COMMUNITY STRUCTURE OF FISH AND MACROBENTHOS AT SELECTED SHALLOW WATER SITES IN RELATION TO THE BARBERS POINT DEEP OCEAN OUTFALL, 1991

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ABSTRACT

This report is the first of an annual series reporting on the monitoring of shallow marine communities inshore of the Barbers Point deep ocean outfall, located in 61 m of water, offshore of ‘Ewa Beach, O‘ahu. This quantitative monitoring effort focuses on benthic and fish community structure and is designed to detect changes in these communities. Field sampling carried out on 19–20 August 1991 established three study areas: a control site 2.2 km inshore and east of the outfall terminus and experimental sites about 1.6 km inshore of the terminus as well as about 2.9 km west and inshore of the terminus. Our preliminary baseline survey suggests that marine communities offshore of ‘Ewa Beach receive disturbance from a number of possible sources. Perhaps the single largest perturbation presently occurring to shallow marine communities is that of natural occasional wave impact which impedes benthic community development. This disturbance is greatest at the station inshore of the outfall terminus. This natural, and other possibly human-induced perturbations (from Honolulu and Pearl Harbor) may serve to obscure impacts (if any are occurring) caused by the deep ocean outfall. However the siting of stations to capitalize on presumed gradients of impact from human and natural sources, as well as the repeated sampling of these sites should allow delineation of change attributable to the deep ocean outfall.

INTRODUCTION
Purpose

The Honouliuli Wastewater Treatment Plant (WWTP), located in ʻEwa, Oʻahu, has been in operation since 1982 and currently releases approximately 24 mgd of primary treated sewage through a 2,670 m pipe at a depth of 61 m offshore of ʻEwa Beach, Oʻahu. In recent years controversy has arisen regarding the impact that sewage effluent from the Honouliuli Wastewater Treatment Plant may have on inshore coral reef species. Accordingly, this study was undertaken commencing in 1991 in an attempt to quantitatively ascertain any impacts that may be occurring. This document presents the results of the first annual survey.

STRATEGY

Marine environmental surveys are usually performed to evaluate the feasibility of, and 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 on 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."

The potential impacts confronting the marine ecosystem offshore of ʻEwa Beach are most probably those associated with chronic or progressive stresses. Because of the proximity of the population center and industry to the east, marine communities fronting ʻEwa Beach are probably subjected to a wide array of impacts. Thus a sampling strategy must attempt to separate impacts due to wastewater treatment plant effluent on coral reef communities located some distance shoreward of a host of other possible perturbations originating in the Honolulu and Pearl Harbor areas.

The waters fronting ʻEwa Beach 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 that occur to the east. Because many of these inputs have probably occurred 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 ʻEwa Beach are those that have evolved under the influence of these ongoing perturbations.

As noted above, if impacts to the shallow marine communities off 'Ewa Beach are occurring due to the deep ocean outfall, they are probably chronic in nature and would likely manifest themselves as 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 offshore of 'Ewa Beach 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, a sampling program was designed that attempted to delineate changes that may be occurring in communities at this scale.

Three sites were selected for monitoring benthic and fish community response to possible sewage impacts. The approximate locations of these sites are given in Figure 1. The sites and the rationale for their selection are given below:

Site BP-1, situated about 2.2 km inshore and to the east (northeast) of the deep ocean outfall terminus, was utilized as a control area. This station was located in water 14.9 to 15.8 m deep (Fig. 1). Although complex, prevailing currents move in an inshore and westerly direction approximately paralleling the shore (Fig. 34 in Laevastu et al. 1964). Therefore this station was probably outside (east) of any shoreward moving sewage plume. The substratum at this station was primarily limestone with a "patchy" distribution of corals. Coral coverage locally exceeded 70 percent. Occasionally, shallow sand-filled depressions were encountered.

Site BP-2 was located about 250 m east of the sewer line, approximately 1,500 m inshore and slightly east (northeast) of the discharge terminus in water 11.3 to 11.9 m deep. The substratum was a relatively featureless limestone flat with few corals present.

Site BP-3 was located about 3.3 km west and inshore (northwest) of the terminus of the sewage diffuser in water 16.5 to 16.8 m deep. The substratum at this station was a mix of rubble/sand and emergent limestone with corals. Coral coverage (about 25 percent) was greater at this station than at the previous location.

At each site two transect lines were permanently established using metal stakes and plastic coated no. 14 copper wire. Transects were 20 m long, and were oriented parallel to shore. Two transects were established at each location to provide some replication. Both sampled approximately the same benthic community. On each transect there were three permanently marked locations (0 m, 10 m, and 20 m) for taking photographs of the benthic communities. Four photo-quadrats (each 0.67 ∞ 1 m) were established at each of these three marked points on each transect line, covering a total area of 8.04 m^2 of substratum.

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., cross coral mounds, sand flats and algal beds), thereby sampling more than one community and obscuring distinctive features of individual communities. To alleviate this problem, a short transect (20 m long) has proven adequate for sampling many Hawaiian benthic communities (see Brock 1982; Brock and Norris 1989).

Information collected at each transect location included a visual assessment of fishes, benthic photo-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 were conducted over a 20 ∞ 4 m corridor (the permanent transect line) and all fishes within this area to the water’s surface were counted. A single diver equipped with SCUBA, slate, and pencil entered the water, counted and noted all fish in the prescribed area (method modified from Brock 1954). Besides counting the numbers of individuals of all fishes seen, the length of each was estimated; these length data were later used in the estimation of fish standing crop by use of 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, sample sizes were in excess of one hundred individuals. The same individual (R. Brock) performed all fish censuses to keep any bias relatively constant between counts and stations.

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 (each covering 0.67 m^2) taken at locations marked for repeated sampling through time. The photographs were used to estimate coverage of corals and other sessile forms. Photographs provide a permanent record from which to estimate coverage. Cover estimates from photographs were recorded as percent cover. Additionally, a visual appraisal was made of each quadrat in the field and notes were taken on the species present to help with later analysis of the photographs in the laboratory. Diurnally exposed motile macroinvertebrates greater than 2 cm in some dimension were counted in the same 4 ∞ 20 m corridor used in the fish counts.

