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COMMUNITY STRUCTURE OF FISH AND MACROBENTHOS AT SELECTED SHALLOW-WATER SITES IN RELATION TO THE BARBERS POINT OCEAN OUTFALL, 2005

Richard E. Brock

June 2005

WATER RESOURCES RESEARCH CENTER
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This report provides the results of the fourteenth year of an annual quantitative monitoring of shallow marine communities inshore of the Barbers Point Ocean Outfall located in 61 m of water offshore of Ewa Beach, Oahu, Hawaii. The monitoring effort focuses on benthic and fish community structure and is designed to detect changes in these communities. Field sampling was first carried out in August 1991 when three study stations were established: Station BP-1, a control station 2.2 km inshore and east of the outfall terminus; Station BP-2, an experimental station about 1.6 km inshore of the terminus; and Station BP-3, an experimental station about 2.9 km west and inshore of the terminus. The second field effort, completed in May and September 1993, resurveyed the above stations as well as established a fourth station (BP-4) on and adjacent to the basalt armor caprock protecting the discharge pipe in 13 m of water and directly inshore of the outfall terminus. Subsequent field surveys were completed in March and April 1994, in June 1995, in May 1996, in February and April 1997, in January and March 1998, in January 1999, in May 2000, in June 2001, in May 2002, in March 2003, in February 2004, and the most recent in May 2005. The permanently marked stations are sited to capitalize on presumed gradients of impact that may be created by the discharge and movement of treated sewage effluent toward the shore and the coral reef communities. Data from the first survey suggested that marine communities offshore of Ewa Beach receive disturbance from a number of possible sources, with the largest perturbation probably coming from natural disturbance caused by occasional wave impact. This was most evident at the station directly inshore of the outfall. Data from Station BP-4 showed that benthic communities situated on armor rock which rises above the flat limestone substratum are not subjected to the same sand scour as those situated on the limestone; thus the coral communities on the elevated caprock are better developed on this substrate. A comparison of the data from the fourteen annual surveys indicated that no statistically significant change has occurred in the measured biological parameters at the four permanent stations that would suggest an impact from the operation of the wastewater outfall, despite the imposition of a major hurricane on these marine communities in September 1992. However, the mean number of macroinvertebrate species seen per transect was significantly greater in 2002 (8.5 species/transect) than in 1991 (5.0 species/transect), with other years showing no significant change. In addition, coral coverage at Transect BP-4-B, which is located directly adjacent to the outfall pipe, has shown a steady and significant increase from the first survey after Hurricane Iniki (1993 mean = 0.1%) to the most recent survey (2005 mean = 12.6%). Thus the data to date support the contention that the operation of the Barbers Point deep-ocean outfall is not having a quantifiable impact on the coral reef resources situated inshore of the outfall terminus.

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ABSTRACT

This report provides the results of the fourteenth year of an annual quantitative monitoring of shallow marine communities inshore of the Barbers Point Ocean Outfall located in 61 m of water offshore of ‘Ewa Beach, O‘ahu, Hawai‘i. The monitoring effort focuses on benthic and fish community structure and is designed to detect changes in these communities. Field sampling was first carried out in August 1991 when three study stations were established: Station BP-1, a control station 2.2 km inshore and east of the outfall terminus; Station BP-2, an experimental station about 1.6 km inshore of the terminus; and Station BP-3, an experimental station about 2.9 km west and inshore of the terminus. The second field effort, completed in May and September 1993, resurveyed the above stations as well as established a fourth station (BP-4) on and adjacent to the basalt armor caprock protecting the discharge pipe in 13 m of water and directly inshore of the outfall terminus. Subsequent field surveys were completed in March and April 1994, in June 1995, in May 1996, in February and April 1997, in January and March 1998, in January 1999, in May 2000, in June 2001, in May 2002, in March 2003, in February 2004, and the most recent in May 2005. The permanently marked stations are sited to capitalize on presumed gradients of impact that may be created by the discharge and movement of treated sewage effluent toward the shore and the coral reef communities. Data from the first survey suggested that marine communities offshore of ‘Ewa Beach receive disturbance from a number of possible sources, with the largest perturbation probably coming from natural disturbance caused by occasional wave impact. This was most evident at the station directly inshore of the outfall. Data from Station BP-4 showed that benthic communities situated on armor rock which rises above the flat limestone substratum are not subjected to the same sand scour as those situated on the limestone; thus the coral communities on the elevated caprock are better developed on this substrate.

A comparison of the data from the fourteen annual surveys indicated that no statistically significant change has occurred in the measured biological parameters at the four permanent stations that would suggest an impact from the operation of the wastewater outfall, despite the imposition of a major hurricane on these marine communities in September 1992. However, the mean number of macroinvertebrate species seen per transect was significantly greater in 2002 (8.5 species/transect) than in 1991 (5.0 species/transect), with other years showing no significant change. In addition, coral coverage at Transect BP-4-B, which is located directly adjacent to the outfall pipe, has shown a steady and significant increase from the first survey after Hurricane Iniki (1993 mean = 0.1%) to the most recent survey (2005 mean = 12.6%). Thus the data to date support the contention that the operation of the Barbers Point deep-ocean

outfall is not having a quantifiable impact on the coral reef resources situated inshore of the outfall terminus.

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INTRODUCTION

Purpose

The Honouliuli Wastewater Treatment Plant (WWTP) located in ‘Ewa, O‘ahu, Hawai‘i, has been in operation since 1982. It releases approximately 19.7 mgd (0.86 m^3/s) of primary, secondary, and tertiary treated sewage through a 2,670-m pipe at a depth of 61 m offshore of ‘Ewa Beach, O‘ahu. In recent years controversy has arisen regarding the impact that sewage effluent from the Honouliuli WWTP may have on inshore coral reef species. Accordingly, commencing in 1991 this study was undertaken in an attempt to quantitatively ascertain the impacts that may be occurring. This document presents the results of the fourteenth fish and coral survey carried out on 20-23 May 2005 and the underwater photography completed between March and May 2005.

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 action that may have an acute impact (such as channel dredging) requires 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 requires identification of system perturbations that 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 impacts confronting the marine ecosystem offshore of ‘Ewa 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 ‘Ewa 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 at some distance shoreward from a host of other possible perturbations originating in the Honolulu and Pearl Harbor areas.

The waters fronting ‘Ewa Beach, into which the deep-ocean outfall discharges, can be considered in terms of gradients. There are numerous “gradients” due to point-source and nonpoint-source (such as storm drains and streams) inputs that are occurring to the east. Because many of these inputs have probably 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 ‘Ewa Beach are those that have evolved under the influence of these ongoing perturbations.

As noted above, if impacts are occurring in the shallow marine communities off ‘Ewa Beach because of effluent discharged from the deep-ocean outfall, they are probably chronic in nature and would probably be manifested 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 which 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 of a few hundred square centimeters (such as the community residing in a *Pocillopora meandrina* coral head) to many hectares (such as areas which are covered by major biotopes). Because considerable interest focuses on visually dominant corals, diurnally exposed macroinvertebrates, and fishes, we designed a sampling program to delineate changes that may be occurring in communities at this scale.

Four permanently marked stations were selected for the monitoring of benthic and fish community response to possible sewage impacts. The approximate locations of these stations are shown in Figure 1. The first three stations (BP-1, BP-2, and BP-3) were established in 1991 and the fourth (BP-4) in 1993. The stations and the rationale for their selection are given below:

Station BP-1 Located about 2.2 km inshore and to the east (northeast) of the deep ocean outfall terminus. This station, which is utilized as a control site, is located in water ranging from 14.9 to 15.8 m in depth (Figure 1). Although complex, prevailing currents move in an inshore and westerly direction approximately parallel to the shoreline (figure 34 in Laevastu et al. 1964). Thus this station is probably outside (to the east) of any shoreward-moving sewage plume. The substratum at this station is primarily limestone, with corals having a “patchy”

