable in the 1992 dataset.

The six transects selected for this study show a considerable range in community development that is probably related to past (historical) impacts. Separating the impact of advanced primary treated effluent released at depth from a multitude of other ongoing and historical impacts that have occurred in and to the shallow marine communities fronting Sand Island is difficult at best. The added natural disturbance of Hurricane Iniki on 11 September 1992 is an additional impact to these communities that varies tremendously with location. However, the siting of these permanent stations to capitalize on presumed gradient(s) of impact created by the variety of land derived sources as well as the repeated sampling of these permanent stations should allow delineation of any changes attributable to the Honolulu deep ocean outfall. The sampling of these stations over the first two years (1990–1991) shows that there was little change to the communities over that period of time suggesting that there was no quantitatively definable impact to shallow water benthic and fish communities due to the operation of the Honolulu deep ocean outfall. Many of the changes seen in the 1992 survey appear to be related to the natural storm event that occurred in September of that year.

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TABLE 1. SUMMARY OF BIOLOGICAL OBSERVATIONS MADE AT TRANSECT 1, OFFSHORE OF KEWALO LANDFILL (SITE A), 21 DECEMBER 1992

TABLE 2. SUMMARY OF RESULTS FOR PHOTO QUADRAT SURVEY, 1992

	PHOTO QUADRAT NUMBER				
SITE A: Transect 1	AAA1	AAA2	AAA3	AAA4	AAB1
(Sampled 3 August 1992)	(0 m)	(5 m)	(10 m)	(15 m)	(20 m)
Corals					
Porites lobata	16	9.5	2	16.5	1.4
P. compressa	1	2		0.8	
Pocillopora meandrina		2	3.4	3.9	6.1
Mollusks					
Cassius cornuta					2.8
Sand	3	2	9.5		7.3
Rubble	22		35	7.3	25.8
Hard Substratum	58	84.5	50.1	71.5	56.6

Mean Coral Coverage Transect 1 = 12.9%

SITE A: Transect 2	AAB2	AAB3	AAB4	AAC1	AAC2
(Sampled 3 August 1992)	(0 m)	(5 m)	(10 m)	(15 m)	(20 m)
Algae					
Corallina sp.	0.3				
Microdictyon japonicum?		3.4		3.6	
Porolithon onkodes			2.5		
Unidentified Red Sponge					
(probably *Spirastrella coccinea*)			0.4		
Corals					
Porites lobata	23	5.3	58.3	17.1	14
P. compressa			2.2	2.8	0.6
Pocillopora meandrina		3.6	2.8	5	2.8
P. eydouxi				1.7	
Sand	3.1	1.4			
Hard Substratum	73.6	86.3	33.8	69.8	82.6

Mean Coral Coverage Transect 2 = 27.8%

SITE B: Transect 3 (Sampled 4 August 1992)	BAA1 (0 m)	BAA2 (5 m)	BAA3 (10 m)	BAA4 (15 m)	BAB1 (20 m)
Unidentified Red Sponge					
(probably *Spirastrella coccinea*)	0.4	0.2	0.3	0.6	0.6
Corals					
Porites lobata		0.6	2.8	1.4	0.3
Pocillopora meandrina	3.6	5	0.1	5.3	
Fungia scutaria					0.6
Montipora verrucosa?					0.3
Sand	1.7	2.8	0.8	4.2	5
Rubble	15.4		9		
Hard Substratum	78.9	91.4	96	79.5	93.2

Mean Coral Coverage Transect 3 = 4%

SITE B: Transect 4 (Sampled 4 August 1992)	BAB2 (0 m)	BAB3 (5 m)	BAB4 (10 m)	BAC1 (15 m)	BAC2 (20 m)
Unidentified Red Sponge					
(probably *Spirastrella coccinea*)	0.6	0.6	0.6	0.6	0.6
Corals					
Porites lobata	1	7.3	0.6	0.6	3.6
Pocillopora meandrina	2.8	3.1	1.1	3.6	7.8
Sand	1.7		5	5.6	3.4
Rubble	69	31.9	5	31.4	11.5
Hard Substratum	24.9	57.1	87.7	58.2	73.1

Mean Coral Coverage Transect 4 = 6.3%

SITE C: Transect 5 (Sampled 25 September 1992)	CAB1 (0 m)	CAA4 (5 m)	CAA3 (10 m)	CAA2 (15 m)	CAA1 (20 m)
Algae					
Porolithon onkodes		4.8	12.9	14	9
Soft Corals					
Palythoa tuberculosa		0.3			0.7

Corals					
Porites lobata		0.1			0.3
Pocillopora meandrina					0.4
Sand3.1			1.4		
Rubble	40.3	25.8	31.9	25.5	
Hard Substratum	56.6	69	55.2	59.1	89.6
Mean Coral Coverage Transect 5 = 0.2%					

SITE C: Transect 6 (Sampled 25 September 1992)	CAB2 (0 m)	CAB3 (5 m)	CAB4 (10 m)	CAC1 (15 m)	CAC2 (20 m)
Algae					
Porolithon onkodes	20.2	10.1	0.6	27.7	16.8
Corals					
Porites lobata	13.7	0.6		6.7	3.1
P. compressa	0.6				
Pocillopora meandrina	0.3				
Rubble			99.4	5.9	43.4
Hard Substratum	65.2	89.3		59.7	36.7
Mean Coral Coverage Transect 6 = 5%					

NOTE: Presented in the body of the table are the percent cover of species and substrate types present for each transect.