If macrothalloid algae were encountered in the photo-quadrats, they were qualitatively 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” characteristic of many coral reef habitats.

At the request of permit agencies, simple physical measurements were made at the three sites. 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.

Oxygen measurements were taken approximately one meter below the water surface and one meter above the bottom.

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 undertaken on 19–20 August 1991. Station locations were selected, permanently marked, and sampled during this period. 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 photographic data were collected by Mr. A. Muranaka (Oceanographic Team, Division of Wastewater Management, City and County of Honolulu).

The results are presented below by station. All transects were oriented parallel to shore.

SITE BP-1 – Eastern Station

As noted above, Station BP-1, situated about 2.2 km inshore and to the east (northeast) of the deep ocean outfall terminus was utilized as a control area. This station was located in water 14.9 to 15.8 m deep (Fig. 1). The substratum at this station was limestone with corals overlaying it. Coral coverage locally exceeded 70 percent and the dominant species were *Porites lobata* and *P. compressa*. The corals formed low ridges ("spurs and grooves") that had an orientation perpendicular to shore. These ridges were 2 to 15 m wide and 4 to 50 m long; they were spaced 2 to 20 m apart. In the open areas between the ridges the substratum had a veneer of rubble and sand.

The two permanently marked transects (BP-1-A and BP-1-B) at this station had an orientation that paralleled the shoreline, were located 27 to 29 m apart, and were out of visual range of one another (see Fig. 2). Visibility at this station was usually in the range of 10 to 15 m.

A summary of the data collected on transect number BP-1-A in August 1991 is presented in Table 1. In the quadrat survey three algal species were encountered: the corallines *Hydrolithon reinboldii*, *Porolithon onkodes*, and *Pliocamium sandvicense;* three soft coral species *Anthelia edmondsoni, Zoanthus pacificus*, and *Palythoa tuberculosa*; two encrusting sponges *Spirastrella coccinea* and *Spongia oceania*; and three coral species *Porites lobata, P. compressa,* and *Montipora verrucosa*. Mean coral coverage was 23.3 percent (all species). *Porites lobata* was the dominant coral at this station. The macroinvertebrate census noted a triton trumpet shell (*Tritonalia tritonis*) approximately 33 cm long, three rock oysters (*Spondylus tenebrosus*), one black sea urchin (*Tripneustes gratilla*), and a black long-spine sea urchin (*Echinothrix diadema*). The results of the fish census are presented in Appendix Table A.

Forty-seven species (745 individuals) were counted in the census on transect number BP-1-A. The most abundant species included: blue-lined snapper or taape (*Lutjanus kasmira*), damselfishes (*Chromis hanui and C. ovalis*), saddleback wrasse or hinalea lauwili (*Thalassoma duperrey*), brown surgeonfish or ma'i'i'i (*Acanthurus nigrofuscus*), goldring surgeonfish or kole (*Ctenochaetus strigosus*), and sleek unicornfish or kala holo (*Naso hexacanthus*). The standing crop of fishes was estimated to be 406 g/m^2. Species contributing heavily to this biomass included: blue-lined snapper or taape (*Lutjanus kasmira*), damselfish

(*Chromis ovalis*), saddleback wrasse or hinalea lauwili (*Thalassoma duperrey*), stareye parrotfish or ponuhunuhu (*Calotomus carolinus*), orangebar surgeonfish or na‘ena‘e (*Acanthurus olivaceus*), and goldring surgeonfish or kole (*Ctenochaetus strigosus*).

Transect BP-1-B was situated 27 to 29 m seaward of the first transect (BP-1-A). The substratum at BP-1-B was as described above. The results of the quantitative survey carried out on this transect are presented in Table 2. The quadrat survey noted two coralline algal species *Hydrolithon reinboldii,* and *Porolithon onkodes*; the sponge *Spirastrella coccinea*; two soft coral species *Anthelia edmondsoni* and *Zoanthus pacificus*; and three corals *Porites lobata, P. compressa,* and *Pocillopora meandrina*. Mean coral coverage at this transect site was 29.4 percent. The dominant coral species was *Porites lobata*. In the 4 ∞ 20 m census area two macroinvertebrate species were seen; one brown sea cucumber (*Bohadschia vitiensis*), and one black sea urchin (*Tripneustes gratilla*). The fish census noted 42 species (453 individuals) in the census area. The most common species present were: blue-lined snapper or taape (*Lutjanus kasmira*), damselfishes (*Chromis hanui* and *C. ovalis*), and goldring surgeonfish or kole (*Ctenochaetus strigosus*). The standing crop of fish was estimated to be 374 g/m^2. The species accounting for much of this estimated biomass were: blue-lined snapper or taape (*Lutjanus kasmira*), emperor or mu (*Monotaxis grandoculis*), and tableboss or a‘awa (*Bodianus bilunulatus*).

In the vicinity of station BP-1 the corals *Pocillopora meandrina, Pavona varians, P. duerdeni, Montipora patula* and *M. flabellata* were seen, as well as the undulated moray eel or puhi laumilo (*Gymnothorax undulatus*), and the wrasse (*Pseudocheilinus tetrataenia*).

SITE BP-2 – Adjacent to the Outfall Pipe

Two transects were established at this site to sample the benthic and fish communities adjacent to the shallow portion of the Barbers Point outfall pipe. This site was located about 1.4 km from the shore in water 11.3 to 11.9 m deep (Fig. 1). The substratum at this location was a relatively flat and featureless limestone with little relief. Common corals included *Pocillopora meandrina* and *Porites lobata*. Other species seen included *Montipora verrilli* and *M. verrucosa*. Two of the common algal species in the area were limu kohu or *Asparagopsis taxiformis,* and the alga *Cladymenia pacifica,* although neither appeared in the quadrat survey.