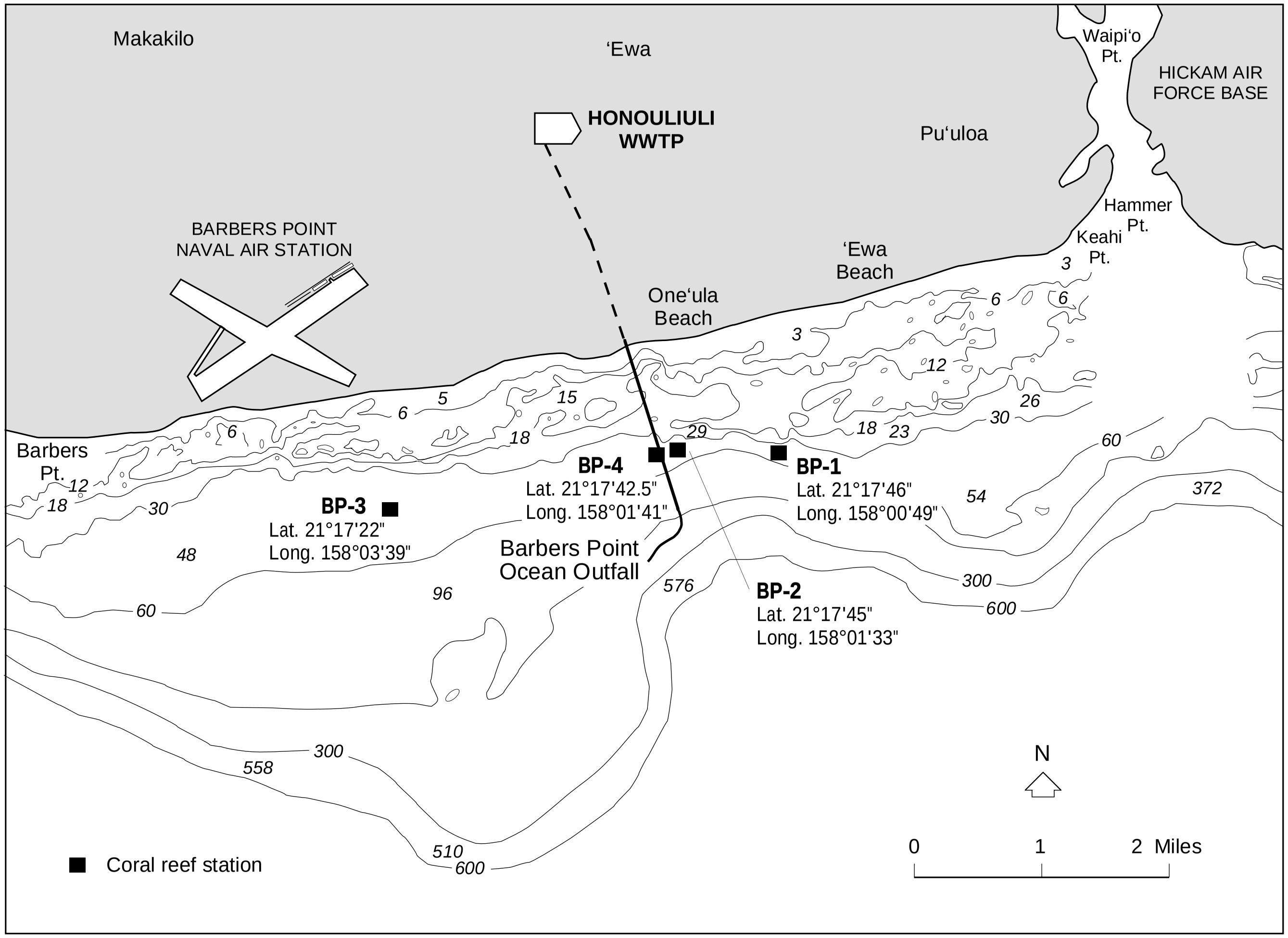

FIGURE 1. General locations of four permanent stations (two transects per station) sampled in the coral reef survey at the Barbers Point Ocean Outfall, O‘ahu, Hawai‘i. These are the eastern station (BP-1) where the first two transects are located (BP-1-A and BP-1-B), the middle station (BP-2) just east of the sewer discharge pipeline where the second pair of transects (BP-2-A and BP-2-B) are situated, the western station (BP-3) where two transects (BP-3-A and BP-3-B) are established, and a new station (BP-4) established in 1993 where two transects on (BP-4-A) and adjacent to (BP-4-B) the discharge pipe are located.

distribution across it. Coral coverage may locally exceed 70%. Occasionally, shallow sand areas located in depressions are found.

Station BP-2 Located about 0.25 km east of the sewer line and approximately 1.6 km inshore and slightly east (northeast) of the discharge terminus in water ranging from 11.3 to 11.9 m in depth. The substratum at this experimental site is a relatively featureless limestone flat with few corals present.

Station BP-3 Located about 2.9 km west and inshore (northwest) of the terminus of the sewage diffuser in water ranging from 16.5 to 16.8 m in depth. The substratum at this experimental site is a mix of rubble/sand and emergent limestone with corals. Coral coverage, which is about 25%, is greater at this station than at Station BP-2.

Station BP-4 Located on the sewer line and approximately 1.4 km inshore of the discharge terminus in water ranging from 15.2 to 17.7 m in depth. The substratum varies from basalt caprock overlying the discharge pipe to relatively flat and featureless limestone adjacent to the discharge pipe. This station was established in 1993 to demonstrate the effect that the elevated basalt caprock substratum has on benthic and fish community development in an area that otherwise is flat and featureless and subjected to occasional sand scour.

At each station two transect lines were permanently established using metal stakes and plastic-coated no. 14 copper wire. The transects are 20 m in length and have an orientation that is parallel to shore. Two transects were established at each location to provide some replication. On each transect are five permanently marked locations (0 m, 5 m, 10 m, 15 m, and 20 m) for the taking of photographs of the benthic communities. A single 0.67 m × 1 m photographic quadrat was established at each of the marked points, for a total sampling of 3.35 m^2 of substratum on each transect line.

Because of a lawsuit initiated by Hawaii's Thousand Friends and the Sierra Legal Defense Fund regarding the Barbers Point discharge in 1992–93, additional field sampling was carried out beginning in 1993. The coverage by photo-quadrats was increased from three to five sites, and a visual assessment of benthic communities using a 1 m × 1 m quadrat was made at each of the photo-quadrat sites (i.e., at the 0 m, 5 m, 10 m, 15 m, and 20 m points on each transect) to provide additional information regarding smaller organisms not readily seen with the photo-quadrat method, such as recently recruited benthic species. These changes have made both the photo-quadrat and visual quadrat assessment methods the same as those formerly used to survey the Sand Island deep-ocean outfall stations offshore of Honolulu.

Fish abundance and diversity are 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), which has proven adequate for sampling many Hawaiʻi benthic communities (see Brock 1982; Brock and Norris 1989), is used.

Information is collected at each transect location using methods including a visual assessment of fishes, benthic photo-quadrats and quadrats for field appraisals of cover estimates by sessile forms (e.g., algae, corals, and colonial invertebrates), and counting of diurnally exposed motile macroinvertebrates along the transect line. Fish censuses are conducted over a 4 m × 20 m corridor (the permanent transect line). All fishes within this area to the water's surface are counted. A single diver equipped with scuba, slate, and pencil enters the water, then counts and records all fishes in the prescribed area (method modified from Brock 1954). Besides counting the individuals of all fishes seen, the length of each is estimated for later use in the determination of fish standing crop using linear regression techniques (Ricker 1975). Species-specific regression coefficients have been developed over the last 30 years by the author and others at the University of Hawaiʻi, the Naval Undersea Center (see Evans 1974), and the Hawaiʻi Division of Aquatic Resources from weight and body measurements of captured fishes; for many species, the coefficients have been developed using sample sizes in excess of a hundred individuals. The same individual (the author) performs 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 underestimating the size of cryptic species such as moray eels (family Muraenidae) and nocturnal species such as squirrelfishes (family Holocentridae) and bigeyes or ʻāweoweo (family Priacanthidae). 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, such as scorpionfishes or nohu (family Scorpaenidae) and flatfishes (family Bothidae), might still be missed. Another problem is the reduced effectiveness of the visual census technique in turbid water. This is compounded by the difficulty of counting fishes that move quickly or are very numerous. Additionally, bias related to the experience of the census taker should be considered in making comparisons between surveys. Despite these problems, the visual census technique carried out by divers is probably the most accurate nondestructive assessment method currently available for counting diurnally active fishes (Brock 1982).

A number of methods are utilized to quantitatively assess benthic communities at each station, including the taking of photographs at locations marked for repeated sampling through time (each covering 0.67 m^2). Photographs provide a permanent record from which coverage of corals and other sessile forms can be estimated. Cover estimates from photographs are recorded as percent cover. Additionally, to help with later analysis in the laboratory of the coverage recorded in photographs, a visual appraisal of each quadrat is made in the field, and notes are taken on the species present. Beginning with the 1993 survey, supplementary information on benthic coverage was obtained by using 1 m × 1 m quadrats at the 0 m, 5 m, 10 m, 15 m, and 20 m points on each transect line. In these quadrats a visual assessment of cover was made for each species present. Diurnally exposed motile macroinvertebrates greater than 2 cm in some dimension are censused in the same 4 m × 20 m corridor used for the fish counts.

If macrothalloid algae are encountered in the quadrats, they are quantitatively recorded as percent cover. Emphasis was placed on those species that are 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 regulatory agencies, divers make simple physical measurements at the four stations. Measurements of percent oxygen concentration and temperature are made with a YSI Model 57 Oxygen meter, salinity is taken with a hand-held refractometer, and water clarity is determined using a 12-inch secchi disk. Oxygen measurements are taken approximately 1 m below the water surface and 1 m above the bottom.

Data are subjected to simple nonparametric statistical procedures provided in the SAS Institute statistical package (SAS Institute Inc. 1985). Nonparametric methods are used to avoid meeting requirements of normal distribution and homogeneity of variance in the data. Data are analyzed using the Kruskal–Wallis analysis of variance to discern statistically significant differences among ranked means for each transect site and sampling period; this procedure is outlined by Siegel (1956) and Sokal and Rohlf (1995). The a posteriori Student–Newman–Keuls multiple-range test (SAS Institute Inc. 1985) is also used to elucidate differences between locations.

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

RESULTS

Field sampling was undertaken on 20 and 23 May 2005, and the photographic data were collected by members of the Oceanographic Team, Department of Environmental Services, City and County of Honolulu, in the period between March and May 2005. The physical measurements (temperature, salinity, and oxygen) were made in the morning on 27 May 2005. Figure 1 shows the approximate locations of the four stations, and Figures 2 through 5 show the orientation of the permanent photographic quadrats on each transect line for the four stations.