TABLE 3. SUMMARY OF BIOLOGICAL OBSERVATIONS MADE AT TRANSECT 2, OFFSHORE OF KEWALO LANDFILL (SITE A), 21 DECEMBER 1992

APPENDIX TABLE A. RESULTS OF QUANTITATIVE VISUAL CENSUSES CONDUCTED AT SIX LOCATIONS OFFSHORE OF SAND ISLAND, O‘AHU, 21 DECEMBER 1992 (STATIONS 1–4) AND 25 JANUARY 1993 (STATIONS 5 AND 6)

	TRANSECT NUMBER					
FAMILY AND SPECIES	1	2	3	4	5	6
MURAENIDAE						
Gymnothorax undulatus	1					
G. meleagris			1			
G. eurostus	1					
G. petelli			1			
AULOSTOMIDAE						
Aulostomus chinensis		1				1
SCORPAENIDAE						
Scorpaenopsis diabolus	1					
SPARIDAE						
Monotaxis grandoculis						1
LUTJANIDAE						
Aprion virescens	1					
MULLIDAE						
Mulloides flavolineatus	109	37				
Parupeneus pleurostigma	2				1	
P. multifasciatus	8	5	8		12	12
P. cyclostomus	3					
CHAETODONTIDAE						
Forcipiger flavissimus	1	2			1	2
F. longirostris						1
Chaetodon multicinctus	2				1	
C. ornatissimus	2					
C. miliaris	6					
POMACANTHIDAE						
Centropyge potteri		3				2
POMACENTRIDAE						
Dascyllus albisella		1				9
Abudefduf abdominalis	9					
Plectroglyphidodon johnstonianus	1	1				
Chromis vanderbilti	29	69		4	1	26
C. hanui					2	9
C. ovalis	27					8
C. verator	4					
C. agilis						9
Stegastes fasciolatus					3	2
CIRRHITIDAE						
Paracirrhitus arcatus	4	11	2	1	1	
Cirrhitops fasciatus		1			1	
Cirrhitus pinnulatus						1

LABRIDAE						
Labroides phthirophagus						2
Cheilio inermis						1
Bodianus bilunulatus	1		1			
Cheilinus bimaculatus			1	12		
C. rhodochrous						1
Pseudocheilinus octotaenia	3	1				1
P. tetrataenia	2					
Thalassoma duperrey	16	4			4	5
T. ballieui	1	1				1
Gomphosus varius					3	7
Coris gaimard	2		1			
Pseudojuloides cerasinus	4	5	3			1
Stethojulis balteata	1				3	1
Novaculichthys taeniourus			1			
SCARIDAE						
Calotomus carolinus						1
Scarus sordidus					4	19
S. psittacus					1	3
S. rubroviolaceus	1					
BLENNIIDAE						
Cirripectus variolosus						1
ACANTHURIDAE						
Acanthurus nigrofuscus	12		2	1	24	30
A. nigroris					5	5
A. thompsoni						26
A. olivaceus	1		1			
Ctenochaetus strigosus					56	48
Zebrasoma flavescens	3	1				
Naso lituratus	3				1	
N. hexacanthus	43					
ZANCLIDAE						
Zanclus cornutus	2				4	1
BALISTIDAE						
Melichthys niger					3	6
Sufflamen bursa	2	5	5	5	3	1
MONACANTHIDAE						
Pervagor spilosoma	1	1				
P. melanocephalus						1
Cantherhines dumerili				1		
OSTRACIIDAE						
Ostracion meleagris			1		1	1
CANTHIGASTERIDAE						
Canthigaster jactator	3	3	4	1	1	1
C. cornata			1	1		
TETRAODONTIDAE						

Arothron hispidus		1		1		
Total No. of Species	36	19	15	9	23	36
Total No. of Individuals	312	153	33	27	136	247
Biomass (g/m^2)	736	247	30	14	69	108

NOTE: Each entry in the body of the table represents the total number of individuals of each species seen; totals are presented at the foot of the table along with an estimate of the standing crop (g/m^2) of fishes present at each location. All censuses were carried out by the author.