The two permanently marked transect lines had an orientation that approximately paralleled the shoreline. The shoreward transect (BP-2-A) was situated in 11.3 m of water (Fig. 3). Table 3 presents a summary of the quantitative study made on transect BP-2-A. The quadrat survey noted five algal species; *Desmia hornemannii, Pliocamium sandvicense, Halimeda opuntia, Sphacelaria furcigera,* and *Polysiphonia* sp.; three sponge species *Aplysilla violacea, Spirastrella coccinea* and *Spongia oceania*; one soft coral *Anthelia edmondsoni*; and three coral species *Montipora verrilli, Porites lobata,* and *Pocillopora meandrina*. Mean coral coverage at this station was estimated to be 3.6 percent, and the dominant species was *Porites lobata*. In the macroinvertebrate census the striped sea urchin (*Echinothrix calamaris*), black long-spine sea urchin (*E. diadema*), black sea urchin (*Tripneustes gratilla)*, green sea urchin (*Echinometra mathaei*), and rock boring sea urchin (*Echinostrephus aciculatum*), along with the cone shell (*Conus lividus*), and black encrusting sponge (*Spongia oceania*) were counted. The results of the fish census are presented in Appendix Table A.1. A total of ten fish species (21 individuals) were counted. The most common fishes present at BP-2-A were wrasse (*Cheilinus bimaculatus*) and saddleback wrasse or hinalea lauwili (*Thalassoma duperrey*). The biomass of fishes on this transect was estimated to be 7 g/m^2. The largest contributor to this standing crop was a single barred filefish or ‘o‘ili (*Cantherhines dumerili*).

Station BP-2-B was established at a distance varying from 17 to 26 m seaward of station BP-2-A (Fig. 3). Water depth at station BP-2-B ranged from 11.6 to 11.9 m and, at the previous station, the substratum was primarily a featureless limestone flat. Table 4 presents the results of the survey carried out at station BP-2-B. The quadrat survey noted three algal species *Desmia hornemannii, Sphacelaria furcigera,* and *Polysiphonia* sp.; two encrusting sponge species *Spirastrella coccinea,* and *Spongia oceania*; and three coral species *Porites lobata, Pocillopora meandrina,* and *Montipora verrucosa*. Corals were not an important component of the benthos at this location; mean coverage was estimated to be 2.7 percent. Noncolonial macroinvertebrates noted in the 4 ∞ 20 m transect included; ten boring sea urchins (*Echinostrephus aciculatum*), black sea urchin (*Tripneustes gratilla*), green sea urchin (*Echinometra mathaei*), and cone shell (*Conus miles*). The fish census noted six species of fishes (Appendix Table A.1) and 12 individual fishes. The most common fish on this transect was saddleback wrasse or hinalea lauwili (*Thalassoma duperrey*). Fish standing crop was estimated to be 2 g/m^2. Cornetfish (*Fistularia commersoni*) as well as smalltail wrasse (*Pseudojuloides cerasinus*) made up the majority of the biomass present.

The low numbers and standing crop of fishes present at BP-2-A and BP-2-B were probably related to the lack of local topographical relief affording shelter for fishes. Similarly, the relatively higher abundance of noncolonial macroinvertebrates was also probably related to the lack of shelter present.

In the vicinity of station BP-2 the coral *Pavona varians*, hebrew cone shell (*Conus ebreus*), juvenile hermit crab (*Dardanus* sp.), black damselfish or ‘alo‘ilo‘i (*Dascyllus albisella*), and belted wrasse or ‘omaka (*Stethojulis balteata*) were seen.

SITE BP-3 – Western Station

The western station was located about 3.3 km west and inshore of the Barbers Point terminus (Fig. 1). This station was situated approximately 1.6 km offshore of the Barbers Point Naval Air Station at a depth from 16.5 to 16.8 m. The substratum at this location was a mix of coral and rubble mounds or ridges separated by sand or flat limestone substratum. The ridges had an orientation approximately perpendicular to shore and were 2 to 15 m wide, 4 to 40 m long, and were up to 0.75 m in height. The ridges were spaced 3 to 10 m apart. Sandy areas in depressions 3 to 10 m wide, and up to about 30 m long were noted. Station BP-3-A was established in water ranging from 16.5 to 16.8 m deep and ran approximately parallel to shore. Station BP-3-B was about 38 m seaward at a depth of 16.5 m (Fig. 4). Visibility at this location was about 12 m at the time of sampling. However, secchi disc readings made on 2 October 1991 showed visibility to be greater at that time, exceeding 16.5 m (i.e., water depth at the site).

Table 5 presents the results of the quantitative survey carried out at BP-3-A. The quadrat survey (locations given in Fig. 4) noted three algal species *Tolypiocladia glomerulata, Hydrolithon reinboldi,* and *Porolithon onkodes*; two encrusting sponge species *Spirastrella coccinea,* and *Spongia oceania*; and four coral species *Porites lobata, P. compressa, Pocillopora meandrina,* and *Montipora verrucosa*. Mean coral coverage at this location was estimated to be 8 percent. *Porites lobata* was the dominant species. Eight macroinvertebrate species were counted, these included rock oyster (*Spondylus tenebrosus*), cushion starfish (*Culcita novaeguineae*), banded sea urchin (*Echinothrix calamaris*), black sea urchin or wana (*E. diadema*), green sea urchin (*Echinometra mathaei*), black sea urchin (*Tripneustes gratilla*), and slate pencil sea urchin (*Heterocentrotus mammillatus*). Interestingly, seven spiny lobsters or ‘ula were encountered in the transect area; one was approximately 1 kg in weight, four approximately 750 g in weight, and two were about 450 g. The results of the fish census at station BP-3-A are presented in Appendix Table A.1. There were 38 species of fishes (367 individuals) counted. The most abundant fish species were: manybar goatfish or moano (*Parupeneus multifasciatus*), black and white damselfish or ‘alo‘ilo‘i (*Dascyllus albisella*), saddleback wrasse or hinalea lauwili (*Thalassoma duperrey*), brown surgeonfish or ma‘i‘i‘i (*Acanthurus nigrofuscus*), blue lined surgeonfish or maiko (*Acanthurus nigroris*), and goldring surgeonfish or kole (*Ctenochaetus strigosus*). The standing crop of fishes was estimated to be 343 g/m^2. Species contributing most heavily to this biomass included: a single jack or ulua (*Caranx lugubris*), manybar goatfish or moano (*Parupeneus multifasciatus*), tableboss or a‘awa (*Bodianus bilunulatus*), spectacled parrotfish or uhu uliuli (*Scarus perspicillatus*), and orangebar surgeonfish or na‘ena‘e (*Acanthurus olivaceus*).