The results are presented below by station. All transects other than those at Station BP-4 have an orientation that is parallel to the shoreline. The orientation of the transects at Station BP-4 is approximately perpendicular to the shoreline (parallel to the discharge pipe).

Station BP-1

As noted earlier, Station BP-1 is utilized as a control site. It is situated about 2.2 km inshore and to the east (northeast) of the deep-ocean outfall terminus and is located in water ranging from 14.9 to 15.8 m in depth. The substratum at this station is limestone, with corals overlaying it; coverage may locally exceed 70%, and the dominant species are *Porites lobata* and *P. compressa*. The corals form low ridges ("spurs and grooves") that have an orientation which is perpendicular to the shoreline. These ridges are 2 to 15 m wide and 4 to 50 m long and are spaced 2 to 20 m apart. In the open areas between the ridges the substratum has a veneer of rubble and sand. The physical damage from Hurricane Iniki, which reduced coral cover at all stations, was greatest at Station BP-3, but Station BP-1 also suffered damage to the coral community, which is evident in the coverage data below.

The two permanently marked transects (BP-1-A and BP-1-B) that sample this station have an orientation that is parallel to the shoreline, are located 27.3 to 29.0 m apart, and are out of visual range of one another (see Figure 2). Water clarity at this station usually ranges from 10 to 15 m.

Transect BP-1-A

A summary of the data collected on Transect BP-1-A in May 2005 is presented in Table 1. In the visually assessed quadrat survey (quadrat locations shown in Figure 2), two algal species (*Porolithon onkodes* and *Peyssonellia rubra*) with a mean coverage of 5.8%, one sponge species (*Chondrosia chucalla*) with a mean coverage of 0.04%, and five coral species (*Porites lobata*, *P. compressa*, *Pocillopora meandrina*, *Montipora verrucosa, and M. patula*) were encountered. *Porites lobata* continues to be the dominant coral at this

STATION BP-1

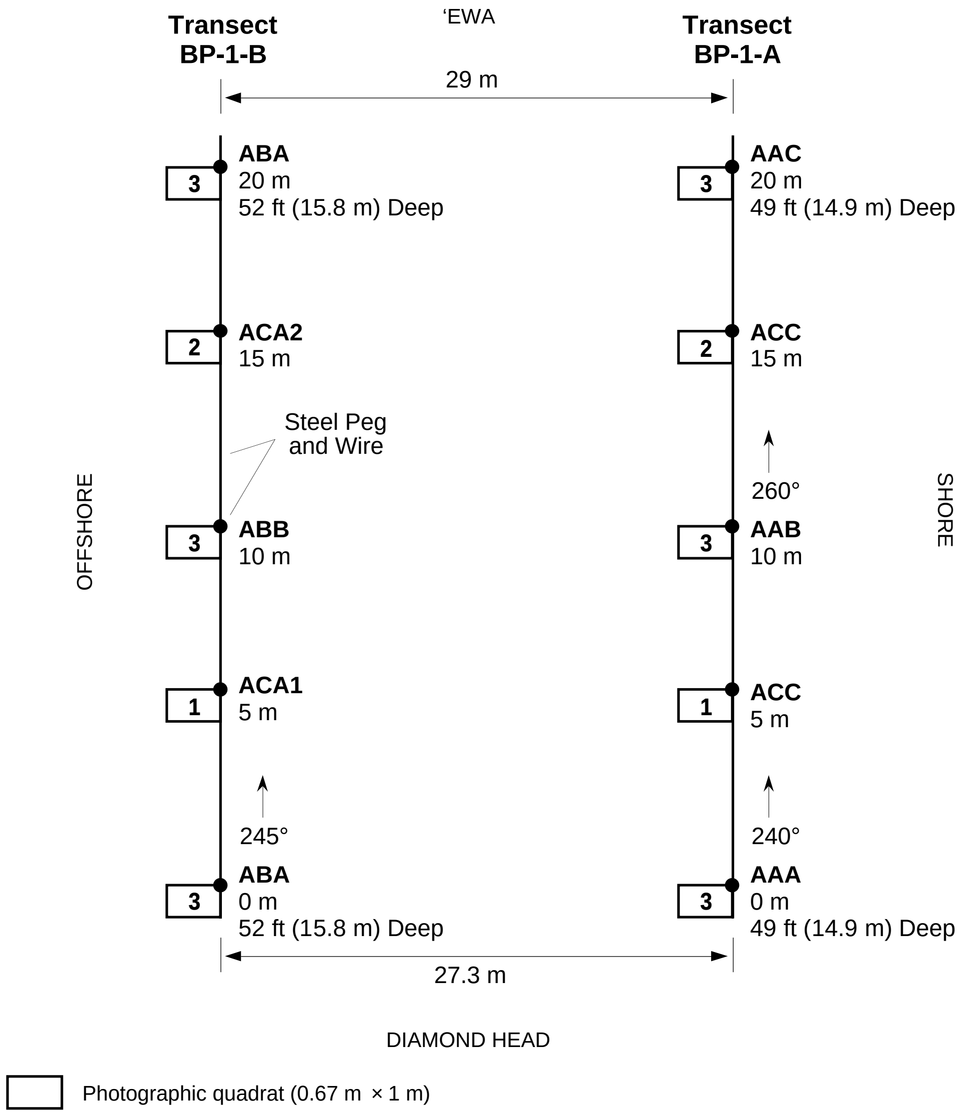

FIGURE 2. Locations of the five photographic quadrats each on Transects BP-1-A and BP-1-B located at the eastern station (BP-1) offshore of 'Ewa Beach, O'ahu, Hawai'i

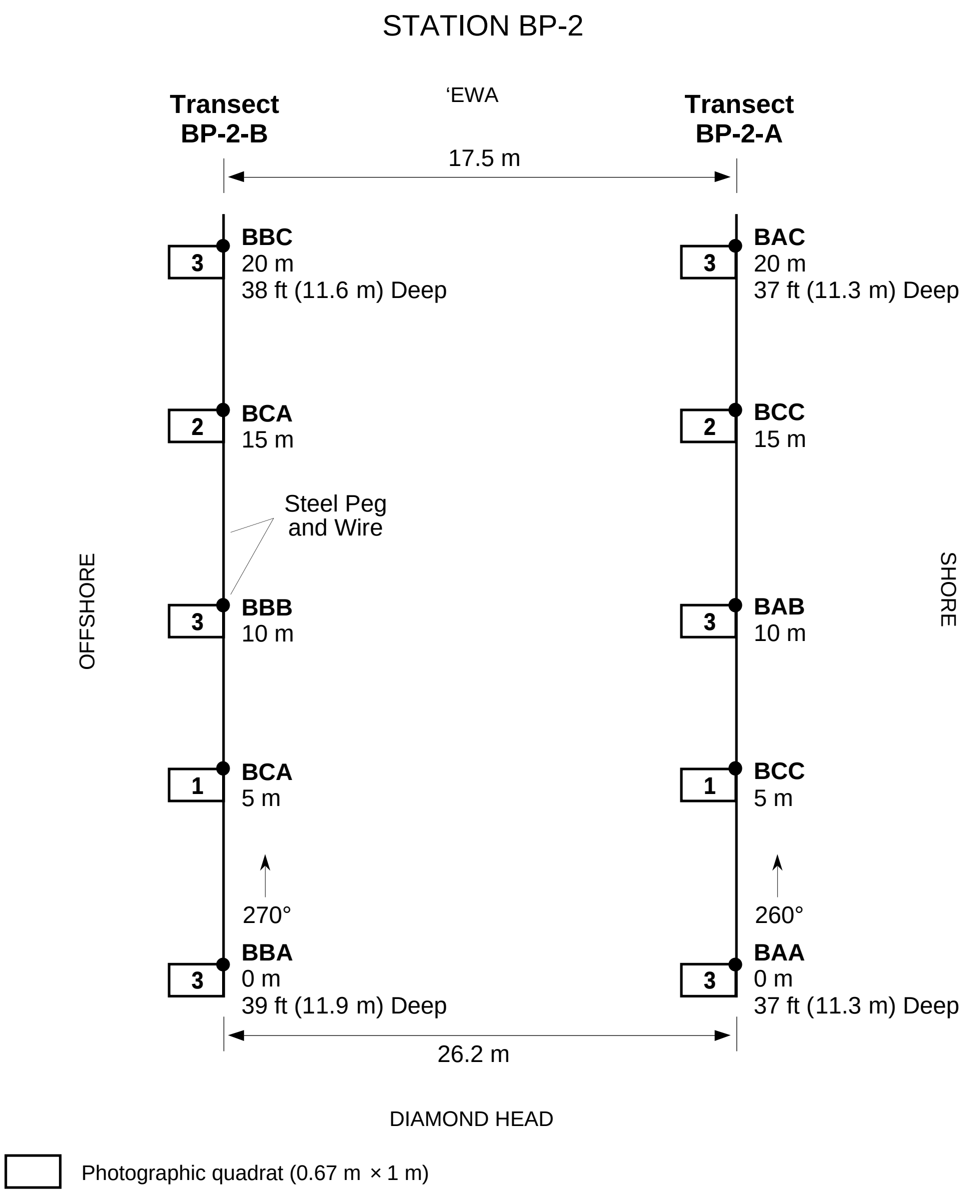

FIGURE 3. Locations of the five photographic quadrats each on Transects BP-2-A and BP-2-B located at the middle station (BP-2) just east of the Barbers Point Ocean Outfall discharge pipe offshore of ʻEwa Beach, Oʻahu, Hawaiʻi

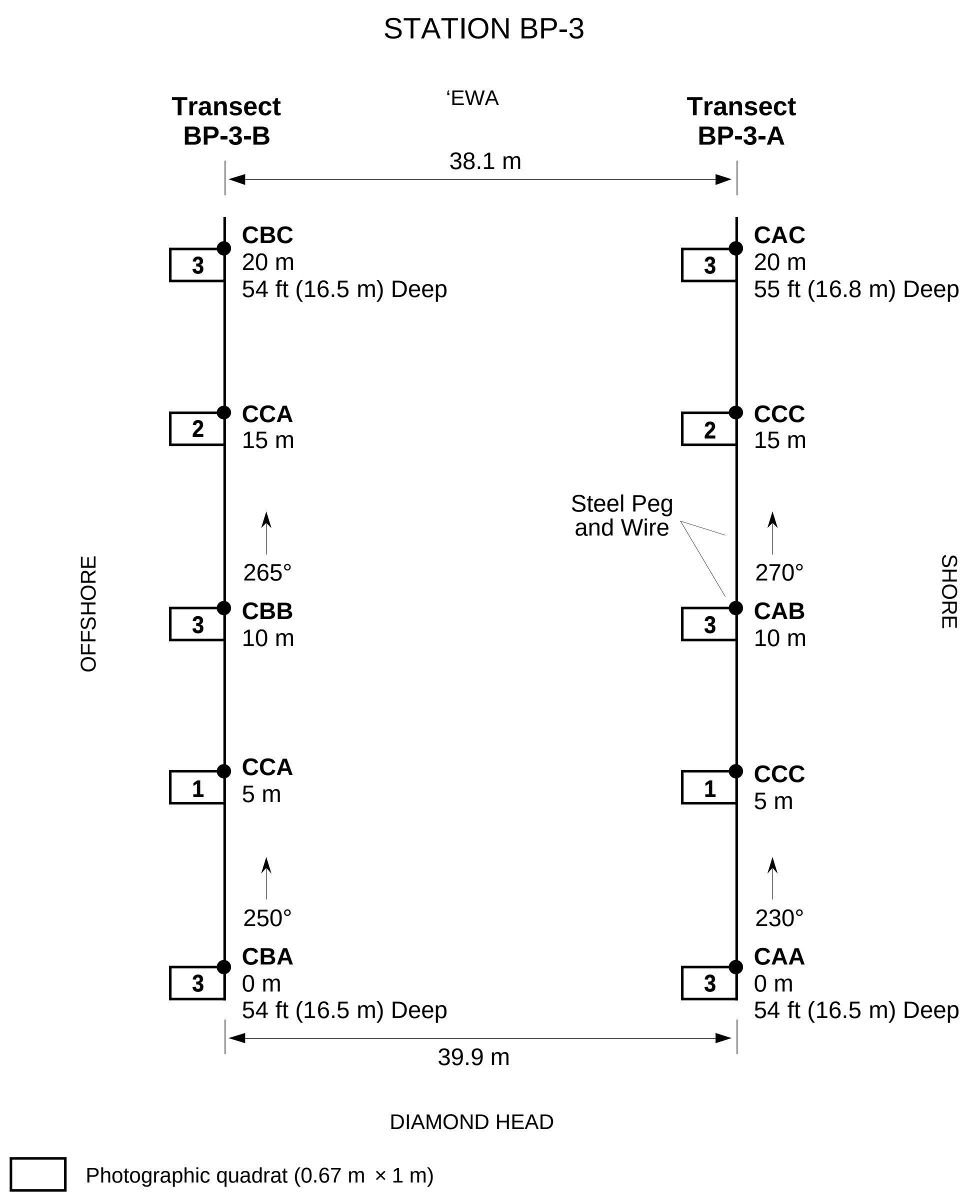

FIGURE 4. Locations of the five photographic quadrats each on Transects BP-3-A and BP-3-B located at the western station (BP-3) offshore of ‘Ewa Beach, O‘ahu, Hawai‘i

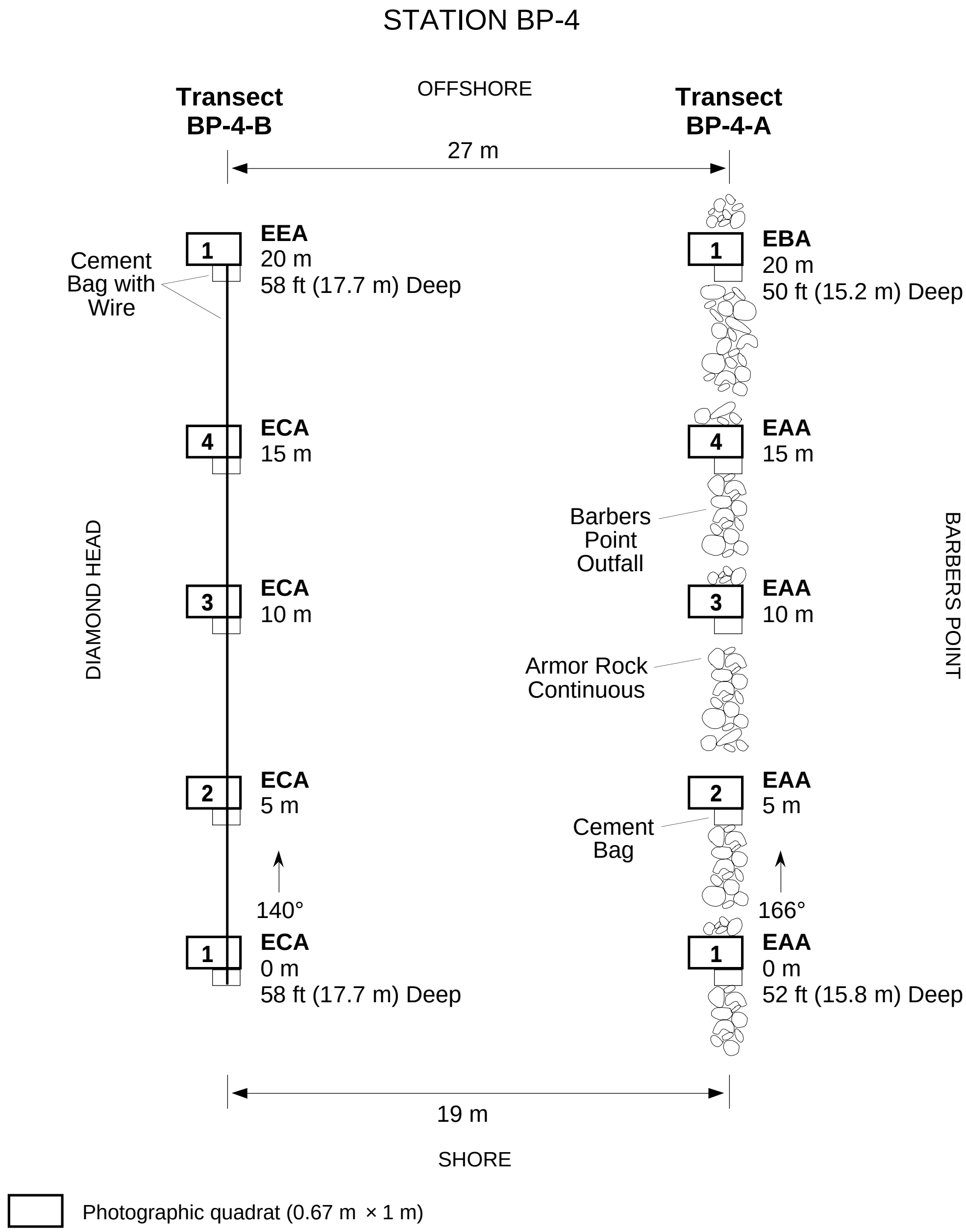

FIGURE 5. Locations of the five photographic quadrats each on Transects BP-4-A and BP-4-B located on and adjacent to the armor rock covering the Barbers Point Ocean Outfall discharge pipe offshore of ʻEwa Beach, Oʻahu, Hawaiʻi

TABLE 1. Summary of Biological Observations Made at Transect BP-1-A, 2.2 km Northeast and Inshore of Barbers Point Ocean Outfall Terminus, on 20 May 2005

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Algae					
Porolithon onkodes	22.0	2.0			3.0
Peyssonellia rubra		2.0			
Sponges					
Chondrosia chucalla			0.2		
Corals					
Porites lobata	2.0	41.0	1.0		12.0
Porites compressa		1.0			
Pocillopora meandrina			4.7	1.1	1.1
Montipora verrucosa				0.2	
Montipora patula			1.0	1.0	8.0
Sand			10.0	2.0	
Rubble	18.0		71.1	80.7	20.0
Hard Substratum	58.0	54.0	12.0	15.0	55.9

II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals
Phylum Mollusca	
Spondylus tenebrosus	1
Arca ventricosa	3
Cassis cornuta	1
Phylum Annelida	
Spirobranchus giganteus corniculatus	13
Phylum Echinodermata	
Echinothrix diadema	28
Tripneustes gratilla	4
Echinometra mathaei	2

III. Fish Census (4 m × 20 m)

23 Species
183 Individuals
Estimated Standing Crop = 79 g/m^2

NOTE: Results of the 5-m^2 quadrat sampling (visual appraisal) 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 presented in Part III. Water depth is 14.9 m; mean coral coverage is 14.8% (visual quadrat method).

transect, where mean coral coverage for all species combined was 14.8%. The macroinvertebrate census noted the rock oyster *Spondylus tenebrosus*, the boring bivalve *Arca ventricosa*, the helmet shell *Cassis cornuta*, the Christmas tree worm *Spirobranchus giganteus corniculatus*, and three sea urchin species (*Echinothrix diadema*, *Tripneustes gratilla*, and *Echinometra mathaei*).