Transect BP-3-B was located approximately 38 m seaward of Transect BP-3-A (Fig. 4). Transect BP-3-B was oriented parallel to BP-3-A, and water depth was 16.5 m. The substratum at this station was as noted above. Table 6 presents the results of the quantitative survey carried out on transect BP-3-B. The quadrat survey noted two algal species *Pliocamium sandvicense* and *Porolithon onkodes*; two sponge species *Spirastrella coccinea* and *Spongia oceania*; and five coral species *Porites lobata, P. compressa, Pocillopora meandrina, Montipora verrucosa,* and *M. patula*. Coral coverage at this station was estimated to be 11.6 percent. Six species of macroinvertebrates were counted in the 4 ∞ 20 m area, these included rock oyster (*Spondylus tenebrosus*), octopus or he‘e (*Octopus cyanea*), slate pencil sea urchin (*Heterocentrotus mammillatus*), black sea urchin (*Tripneustes gratilla*), banded sea urchin (*Echinothrix calamaris*), and green sea urchin (*Echinometra mathaei*). The most abundant macroinvertebrate was the black sea urchin which may have been aggregated for spawning purposes.

Appendix Table A.1 presents the results of the fish census carried out on transect BP-3-B. A total of 30 species (187 individuals) were counted. The most abundant fishes at this location included: manybar goatfish or moano (*Parupeneus multifasciatus*), saddleback wrasse or hinalea lauwili (*Thalassoma duperrey)*, brown surgeonfish or ma‘i‘i‘i (*Acanthurus nigrofuscus*), blue-lined surgeonfish or maiko (*Acanthurus nigroris*), and orangebar surgeonfish or na‘ena‘e (*Acanthurus olivaceus*). The standing crop of fish on transect BP-3-B was estimated to be 121 g/m^2. The species contributing most heavily to this biomass were: the manybar goatfish or moano (*Parupeneus multifasciatus*), a single tableboss or a‘awa (*Bodianus bilunulatus*), and orangebar surgeonfish or na‘ena‘e (*Acanthurus olivaceus*).

In the vicinity of station BP-3 the corals *Fungia scutaria* and *Pavona varians,* as well as belted wrasse or ‘omaka (*Stethojulis balteata)*, brown moray eel or puhi paka (*Gymnothorax flavimarginatus*), and rock boring sea urchin (*Echinostrephus aciculatum*) were seen.

No green turtles (*Chelonia mydas*) were encountered at any of the transect sites, however individual turtles were commonly seen on the surface by the researcher while in transit from Honolulu Harbor to ‘Ewa Beach. Most individuals seen were juveniles (i.e., less than 80 cm straight line carapace length).

Physical measurements were made on the morning of 2 October 1991. These data are presented in Table 7. Little variation was noted in temperature (24.9 to 25.4°C), percent oxygen saturation (101 to 103%), or salinity (all 34‰) despite the fact that measurements for oxygen and temperature were made both at the water 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 on the bottom was still visible from the surface. A better method of determining water clarity would probably be to collect water samples and measure turbidity with a nephalometer in the laboratory.

The biological data for the 1991 survey are summarized in Table 8 as means for each transect. The biological parameters measured in this survey (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 both stations BP-1 (eastern) and BP-3 (western) exhibited greater species diversity than station BP-2 (adjacent to the Barbers Point outfall pipe). BP-2's low diversity was not surprising in view of the little topographical relief present at the station.

From a commercial fisheries standpoint, a number of important species were encountered at both stations BP-1 (eastern) and BP-3 (western) including the soldierfish or menpachi (*Myripristes amaenus*), goatfishes such as moano (*Parupeneus multifasciatus*), weke'ula (*Mulloides vanicolensis*), emperor or mu (*Monotaxis grandoculis*), jack or ulua (*Caranx lugubris*), and spiny lobster or 'ula (*Panulirus marginatus*).

DISCUSSION

The working hypothesis was that all three study sites, being situated in relatively shallow water, were outside of the zone of influence of the present Barbers Point deep ocean outfall. However, if the present outfall is having an impact on the shallow water coral reef areas shoreward of the outfall, our continuing monitoring should be able to quantitatively discern those 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 deep, the placement of biological monitoring stations was restricted to waters less than 20 m deep in this study.

Much of the geographical area of concern in this study has probably been impacted by both point and non-point sources of pollution for years. In general the nearshore currents parallel the shoreline and have a net westerly movement along the coast (Laevastu et al. 1964); thus stream and industrial inputs from Honolulu Harbor, Keehi Lagoon and Pearl Harbor, situated to the east, would be carried towards the area offshore of 'Ewa Beach. Also the old Honolulu sewer outfall, located 15 km to the east of the present study area, released 3 m^3/sec (62 mgd) of raw sewage in 10 m of water offshore of Sand Island from 1955 to 1977.

This effluent was undoubtedly diluted but probably advected primarily in a west-southwest direction.

Presumably the present Barbers Point outfall releases sewage below the thermocline and little interaction occurs with the inshore biota. If, however, effluent was carried into inshore waters, any impacts to shallow marine communities would probably occur in those communities situated primarily to the west of the outfall, if the information on nearshore currents is correct (see Laevastu et al. 1964; Bathen 1978). Therefore, the eastern station (BP-1) was viewed as a control while the station inshore and adjacent to the discharge pipe (BP-2), as well as the station to the west (BP-3), served as experimental sites.

The spatial separation of the stations precludes direct comparison of the data between them, and only one period of observation has been made on the coral and fish communities, therefore statistical treatment of the data is not appropriate at this point in time.

Relative to many other locations in the Hawaiian Islands the fish communities were well developed at both the eastern and western stations. The high standing crop estimates were much greater than those 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 noted at these two stations, these are: (1) the shelter created by the natural topographical relief attracts many fishes, locally enhancing the fish community, and (2) chance encounters with roving predators or planktivorous schooling species during censuses served to increase the biomass estimates.

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. 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 enhance the biomass of fish. Such manipulations are well-known and usually take the form of artificial reefs. Artificial reefs in Hawaiian waters may serve to increase fish standing crops in excess of 1 kg/m^2 (Brock and Norris 1989).

Chance encounters with large roving predators such as emperor or mu (*Monotaxis grandoculis*), and large jacks or ulua (*Caranx lugubris*), or schools of planktivorous fishes such as mackerel scad or opelu (*Decapterus macarellus*), sleek unicornfish or kala holo

(*Naso hexacanthus*), milletseed butterflyfish or lauwiliwili (*Chaetodon milaris*), sergeant major or mamo (*Abudefduf abdominalis*) may greatly increase counts and biomass on a particular transect. The presence of the natural topographical relief in the vicinity of the eastern and western stations served to focus numerous predators and planktivorous fishes in the vicinity of the transects at these locations. Many of these species have home ranges that are considerably larger than the area covered by our transects, making encounters during a census a haphazard event. The inclusion of these fishes in a census results in higher biomass estimates than would otherwise be obtained.

Schooling species such as the emperor or mu (*Monotaxis grandoculis)*, blue-lined snapper or taape (*Lutjanus kasmira*), and orangebar surgeonfish or na‘ena‘e (*Acanthurus olivaceus*) all contributed substantially to the standing crop on several transects. On transect BP-1-A, taape contributed 18 percent of the biomass and mu accounted for 15 percent. On transect BP-1-B, mu comprised 8 percent of the standing crop and on transect BP-3-A the na‘ena‘e made up 17 percent of the biomass. More solitary predators that were important to the estimated standing crop on transects included the jack or ulua (*Caranx lugubris*), and the tableboss or a‘awa (*Bodianus bilunulatus*). The a‘awa comprised 9 percent of the biomass on BP-1-B, 13 percent of the standing crop on BP-3-A, and 23 percent of the biomass on BP-3-B. The ulua was only encountered on transect BP-3-A where it accounted for 17 percent of the standing crop at that site.

The relatively scoured appearance of the substratum and poor coral development at station BP-2 suggests that this area may receive occasional wave impact. Physical disturbance from occasional storm surf is one of the most important parameters in determining the structure of Hawaiian coral communities (Dollar 1982). Numerous studies have shown that occasional storm generated surf may keep coral reefs in a non-equilibrial or sub-climax state (Grigg and Maragos 1974; Connell 1978; Woodley et al. 1981; Grigg 1983). The large expanses of nearly 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 impinge upon and impact fish communities (Walsh 1983).

The impact of storm waves may be quite localized leading to the mosaic of coral development encountered on many reefs (Connell 1978). Because Hawaiian corals are relatively slow growing, storm events need only occur infrequently (ca. 20–50 years) to be a major structuring force (Grigg 1983). Corals may provide the topographical relief and shelter necessary for fish community development.

Of the sites examined in this study, the coral and fish communities were well developed at the eastern (BP-1) and western (BP-3) stations. In contrast, they were poorly developed at the middle station (BP-2). The degree of coral (and fish) community development suggests that disturbance has been minimal at the eastern and western sites. The relatively open flat and featureless substratum at the middle station suggests that occasional wave impact and scour has retarded benthic community development at that site.

If the present sewage discharge from the Barbers Point deep ocean outfall was having a major impact on the communities at our permanent stations, there should have been evidence of dead or dying corals, etc. This preliminary "baseline" survey has not detected such an impact. However, the siting of these permanent stations to capitalize on presumed gradient(s) of impacts that may be created by the movement of sewage towards shore, and the repeated sampling of these sites should allow delineation of any changes that may be caused by Barbers Point deep ocean outfall.

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TABLE 1. SUMMARY OF BIOLOGICAL OBSERVATIONS MADE AT TRANSECT A (INSHORE) AT STATION BP-1, 20 AUGUST 1991

Location and Species	Quadrat Number			
I. QUADRAT SURVEY				
BP-1 at 0 m	**AAA-1**	**AAA-2**	**AAA-3**	**AAA-4**
Algae				
Hydrolithon reinboldii	13.2	1.7	4.2	9.2
Porolithon onkodes	0.8	0.8		
Soft Corals				
Zoanthus pacificus			0.3	
Anthelia edmondsoni	0.3			
Palythoa tuberculosa				1.7
Corals				
Porites lobata	12.6	45.4	69.4	31.4
P. compressa		2.2	1.4	
Montipora verrucosa			0.3	
Rubble		6.7		
Hard Substratum	73.1	43.2	24.4	57.7
BP-1 at 10 m	**AAB-1**	**AAB-2**	**AAB-3**	**AAB-4**
Algae				
Hydrolithon reinboldii	2.2	0.6	1.7	0.8
Porolithon onkodes	0.8		0.8	0.6
Sponge				
Spirastrella coccinea			0.1	
Corals				
Porites lobata	17.9	3.3	13.2	19.9
P. compressa	3.9	2.5	3.6	3.9
Sand	2.0	0.8	1.7	
Rubble	22.4	86.4	31.7	74.8
Hard Substratum	55.2	6.4	47.2	
BP-1 at 20 m	**AAC-1**	**AAC-2**	**AAC-3**	**AAC-4**
Algae				
Hydrolithon reinboldii	1.7	5.6	3.9	
Porolithon onkodes			0.6	
Pliocamium sandvicense			0.3	0.3
Sponge				
Spongia oceania	0.3	4.5	1.4	
Soft Coral				
Anthelia edmondsoni	1.1	0.6	1.1	0.8
Coral				

Porites lobata	5.6	8.7	27.5	7.3
Montipora verrucosa				0.1
Sand	0.3	6.7		0.6
Rubble	72.5	28.0	30.8	60.1
Hard Substratum	18.5	45.9	34.4	30.8

Mean Coral Coverage = 23.3%

TABLE 1.—*Continued*

Species	NUMBER
II. INVERTEBRATE CENSUS (4	
Phylum Mollusca	
Spondylus tenebrosus	3
Tritonalia tritonis	1
Phylum Echinodermata	
Echinothrix diadema	1
Trineustes gratilla	1
III. FISH CENSUS (4 ∞ 20 m)	
47 Species	
745 Individuals	
Estimated Standing Crop = 406 g/m^2	

NOTE: Results of the 8 m^2 quadrat sampling of the benthic community are presented in Part I, counts of diurnally exposed macroinvertebrates are given in Part II, and a summary of the fish census is given in Part III. Water depth = 14.9 m; mean coral coverage = 23.3 percent (quadrat method).