The results of the photo-quadrat survey made at the four stations are presented in Table 2. At Transect BP-1-A, three coral species having a mean coverage of 17.8% were noted. Also noted was the algal species *Porolithon onkodes* with a mean coverage of 2.5%.

The results of the fish census are presented in Appendix Table A.1. Twenty-three species representing 183 individuals were counted on Transect BP-1-A. The most abundant species included the Hawaiian dascyllus or ‘ālo‘ilo‘i (*Dascyllus albisella*), the brown surgeonfish or mā‘i‘i‘i (*Acanthurus nigrofuscus*), the goldring surgeonfish or kole (*Ctenochaetus strigosus*), and the sleek unicornfish or kala holo (*Naso hexacanthus*). The standing crop of fishes was estimated at 79 g/m^2, with the largest contributors including *C. strigosus* (31% of the total) and *N. hexacanthus* (16%).

Transect BP-1-B

Transect BP-1-B is situated seaward of Transect BP-1-A. The results of the quantitative survey carried out on this transect (quadrat locations shown in Figure 2) are presented in Table 3. The quadrat survey noted one algal species (*Porolithon onkodes*) with a mean coverage of 0.8%, one sponge species (*Spirastrella coccinea*) having a mean coverage of 0.08%, one soft coral species (*Anthelia edmondsoni*) with coverage of 0.3%, and eight coral species (*Porites lobata*, *P. compressa*, *Pocillopora meandrina*, *Pavona varians*, *P. duerdeni*, *Montipora verrucosa*, *M. verrilli*, and *M. patula*). The dominant coral species was *Porites lobata*, and mean coral coverage was 14.4%. In the 4 m × 20 m census area, five macroinvertebrate species were seen: the boring bivalve *Arca ventricosa*, the helmet shell *Cassis cornuta*, the Christmas tree worm *Spirobranchus giganteus corniculatus*, the black sea urchin *Tripneustes gratilla*, and the long-spined black sea urchin *Echinothrix diadema*.

The results of the photo-quadrat survey are given in Table 2 for this transect. Four coral species (*Porites lobata*, *P. compressa*, *Pocillopora meandrina*, and *Montipora patula*) having a mean coverage of 26.6% were noted. Also encountered was the alga *Porolithon onkodes* with a mean coverage of 2.2%.

The results of the fish census are presented in Appendix Table A.1. Twenty-eight species representing 704 individuals were censused at Transect BP-1-B, where the most common species present were the bluelined snapper or ta‘ape (*Lutjanus kasmira*), the brown surgeonfish or mā‘i‘i‘i (*Acanthurus nigrofuscus*), and the goldring surgeonfish or kole

TABLE 2. Summary of the Results of the Photographic Quadrat Survey for Transects at Stations BP-1 Through BP-4, Barbers Point Ocean Outfall, ‘Ewa Beach, O‘ahu, Hawai‘i, 2005

Transect BP-1-A	Percent Cover				
	Photographic Quadrat				
	AAA3 (0 m)	ACC1 (5 m)	AAB3 (10 m)	ACC2 (15 m)	AAC3 (20 m)
Algae					
Porolithon onkodes	9.5	1.7			1.4
Corals					
Porites lobata	31.1	43.4	1.1	0.6	9.6
Pocillopora meandrina			1.4		
Montipora patula			0.3	0.3	1.1
Sand			7.0		
Rubble			17.6	99.1	28.6
Hard Substratum	59.4	54.3	72.5		59.9

Mean Coral Coverage = 17.8%

Transect BP-1-B	Percent Cover				
	Photographic Quadrat				
	ABA3 (0 m)	ACA1 (5 m)	ABB3 (10 m)	ACA2 (15 m)	ABC3 (20 m)
Algae					
Porolithon onkodes	3.4	1.4		1.7	4.5
Corals					
Porites lobata	20.2	20.7	23.0	23.0	11.2
Porites compressa	4.2	3.4		4.2	2.5
Pocillopora meandrina	3.6	5.3		0.3	0.8
Montipora patula		9.0	1.1		0.6
Sand		0.3	1.1	0.3	
Rubble		7.8	44.0		
Hard Substratum	68.6	52.1	30.8	70.6	80.4

Mean Coral Coverage = 26.6%

TABLE 2—*Continued*

Transect BP-2-A	Percent Cover				
	Photographic Quadrat				
	BAA3 (0 m)	BCC1 (5 m)	BAB3 (10 m)	BCC2 (15 m)	BAC3 (20 m)
Sponges					
Spirastrella coccinea	0.1	0.1	0.1	0.1	0.1
Chondrosia chucalla	0.1	0.1			
Microciona maunaloa	0.6				
Corals					
Porites lobata	1.1			4.8	
Pocillopora meandrina	7.0		2.2	9.8	3.9
Montipora patula				0.3	
Sand	1.1	1.4	1.4	0.6	1.1
Hard Substratum	89.9	98.3	96.2	84.5	94.8

Mean Coral Coverage = 5.8%

Transect BP-2-B	Percent Cover				
	Photographic Quadrat				
	BBA3 (0 m)	BCA1 (5 m)	BBB3 (10 m)	BCA2 (15 m)	BBC3 (20 m)
Sponges					
Spirastrella vagabunda	0.1		0.1		
Chondrosia chucalla	0.1				
Microciona maunaloa		0.1			
Corals					
Porites lobata	1.7	3.1			0.3
Pocillopora meandrina	2.8	5.0			2.8
Sand	1.1		0.8	1.1	0.8
Hard Substratum	94.1	91.7	99.1	98.9	96.1

Mean Coral Coverage = 3.1%

TABLE 2—*Continued*

Transect BP-3-A	Percent Cover Photographic Quadrat CAA3 (0 m)	CCC1 (5 m)	CAB3 (10 m)	CCC2 (15 m)	CAC3 (20 m)
Algae					
Porolithon onkodes		0.8			
Sponges					
Microciona maunaloa		0.6		2.0	
Corals					
Porites lobata		8.4		3.9	0.3
Pocillopora meandrina				7.3	
Montipora patula		0.3			
Sand	1.4		1.1		0.8
Rubble	73.9	44.5	98.9	67.2	98.9
Hard Substratum	24.6	45.4		19.6	

Mean Coral Coverage = 4.0%

Transect BP-3-B	Percent Cover Photographic Quadrat CBA3 (0 m)	CCA1 (5 m)	CBB3 (10 m)	CCA2 (15 m)	CBC3 (20 m)
Algae					
Porolithon onkodes		0.8			
Sponges					
Microciona maunaloa	2.5	0.6		0.1	
Corals					
Porites lobata	16.0	4.5		32.2	0.6
Pocillopora meandrina	2.5	7.8	0.6	3.9	
Sand	0.3		0.6		1.1
Rubble		38.1		64.0	98.3
Hard Substratum	89.4	48.2	98.8	57.4	

Mean Coral Coverage = 13.6%

TABLE 2—*Continued*

Transect BP-4-A	Percent Cover				
	Photographic Quadrat				
	EAA1 (0 m)	EAA2 (5 m)	EAA3 (10 m)	EAA4 (15 m)	EBA1 (20 m)
Algae					
Porolithon onkodes	1.1	0.8	0.8	1.4	3.9
Corals					
Porites lobata	3.1	32.8	31.9	23.0	36.4
Rubble	38.1				
Hard Substratum	57.7	66.4	67.3	75.6	59.7
Mean Coral Coverage = 25.4%					

Transect BP-4-B	Percent Cover				
	Photographic Quadrat				
	ECA1 (0 m)	ECA2 (5 m)	ECA3 (10 m)	EAC4 (15 m)	EEA1 (20 m)
Sponges					
Plakortis simplex			1.7		
Corals					
Porites lobata	7.0	1.7	8.1	11.8	2.2
Pocillopora meandrina	3.6		2.8	0.8	
Montipora patula	2.8				
Sand					0.6
Hard Substratum	86.6	98.3	87.4	87.4	97.2
Mean Coral Coverage = 8.2%					

NOTE: Presented in the body of the table are the percent cover of species and substrate types for each transect. Data for all stations are based on one 0.67-m^2 photo-quadrat at each 5-m stop (i.e., at the 0 m, 5 m, 10 m, 15 m, and 20 m points along the transect).