TABLE 2. SUMMARY OF BIOLOGICAL OBSERVATIONS MADE AT TRANSECT B (OFFSHORE) AT STATION BP-1, 20 AUGUST 1991

Location and Species	Quadrat Number			
I. QUADRAT SURVEY				
BP-1 at 0 m	**ABA-1**	**ABA-2**	**ABA-3**	**ABA-4**
Algae				
Hydrolithon reinboldii	2.2	14.0	12.6	8.1
Porolithon onkodes	0.6	1.1	0.6	0.3
Sponge				
Spirastrella coccinea	0.8	0.8		
Coral				
Porites lobata	27.7	15.4	19.3	57.1
P. compressa	8.1	13.7	10.4	
Rubble	36.7			3.1
Hard Substratum	23.9	55.0	57.1	31.4
BP-1 at 10 m	**ABB-1**	**ABB-2**	**ABB-3**	**ABB-4**
Soft Coral				
Anthelia edmondsoni	2.5	1.4	0.3	1.7
Zonanthus pacificus			0.6	
Coral				
Porites lobata	2.0	0.6	2.5	
P. compressa		2.2		
Sand	9.2	11.2	3.4	3.6
Rubble	86.3	75.6	93.2	94.7
Hard Substratum		9.0		
BP-1 at 20 m	**ABC-1**	**ABC-2**	**ABC-3**	**ABC-4**
Algae				
Hydrolithon reinboldii	11.5	7.8	5.0	4.2
Porolithon onkodes	0.6	2.2	1.1	1.4
Coral				
Porites lobata	42.0	37.5	38.9	50.7
P. compressa	5.0	2.8	10.9	5.9
Pocillopora meandrina		0.3		
Hard Substratum	40.9	49.4	44.1	37.8

Mean Coral Coverage = 29.4%

II. INVERTEBRATE CENSUS (4		NUMBER		

Phylum Echinodermata

Bohadschia vitiensis	1
Tripneustes gratilla	1

III. FISH CENSUS (4 ∞ 20 m)

42 Species
453 Individuals
Estimated Standing Crop = 374 g/m^2

NOTE: Results of the 8 m^2 quadrat sampling of the benthic community are presented in Part I, counts of diurnally exposed macroinvertebrates are given in Part II, and a summary of the fish census is given in Part III. Water depth = 15.8 m; mean coral coverage = 29.4 percent (quadrat method).

TABLE 3. SUMMARY OF BIOLOGICAL OBSERVATIONS MADE AT TRANSECT A (INSHORE) AT STATION BP-2, 19 AUGUST 1991

Location and Species	Quadrat Number			
I. QUADRAT SURVEY				
BP-2 at 0 m	**BAA-1**	**BAA-2**	**BAA-3**	**BAA-4**
Algae				
Desmia hornemannii	1.4	0.3		
Sponge				
Spongia oceania	0.6	0.4	0.3	0.1
Spirastrella coccinea		0.1		
Aplysilla violacea			1.5	
Soft Coral				
Anthelia edmondsoni				0.3
Coral				
Porites lobata	3.1	6.2	0.6	4.2
Pocillopora meandrina	0.3			
Montipora verrilli	0.1			
Sand	0.6	0.6	0.8	1.7
Hard Substratum	93.9	92.4	96.8	93.7
BP-2 at 10 m	**BAB-1**	**BAB-2**	**BAB-3**	**BAB-4**
Algae				
Desmia hornemannii	0.3		0.3	0.3
Pliocamium sandvicense		0.3	0.3	
Halimeda opuntia			0.3	
Sphacelaria furcigera				0.3
Sponge				
Spongia oceania	1.1			0.3
Spirastrella coccinea		0.1	0.3	
Coral				
Porites lobata	4.8	0.8	0.8	0.3
Pocillopora meandrina		1.1	0.8	0.8
Sand	2.8	2.8	2.2	1.1
Hard Substratum	91.0	94.9	95.0	96.9
BP-2 at 20 m	**BAC-1**	**BAC-2**	**BAC-3**	**BAC-4**
Algae				
Desmia hornemannii			0.3	
Pliocamium sandvicense	0.1		0.3	0.3
Sphacelaria furcigera	0.3			
Polysiphonia sp.	0.3	0.1		
Sponge				

Spongia oceania	0.6	0.3		0.8
Spirastrella coccinea	0.6			
Coral				
Porites lobata			0.3	0.3
Pocillopora meandrina	12.3	2.0	1.1	3.4
Sand	2.2	3.4	1.7	1.7
Hard Substratum	83.6	94.2	96.3	93.5

Mean Coral Coverage = 3.6%

TABLE 3.—*Continued*

Species	NUMBER
II. INVERTEBRATE CENSUS (4	
Phylum Mollusca	
Conus lividus	1
Phylum Echinodermata	
Echinothrix calamaris	3
E. diadema	1
Tripneustes gratilla	2
Echinostrephus aciculatum	2
Echinometra mathaei	7
III. FISH CENSUS (4 ∞ 20 m)	
10 Species	
21 Individuals	
Estimated Standing Crop = 7 g/m^2	

NOTE: Results of the 8 m^2 quadrat sampling of the benthic community are presented in Part I, counts of diurnally exposed macroinvertebrates are given in Part II, and a summary of the fish census is given in Part III. Water depth = 11.3 m; mean coral coverage = 3.6 percent (quadrat method).