TABLE 3. Summary of Biological Observations Made at Transect BP-1-B, 2.2 km Inshore and Northeast of Barbers Point Ocean Outfall Terminus, on 20 May 2005

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Algae					
Porolithon onkodes	3.0				1.0
Sponges					
Spirastrella coccinea			0.4		
Soft Corals					
Anthelia edmondsoni			1.0	0.4	
Corals					
Porites lobata	10.0	13.0		3.0	11.0
Porites compressa	0.3	1.0		2.1	5.0
Pocillopora meandrina	2.5		1.0	1.0	1.0
Montipora verrucosa				0.2	0.4
Montipora patula		2.2	7.1	5.0	
Montipora verrilli					0.9
Pavona varians					4.5
Pavona duerdeni			0.6		
Sand		4.0	10.0	3.0	
Rubble	30.0	38.0	59.9	65.3	61.2
Hard Substratum	54.2	41.8	20.0	20.0	15.0

II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals
Phylum Mollusca	
Arca ventricosa	5
Cassis cornuta	1
Phylum Annelida	
Spirobranchus giganteus corniculatus	14
Phylum Echinodermata	
Echinothrix diadema	41
Tripneustes gratilla	8

III. Fish Census (4 m × 20 m)

28 Species
704 Individuals
Estimated Standing Crop = 800 g/m^2

NOTE: Results of the 5-m^2 quadrat sampling (visual appraisal) 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 presented in Part III. Water depth is 15.8 m; mean coral coverage is 14.4% (visual quadrat method).

(*Ctenochaetus strigosus*). The standing crop of fish was estimated at 800 g/m^2, with the largest contributors being *Lutjanus kasmira* (comprising 88% of the total) and *C. strigosus* (adding 2%).

Station Observations

In the vicinity of Station BP-1 were seen the corals *Porites evermanni* and *Montipora flabellata*, as well as the moray eel *Gymnothorax undulatus* and the cone shell *Conus leopardus*.

Station BP-2

Station BP-2 is located about 1.4 km from shore in water from 11.3 to 11.9 m in depth (Figure 1). The substratum at this location is a relatively flat and featureless limestone with little relief present. Common corals seen include *Pocillopora meandrina* and *Porites lobata*; other corals seen include three *Montipora* species. Some of the common algal species seen seasonally in the area are limu kohu or *Asparagopsis taxiformis*, *Spyridia filamentosa*, and the recently introduced *Avrainvillea amadelpha*.

The two permanently marked transect lines at this station have an orientation that is approximately parallel to the shoreline, with the shoreward transect (BP-2-A) situated at a depth of 11.3 m and the seaward transect (BP-2-B) at a depth of 11.6 to 11.9 m (Figure 3).

Transect BP-2-A

Table 4 presents a summary of the quantitative study made at Transect BP-2-A. The visual quadrat survey (quadrat locations shown in Figure 3) noted two algal species (*Spyridia filamentosa* and *Asparagopsis taxiformis*) having a mean coverage of 1.5%, two sponge species (*Chondrosia chucalla* and *Spirastrella vagabunda*) with a mean coverage of 0.1%, and four coral species (*Porites lobata*, *Pocillopora meandrina*, *Montipora patula*, and *M. verrucosa*). Mean coral coverage at this transect was estimated at 3.8%. The macroinvertebrate census carried out over the 4 m × 20 m area noted eight species: the boring bivalve *Arca ventricosa*, the cone shell *Conus imperialis*, the Christmas tree worm *Spirobranchus giganteus corniculatus*, the brown hermit crab *Dardanus deformis*, and four sea urchin species (*Echinothrix calamaris*, *E. diadema*, *Echinostrephus aciculatum*, and *Tripneustes gratilla*).

The results of the photo-quadrat survey are presented in Table 2. Three sponge species (*Spirastrella vagabunda*, *Chondrosia chucalla*, and *Microciona maunaloa*) having a mean coverage of 0.3% and three coral species (*Porites lobata*, *Montipora patula*, and *Pocillopora meandrina*) with a mean coverage of 5.8% were noted.

TABLE 4. Summary of Biological Observations Made at Transect BP-2-A, 0.25 km East of the Discharge Pipe and 1.6 km Inshore and Northeast of Barbers Point Ocean Outfall Terminus, on 20 May 2005

I. Quadrat Survey	Percent Cover Quadrat Distance Along Transect 0 m	5 m	10 m	15 m	20 m
Algae					
Spyridia filamentosa	0.3	0.7			
Asparagopsis taxiformis	0.5		1.8		4.0
Sponges					
Chondrosia chucalla			0.4		
Spirastrella vagabunda		0.1	0.2		
Corals					
Porites lobata	0.5		0.1	7.0	0.2
Pocillopora meandrina	1.3	0.1		7.0	1.4
Montipora verrucosa			0.2		
Montipora patula				1.0	
Sand		4.0		3.0	
Hard Substratum	97.4	95.1	97.3	82.0	94.4

II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals
Phylum Mollusca	
Arca ventricosa	1
Conus imperialis	1
Phylum Annelida	
Spirobranchus giganteus corniculatus	5
Phylum Arthropoda	
Dardanus deformis	1
Phylum Echinodermata	
Echinostrephus aciculatum	8
Echinothrix diadema	2
Echinothrix calamaris	8
Tripneustes gratilla	1

III. Fish Census (4 m × 20 m)

9 Species
33 Individuals
Estimated Standing Crop = 5 g/m^2

NOTE: Results of the 5-m^2 quadrat sampling (visual appraisal) 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 presented in Part III. Water depth is 11.3 m; mean coral coverage is 3.8% (visual quadrat method).

The results of the fish census are presented in Appendix Table A.1. In total 9 fish species representing 33 individuals were censused at Transect BP-2-A. The most abundant fish species was the two-spot wrasse (*Oxycheilinus bimaculatus*). The standing crop of fishes was estimated at 5 g/m^2, with a single barred filefish or ‘ō‘ili (*Cantherhines dumerilii*) making up 48% of the total.

Transect BP-2-B

Transect BP-2-B was established at a distance varying from 17.5 to 26.2 m seaward of Transect BP-2-A (Figure 3). Table 5 presents the results of the visual quadrat survey (quadrat locations shown in Figure 3) carried out at Transect BP-2-B. One algal species (*Asparagopsis taxiformis*) with a mean coverage of 0.9%, three sponge species (*Spirastrella coccinea*, *Microciona maunaloa*, and *Chondrosia chucalla*) having a mean coverage of 0.1%, and five coral species (*Porites lobata*, *Pocillopora meandrina*, *P. damicornis*, *Montipora patula*, and *M. verrucosa*) were noted. Mean coral coverage was estimated at 2.9%. Noncolonial macroinvertebrates censused in the 4 m × 20 m transect include the pearl oyster *Pinctada margaritifera* and five echinoderm species (*Echinostrephus aciculatum*, *Echinothrix calamaris*, *E. diadema*, *Echinometra mathaei*, and *Tripneustes gratilla*).

The results of the photo-quadrat survey for Transect BP-2-B are given in Table 2. Three sponge species (*Chondrosia chucalla*, *Microciona maunaloa*, and *Spirastrella vagabunda*) provided a mean coverage of 0.08%, and two coral species (*Porites lobata* and *Pocillopora meandrina*) contributed a mean coverage of 3.1%.

The fish census noted 12 species of fishes representing 34 individuals (Appendix Table A.1). The most common species on this transect was the saddleback wrasse or hīnālea lauwili (*Thalassoma duperrey*), the twospot wrasse *Oxycheilinus bimaculatus*, and the smalltail wrasse *Pseudojuloides cerasinus*. Fish standing crop was estimated at 22 g/m^2, with the barred filefish or ‘ō‘ili (*Cantherhines dumerilii*) contributing 36% and the orangebar surgeonfish or na‘ena‘e (*Acanthurus olivaceus*) adding 32% to the total.

Station Observations

The relatively low numbers and low standing crop of fishes present at Transects BP-2-A and BP-2-B are probably related to the lack of local topographical relief that affords shelter for fishes. Similarly, the relatively higher abundance of noncolonial macroinvertebrates is also probably related to the lack of shelter, which makes their detection easier. In the vicinity of Station BP-2 were seen the corals *Pavona varians* and *Montipora verrilli*, the alga *Dictyosphaeria cavernosa*, the reef crab *Thalamita edwardsi*, the undulated moray eel *Gymnothorax undulatus*, and the elegant wrasse *Coris venusta*.

TABLE 5. Summary of Biological Observations Made at Transect BP-2-B, 0.25 km East of the Discharge Pipe and 1.6 km Inshore and Northeast of Barbers Point Ocean Outfall Terminus, on 20 May 2005

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Algae					
Asparagopsis taxiformis		0.3			4.0
Sponges					
Chondrosia chucalla		0.1		0.1	
Spirastrella coccinea				0.2	
Microciona maunaloa		0.3			
Corals					
Porites lobata	1.3	1.0		0.1	
Pocillopora meandrina	1.1	1.0	8.5	0.2	0.1
Pocillopora damicornis	0.2	0.1			
Montipora patula		0.9			
Montipora verrucosa			0.1		
Sand			1.0		
Hard Substratum	97.4	96.4	90.3	99.5	95.8

II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals
Phylum Mollusca	
Pinctada margaritifera	1
Phylum Echinodermata	
Echinostrephus aciculatum	14
Echinothrix diadema	2
Echinothrix calamaris	6
Echinometra mathaei	4
Tripneustes gratilla	1

III. Fish Census (4 m × 20 m)

12 Species
34 Individuals
Estimated Standing Crop = 22 g/m^2

NOTE: Results of the 5-m^2 quadrat sampling (visual appraisal) 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 presented in Part III. Water depth ranges from 11.6 to 11.9 m; mean coral coverage is 2.9% (visual quadrat method).

Station BP-3

Station BP-3 is located about 2.9 km west and inshore of the Barbers Point terminus (Figure 1). This western station is situated approximately 1.6 km offshore of the former Barbers Point Naval Air Station at a depth of 16.5 to 16.8 m. The substratum at this location is a mix of coral and rubble mounds or ridges with sand or flat limestone substratum between them. The ridges, which have an orientation that is approximately perpendicular to the shoreline, are 2 to 15 m in width, 4 to 40 m in length, and up to 0.75 m in height. The ridges are spaced 3 to 10 m apart; sand in depressions may occur on a scale from 3 to 10 m in width and up to about 30 m in length. Transect BP-3-A, established in water ranging from 16.5 to 16.8 m in depth, is approximately parallel to the shoreline; Transect BP-3-B is about 38 m seaward of Transect BP-3-A at a depth of 16.5 m (Figure 4). Water clarity is usually between 12 and 15 m.

Transect BP-3-A

Table 6 presents the results of the quantitative survey carried out at Transect BP-3-A. The visual quadrat survey (quadrat locations shown in Figure 4) noted one algal species (*Porolithon onkodes*) with a mean coverage of 0.8%, one encrusting sponge species (*Spirastrella coccinea*) having a mean coverage of 1.3%, and four coral species (*Porites lobata*, *P. compressa*, *Montipora patula*, and *Pocillopora meandrina*). Mean coral coverage at this location was estimated at 8.1% (visual quadrat method), and the dominant species was *Porites lobata*. Nine macroinvertebrate species were censused, including the boring bivalve *Arca ventricosa*, the rock oyster *Spondylus tenebrosus*, the Christmas tree worm *Spirobranchus giganteus corniculatus*, and six sea urchin species (*Echinothrix calamaris*, *E. diadema*, *Echinostrephus aciculatum*, *Echinometra mathaei*, *Heterocentrotus mammillatus*, and *Tripneustes gratilla*).

The results of the photo-quadrat analyses for Transect BP-3-A are presented in Table 2. One algal species *Porolithon onkodes* with a mean coverage of 0.2%, one sponge species (*Microciona maunaloa*) with a mean coverage of 0.5%, and three coral species (*Porites lobata*, *Montipora patula*, and *Pocillopora meandrina*) having a mean coverage of 4.0% were noted.

The results of the fish census at Transect BP-3-A are presented in Appendix Table A.1. Twenty-five species representing 122 individuals were censused. The most abundant fish species were the manybar goatfish or moano (*Parupeneus multifasciatus*), and the brown surgeonfish or māʻiʻi (*Acanthurus nigrofuscus*). The standing crop was estimated at 75 g/m^2, with *P. multifasciatus* contributing 32% to the total, the saddleback wrasse or hīnālea lauwili (*Thalassoma duperrey*) adding 6%, and *A. nigrofuscus* also adding 10%.

TABLE 6. Summary of Biological Observations Made at Transect BP-3-A, 2.9 km West and Inshore of Barbers Point Ocean Outfall Terminus, on 23 May 2005

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Algae					
Porolithon onkodes		1.0		3.0	
Sponges					
Spirastrella coccinea		4.0		2.5	
Corals					
Porites lobata		5.8		16.5	0.2
Porites compressa				1.5	
Pocillopora meandrina		12.0		3.0	0.8
Montipora patula					0.7
Sand	5.0		3.0		2.5
Rubble	95.0	27.0	97.0	8.0	86.8
Hard Substratum		50.2		65.5	9.0

II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals
Phylum Mollusca	
Arca ventricosa	11
Spondylus tenebrosus	2
Phylum Annelida	
Spirobranchus giganteus corniculatus	12
Phylum Echinodermata	
Echinothrix calamaris	7
Echinothrix diadema	34
Echinostrephus aciculatum	1
Echinometra mathaei	3
Heterocentrotus mammillatus	4
Tripneustes gratilla	4

III. Fish Census (4 m × 20 m)

25 Species
122 Individuals
Estimated Standing Crop = 75 g/m^2

NOTE: Results of the 5-m^2 quadrat sampling (visual appraisal) 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 presented in Part III. Water depth ranges from 16.5 to 16.8 m; mean coral coverage is 8.1% (visual quadrat method).

Transect BP-3-B

Transect BP-3-B is located approximately 38 m seaward of Transect BP-3-A (Figure 4). Table 7 presents the results of the quantitative survey (quadrat locations shown in Figure 4) carried out at this transect. Six coral species (*Porites lobata*, *P. compressa*, *Pocillopora meandrina*, *P. damicornis*, *Montipora patula*, and *M. verrucosa*) were noted in the quadrat survey. Coral coverage at this transect was estimated at 8.4% (visual quadrat method). Six species of macroinvertebrates were censused in the 4 m × 20 m area, including the boring bivalve *Arca ventricosa*, the rock oyster *Spondylus tenebrosus*, the Christmas tree worm *Spirobranchus giganteus corniculatus*, and three sea urchin species (*Echinothrix calamaris, E. diadema*, and *Tripneustes gratilla*).

Table 2 presents the results of the photo-quadrat survey carried out at Transect BP-3-B. Noted were one coralline algal species (*Porolithon onkodes*) having a mean coverage of 0.2%, one sponge species (*Microciona maunaloa*) with a mean coverage of 0.6%, and two coral species (*Porites lobata* and *Pocillopora meandrina*) having a mean coverage of 13.6%.

The results of the fish census carried out at Transect BP-3- B are presented in Appendix Table A.1. In total 19 species representing 130 individuals were counted, with the most abundant fishes including the palenose parrotfish or uhu (*Scarus psittacus*), the brown surgeonfish or mā‘i‘i‘i (*Acanthurus nigrofuscus*), the Hawaiian dascyllus or ‘ālo‘ilo‘i (*Dascyllus albisella*), and the goldring surgeonfish or kole (*Ctenochaetus strigosus*). The standing crop of fishes was estimated at 79 g/m^2, with the species contributing most heavily including a single peacock grouper or roi (*Cephalopholis argus*—comprising 17% of the total), the saddleback wrasse or hīnālea lauwili (*Thalassoma duperrey*—11%), and *S. psittacus* (30%).

Station Observations

In the vicinity of Station BP-3 were seen the coral *Montipora flabellata*, the cardinalfish or ‘upāpalu (*Apogon kallopterus*), the crown squirrelfish or ‘ala‘ihi (*Adioryx diadema*), and the cone shell *Conus imperialis*.

Station BP-4

Station BP-4 was established on 10 September 1993 with two transects placed on and adjacent to the basalt caprock shield that covers and protects the discharge pipe. It is located approximately 250 m west of Station BP-2 in 15.2 to 17.7 m of water and approximately 1.4 km shoreward (northeast) of the outfall terminus (Figure 1). Transect BP-4-A was established on top of the caprock shield, and Transect BP-4-B is located approximately 19.0 to 27.0 m to the east on the adjacent flat natural limestone substratum.

TABLE 7. Summary of Biological Observations Made at Transect BP-3-B, 3.3 km West and Inshore of Barbers Point Ocean Outfall Terminus, on 23 May 2005

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Corals					
Porites lobata	5.5	8.5	0.2	6.0	1.2
Porites compressa	1.8				0.3
Pocillopora meandrina	3.2	2.4		7.5	
Pocillopora damicornis	0.1				
Montipora verrucosa	0.1	0.1			
Montipora patula		4.0		1.2	
Sand		2.0	2.5	4.0	3.0
Rubble	64.3	69.0	97.3	68.3	83.5
Hard Substratum	25.0	14.0		13.0	12.0

II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals
Phylum Mollusca	
Spondylus tenebrosus	1
Arca ventricosa	5
Phylum Annelida	
Spirobranchus giganteus corniculatus	28
Phylum Echinodermata	
Echinothrix diadema	28
Echinothrix calamaris	3
Tripneustes gratilla	39

III. Fish Census (4 m × 20 m)

19 Species
130 Individuals
Estimated Standing Crop = 79 g/m^2

NOTE: Results of the 5-m^2 quadrat sampling (visual appraisal) 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 presented in Part III. Water depth is 16.5 m; mean coral coverage is 8.4% (visual quadrat method).

Transect BP-4-A

Transect BP-4-A was established on the basalt capstones that serve to protect the discharge pipe from storm damage. The capstones at this site range in size from 0.5 m to more than 1.0 m in dimensions and are spaced from overlapping contact with one another to about 2 m apart. The open areas between the capstones are comprised of sand and loose coral rubble. Water depth to the top of the capstones is 12.2 m. This transect has an orientation that follows the discharge pipe and is thus roughly perpendicular to the shoreline (Figure 5).