TABLE 4. SUMMARY OF BIOLOGICAL OBSERVATIONS MADE AT TRANSECT B (OFFSHORE) AT STATION BP-2, 19 AUGUST 1991

Location and Species	Quadrat Number			
I. QUADRAT SURVEY				
BP-2 at 0 m	**BBA-1**	**BBA-2**	**BBA-3**	**BBA-4**
Algae				
Desmia hornemannii	0.3		0.3	
Polysiphonia sp.		0.1		
Sponge				
Spongia oceania	0.4		0.3	
Spirastrella coccinea	0.1	0.1	0.3	
Corals				
Porites lobata		0.3	1.1	0.6
Pocillopora meandrina		1.1		
Sand	3.4	1.7	6.4	2.8
Hard Substratum	95.8	96.7	91.6	96.6
BP-2 at 10 m	**BBB-1**	**BBB-2**	**BBB-3**	**BBB-4**
Algae				
Desmia hornemannii	0.3	0.3	0.1	
Sphacelaria furcigera	0.1			
Polysiphonia sp.	0.1	0.3	0.3	0.3
Sponge				
Spongia oceania				0.3
Spirastrella coccinea	0.3		0.1	
Corals				
Porites lobata	1.1	3.9	1.7	3.4
Pocillopora meandrina		1.7	6.2	3.9
Montipora verrucosa			0.3	
Sand	2.8	2.2	2.8	1.7
Hard Substratum	95.3	91.6	88.5	90.4
BP-2 at 20 m	**BBC-1**	**BBC-2**	**BBC-3**	**BBC-4**
Algae				
Desmia hornemannii		0.3		
Polysiphonia sp.	0.3		0.3	
Sponge				
Spongia oceania	0.3	0.3	0.6	0.1
Spirastrella coccinea				0.1
Corals				
Porites lobata	0.8	0.8	0.3	0.3
Pocillopora meandrina		2.5	2.5	
Montipora verrucosa		0.3		

Sand	1.7	1.1	1.1	2.2
Hard Substratum	96.9	94.7	95.2	7.3

Mean Coral Coverage = 2.7%

TABLE 4.—*Continued*

Species	Number
II. INVERTEBRATE CENSUS (4	NUMBER
Phylum Mollusca	
Conus miles	1
Phylum Echinodermata	
Echinostrephus aciculatum	10
Echinometra mathaei	3
Tripneustes gratilla	1

III. FISH CENSUS (4 ∞ 20 m)

III. Fish Census (4 x 20m)

6 Species

12 Individuals

Estimated Standing Crop = 2 g/m^2

NOTE: Results of the 8 m^2 quadrat sampling of the benthic community are presented in Part I, counts of diurnally exposed macroinvertebrates are given in Part II, and a summary of the fish census is given in Part III. Water depth from 11.6 to 11.9 m; mean coral coverage = 2.7 percent (quadrat method).

TABLE 5. SUMMARY OF BIOLOGICAL OBSERVATIONS MADE AT TRANSECT A (INSHORE) AT STATION BP-3, 19 AUGUST 1991

Location and Species	Quadrat Number			
I. QUADRAT SURVEY				
BP-3 at 0 m	**CAA-1**	**CAA-2**	**CAA-3**	**CAA-4**
Algae				
Tolypiocladia glomerulata	0.3			
Hydrolithon reinboldi	0.3	1.1		
Porolithon onkodes	0.8	0.6	0.8	0.3
Sponge				
Spirastrella coccinea	0.3		0.3	1.1
Spongia oceania	0.3			
Coral				
Porites lobata	11.8	7.3	5.6	2.5
Pocillopora meandrina	0.3	1.1		
Sand			11.8	
Rubble	37.3	46.2	50.4	76.8
Hard Substratum	48.6	43.7	31.1	19.3
BP-3 at 10 m	**CAB-1**	**CAB-2**	**CAB-3**	**CAB-4**
Algae				
Hydrolithon reinboldi			0.8	
Coral				
Porites lobata	0.3	0.3	0.3	0.3
P. compressa		0.6		
Pocillopora meandrina	1.1			0.6
Montipora verrucosa		0.3		
Sand	4.2	0.8	0.6	1.4
Rubble	94.4	98.0	98.3	97.7
BP-3 at 20 m	**CAC-1**	**CAC-2**	**CAC-3**	**CAC-4**
Algae				
Hydrolithon reinboldi	1.4	1.1	1.1	0.6
Porolithon onkodes	6.4	10.1	5.3	4.5
Sponge				
Spriastrella coccinea	0.1	0.4	0.1	0.1
Coral				
Porites lobata	23.8	13.7	7.8	17.9
Sand	0.3	2.8	2.5	
Rubble	5.6	31.4	45.4	29.4
Hard Substratum	62.4	40.5	37.8	47.5

Mean Coral Coverage = 8.0%

TABLE 5.—*Continued*

Species	Number
II. INVERTEBRATE CENSUS (4	
Phylum Mollusca	
Spondylus tenebrosus	3
Phylum Arthropoda	
Panulirus marginatus	7
Phylum Echinodermata	
Heterocentrotus mammillatus	10
Tripneustes gratilla	15
Echinothrix diadema	1
E. calamaris	1
Echinometra mathaei	11
Culcita novaeguineae	1
III. FISH CENSUS (4 ∞ 20 m)	
38 Species	
367 Individuals	
Estimated Standing Crop = 343 g/m^2	

NOTE: Results of the 8 m^2 quadrat sampling of the benthic community are presented in Part I, counts of diurnally exposed macroinvertebrates are given in Part II, and a summary of the fish census is given in Part III. Water depth ranged from 16.5 to 16.8 m; mean coral coverage = 8.0 percent (quadrat method).

TABLE 6. SUMMARY OF BIOLOGICAL OBSERVATIONS MADE AT TRANSECT B (OFFSHORE) AT STATION BP-3, 19 AUGUST 1991

Location and Species	Quadrat Number			
I. QUADRAT SURVEY				
BP-3 at 0 m	**CBA-1**	**CBA-2**	**CBA-3**	**CBA-4**
Algae				
Pliocamium sandvicense			0.6	
Porolithon onkodes	0.8	0.3		2.0
Sponge				
Spirastrella coccinea	0.6	0.1	2.5	0.8
Corals				
Porites lobata	12.0	41.5	19.9	4.8
P. compressa	9.0	0.8	0.3	0.3
Pocillopora meandrina			1.1	
Sand			0.6	
Rubble			16.8	19.6
Hard Substratum	77.6	57.3	58.2	72.5
BP-3 at 10 m	**CBB-1**	**CBB-2**	**CBB-3**	**CBB-4**
Algae				
Porolithon onkodes	0.3			
Sponge				
Spirastrella coccinea	0.1	0.6	0.6	0.7
Spongia oceania	0.1			
Corals				
Porites lobata	1.1	0.8	0.3	0.8
P. compressa	2.5	11.8	8.4	6.7
Pocillopora meandrina		0.3	0.3	2.0
Montipora verrucosa		0.3	0.8	0.3
M. patula	0.3			
Sand			0.3	0.6
Rubble	95.6	82.6	89.3	88.9
BP-3 at 20 m	**CBC-1**	**CBC-2**	**CBC-3**	**CBC-4**
Sponge				
Spirastrella coccinea		0.1		
Spongia oceania	0.3			
Coral				
Porites lobata	0.3	0.6		0.3
P. compressa	5.9	2.8	0.8	1.1
Pocillopora meandrina	0.3	0.8		0.6
Montipora verrucosa	0.6			
Sand	0.8			0.6

Rubble	91.8	95.7	99.2	97.4

Mean Coral Coverage = 11.6%

TABLE 6.—*Continued*

Species	NUMBER
II. INVERTEBRATE CENSUS (4	
Phylum Mollusca	
Spondylus tenebrosus	3
Octopus cyanea	1
Phylum Echinodermata	
Heterocentrotus mammillatus	1
Tripneustes gratilla	83
Echinothrix calamaris	14
Echinometra mathaei	33
III. FISH CENSUS (4 ∞ 20 m)	
30 Species	
187 Individuals	
Estimated Standing Crop = 121 g/m^2	

NOTE: Results of the 8 m^2 quadrat sampling of the benthic community are presented in Part I, counts of diurnally exposed macroinvertebrates are given in Part II, and a summary of the fish census is given in Part III. Water depth = 16.5 m; mean coral coverage = 11.6 percent (quadrat method).

APPENDIX TABLE A.1. RESULTS OF QUANTITATIVE VISUAL FISH CENSUS CONDUCTED AT 3 LOCATIONS OFFSHORE OF ‘EWA BEACH, O‘AHU, HAWAI‘I, AUGUST 1991

FAMILY AND SPECIES	STATION NUMBER 1-A	1-B	2-A	2-B	3-A	3-B
SYNODONTIDAE						
Saurida gracilis	1					
HOLOCENTRIDAE						
Myripristes amaenus	13				12	
Adiroyx xantherythrus	9				4	
Flammeo sammara	3					
AULOSTOMIDAE						
Aulostomus chinensis					1	
FISTULARIIDAE						
Fistularia commersoni				1		
APOGONIDAE						
Apogon kallopterus	1				8	
CARANGIDAE						
Caranx lugubris					1	
LUTJANIDAE						
Lutjanus kasmira	26	99				
SPARIDAE						
Monotaxis grandoculis	12	7				
MULLIDAE						
Mulloides vanicolensis	9					
Parupeneus pleurostigma	10	4			4	1
P. multifasciatus	8	7			45	39
CHAETODONTIDAE						
Forcipiger flavissimus		1			5	
Chaetodon multicinctus	4	2				2
C. ornatissimus					2	
C. fremblii		1			3	1
C. kleini		3			1	4
C. auriga	2					
C. lunula	1	1			2	1
C. quadrimaculatus					2	
C. miliaris	11	16			1	
POMACANTHIDAE						
Centropyge potteri	13	13				
POMACENTRIDAE						
Dascyllus albisella		9			49	4
Plectroglyphidodon imparipennis			2			1
Chromis vanderbilti			1			9
C. hanui	31	33			4	
C. verator	8	10				

C. ovalis	256	127				
C. agilis	9	4				
Stegastes fasciolatus	3	3				
Abudefduf abdominalis	52					

APPENDIX TABLE A.1.—*Continued*

FAMILY AND SPECIES	STATION NUMBER 1-A	1-B	2-A	2-B	3-A	3-B
CIRRHITIDAE						
Paracirrhitus arcatus	1	2	3	2		1
P. forsteri		2				
Cirrhitops fasciatus					3	3
LABRIDAE						
Labroides phthirophagus		1			2	
Bodianus bilunulatus		2			2	1
Cheilinus bimaculatus			5	2		
C. rhodochrous	2	2				
Pseudocheilinus octotaenia	7	3			1	
Thalassoma duperrey	37	16	4	3	26	19
T. ballieui	1	2			2	
Coris gaimard					5	
Pseudojuloides cerasinus	1	16		3	1	6
Stethojulis balteata			1			
Macropharyngodon geoffroy	4	3			2	7
Anampses chrysocephalus					1	
SCARIDAE						
Calotomus carolinus	4				4	1
Scarus perspicillatus					1	
S. sordidus		1				2
S. psittacus	10	1				
PARAPERCIDAE						
Parapercis schauslandii			1			
GOBIIDAE						
Gnathelepis anjerensis				1		
ACANTHURIDAE						
Acanthurus nigrofuscus	32	12			36	32
A. nigroris	9	9			35	14
A. olivaceus	14	1			7	15
A. dussumieri						4
A. triostegus	2	2				
A. mata						1
Ctenochaetus strigosus	80	28			68	8
Zebrasoma flavescens	5	1				
Naso lituratus					10	3
N. hexacanthus	31					
N. unicornis	4					
N. brevirostris	11					
ZANCLIDAE						
Zanclus cornutus					8	1
BALISTIDAE						

Melichthys niger	1	1				1
M. vidua	1	1			1	2
Sufflamen bursa	1	3			1	1

APPENDIX TABLE A.1.—*Continued*

FAMILY AND SPECIES	STATION NUMBER 1-A	1-B	2-A	2-B	3-A	3-B
MONACANTHIDAE						
Pervagor spilosoma		1				
P. melanocephalus		1				
Cantherhines dumerili	1	1	1		1	1
C. sandwichiensis	1					
OSTRACIIDAE						
Ostracion whitleyi	1					
CANTHIGASTERIDAE						
Canthigaster jactator	5	1	2		1	3
C. cornata			1			
TETRAODONTIDAE						
Arothron hispidus	1					
Total Number of Species	47	42	10	6	38	30
Total Number of Individuals	745	453	21	12	367	187
Biomass (g/m^2)	406	374	7	2	343	121