The results of the quantitative survey carried out at Transect BP-4-A are given in Table 8. The visual quadrat survey (quadrat locations shown in Figure 5) noted one algal species (*Porolithon onkodes*) with a mean coverage of 4.5%, and two coral species (*Porites lobata* and *P. compressa*) having a mean coverage of 36.8%. The census of macroinvertebrates noted four species: the rock bivalve *Spondylus tenebrosus*, the Christmas tree worm *Spirobranchus giganteus corniculatus*, the long-spined black sea urchin *Echinothrix diadema*, and the black sea urchin *Tripneustes gratilla*.

The results of the photo-quadrat survey are given in Table 2. Noted were one coralline algal species (*Porolithon onkodes*) having a mean coverage of 1.6%, and one coral species (*Porites lobata*) having a mean coverage of 25.4%.

The results of the fish census carried out at Transect BP-4-A are presented in Appendix Table A.1. Thirty-three species representing 1,080 individuals having an estimated biomass of 1,239 g/m^2 were censused. The most abundant fish species included the Hawaiian dascyllus or ‘ālo‘ilo‘i (*Dascyllus albisella*), the sergeant major or mamo (*Abudefduf abdominalis*), the bluelined snapper or ta‘ape (*Lutjanus kasmira*), the brick soldierfish or mempachi (*Myripristis amaena*), the sleek unicornfish or kala holo (*Naso hexacanthus*), and the milletseed butterflyfish or lau wiliwili (*Chaetodon miliaris*). Species contributing most to the estimated standing crop included *L. kasmira* (67% of the total), *N. hexacanthus* (9%), and *M. amaena* (5%).

Transect BP-4-B

Transect BP-4-B was established approximately 19.0 to 27.0 m east of Transect BP-4-A in 17.7 m of water. This transect has an orientation that is parallel to Transect BP-4-A and perpendicular to the shoreline. The substratum at this transect is flat limestone with very little relief. A sand/coral rubble veneer overlies portions of the limestone; this veneer does not usually exceed 2 cm in thickness and may cover up to 50 m^2. These patches of sand are spaced 5 to 50 m apart.

The results of the quantitative assessment carried out at Transect BP-4-B are presented in Table 9. The visual quadrat survey (quadrat locations shown in Figure 5) noted two

TABLE 8. Summary of Biological Observations Made at Transect BP-4-A, Situated on the Basalt Caprock of the Barbers Point Discharge Pipe, Approximately 1.4 km Inshore (North) of Barbers Point Ocean Outfall Terminus, on 20 May 2005

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Algae					
Porolithon onkodes	1.5	5.0	5.0	4.0	7.0
Corals					
Porites lobata	47.0	39.0	44.0	19.0	33.0
Porites compressa	2.0				
Hard Substratum	49.5	56.0	51.0	77.0	60.0

II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals
Phylum Mollusca	
Spondylus tenebrosus	6
Phylum Annelida	
Spirobranchus giganteus corniculatus	19
Phylum Echinodermata	
Echinothrix diadema	120
Tripneustes gratilla	8

III. Fish Census (4 m × 20 m)

33 Species
1,080 Individuals
Estimated Standing Crop = 1,239 g/m^2

NOTE: Results of the 5-m^2 quadrat sampling (visual appraisal) 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 presented in Part III. Water depth ranges from 15.2 to 15.8 m; mean coral coverage is 36.8% (visual quadrat method).

TABLE 9. Summary of Biological Observations Made at Transect BP-4-B, Situated on Smooth Limestone Substratum 15 m East of the Basalt Caprock of the Barbers Point Discharge Pipe, Approximately 1.4 km Inshore (North) of Barbers Point Ocean Outfall Terminus, 20 May 2005

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Sponges					
Spirastrella coccinea	1.2	0.5	1.0	1.0	
Chondrosia chucalla		1.0			
Corals					
Porites lobata	6.0	2.0	2.4	4.0	4.0
Pocillopora meandrina	1.5	1.0	3.5	2.2	7.0
Montipora verrucosa	1.1			0.5	0.2
Montipora patula	22.0		1.0	3.0	
Leptastrea purpurea		1.4			
Hard Substratum	68.2	94.1	92.1	89.3	88.8

II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals
Phylum Mollusca	
Spondylus tenebrosus	1
Pinctada margaritifera	1
Conus lividus	1
Phylum Annelida	
Spirobranchus giganteus corniculatus	13
Phylum Echinodermata	
Echinostrephus aciculatum	7
Echinothrix diadema	91

III. Fish Census (4 m × 20 m)

11 Species
60 Individuals
Estimated Standing Crop = 34 g/m^2

NOTE: Results of the 5-m^2 quadrat sampling (visual appraisal) 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 presented in Part III. Water depth is 17.7 m; mean coral coverage is 12.6% (visual quadrat method).

encrusting sponge species (*Spirastrella coccinea* and *Chondrosia chucalla*) having a mean coverage of 0.9%, and five coral species (*Porites lobata*, *Pocillopora meandrina*, *Leptastrea purpurea*, *Montipora verrucosa*, and *M. patula*) with a mean coverage of 12.6%. The macroinvertebrate census noted the black-lipped pearl oyster or pā (*Pinctada margaritifera*), the rock oyster *Spondylus tenebrosus*, the cone shell *Conus lividus*, the Christmas tree worm *Spirobranchus giganteus corniculatus*, and two sea urchin species (*Echinothrix diadema* and *Echinostrephus aciculatum*).

The results of the photo-quadrat survey carried out at Transect BP-4-B are given in Table 2. Noted were one sponge species (*Plakortis simplex*) with a mean coverage of 0.3% and three coral species (*Porites lobata*, *Pocillopora meandrina*, and *Montipora patula*) having a mean coverage of 8.2%.

The results of the fish census carried out at Transect BP-4-B are presented in Appendix Table A.1. Eleven species of fishes representing 60 individuals having an estimated standing crop of 34 g/m^2 were encountered. The most abundant fish species at this transect were the orangebar surgeonfish or na‘ena‘e (*Acanthurus olivaceus*), the Hawaiian dascyllus or ‘ālo‘ilo‘i (*Dascyllus albisella*), and the gilded triggerfish *Xanthichthys auromarginatus*. The major contributors to the estimated standing crop included *X. auromarginatus* (29% of the total) and *A. olivaceus* (54%).

Station Observations

In the vicinity of Station BP-4 were seen the helmet shell *Cassis cornuta*, the cone shell *Conus leopardus*, the blue goatfish or moano kea (*Parupeneus cyclostomus*), and the flagtail tilefish or maka‘ā (*Malacanthus brevirostris*).

Physical Measurements and Biological Parameters

Physical measurements made in the morning on 27 May 2005 are presented in Table 10.

Little variation was noted in temperature (24.7° to 25.1°C), oxygen saturation (96% to 100%), 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 visible on the bottom. Probably a better method of determining water clarity would be to collect water samples and measure turbidity with a nephalometer in the laboratory. The salinity measurements were made 30 cm below the water surface.

The biological data for the fourteen annual surveys are summarized as means for each transect in Table 11. The means of all biological parameters measured in these surveys (i.e.,

TABLE 10. Summary of Physical Measurements Made at Each Station in the Vicinity of Transect Pairs, 2 October 1991, 16 September 1993, 28 April 1994, 22 June 1995, 20 May 1996, 27 February 1997, 5 February 1998, 27 January 1999, 16 May 2000, 9 July 2001, 30 May 2002, 19 March 2003, 17 March 2004, and 27 May 2005

Location and Time	Oxygen (% of Saturation)		Salinity (‰)	Temperature (°C)		Depth to Secchi Extinction (m)
	Top	Bottom		Top	Bottom	
2 OCTOBER 1991						
Station BP-1						
1000 hr	103	102	34	25.3	25.1	>15.0
Station BP-2						
1025 hr	101	101	34	25.0	24.9	>11.0
Station BP-3						
1110 hr	102	102	34	25.4	25.2	>16.5
16 SEPTEMBER 1993						
Station BP-1						
0945 hr	102	101	34	25.4	25.1	>15.0
Station BP-2						
1020 hr	103	102	34	25.5	25.2	>11.0
Station BP-3						
1100 hr	103	100	34	25.7	25.4	>16.5
Station BP-4						
1040 hr	102	102	34	25.5	25.4	>13.0
28 APRIL 1994						
Station BP-1						
0930 hr	103	102	34	23.1	23.0	>15.0
Station BP-2						
1010 hr	102	101	34	22.7	23.0	>11.0
Station BP-3						
1100 hr	101	101	34	23.0	23.0	>16.5
Station BP-4						
1040 hr	103	103	34	23.1	23.0	>13.0
22 JUNE 1995						
Station BP-1						
0930 hr	102	102	34	25.5	25.3	>15.0
Station BP-2						
1015 hr	104	103	34	25.6	25.5	>11.0
Station BP-3						
1110 hr	102	103	34	25.0	25.0	>16.5
Station BP-4						
1050 hr	102	102	34	25.3	25.4	>13.0
20 MAY 1996						
Station BP-1						
0945 hr	102	101	34	25.1	24.9	>15.0
Station BP-2						
1030 hr	102	102	34	25.3	25.2	>11.0
Station BP-3						
1115 hr	102	103	34	25.2	25.2	>16.5
Station BP-4						
1215 hr	101	102	34	25.4	25.2	>13.0

TABLE 10—*Continued*

Location and Time	Oxygen (% of Saturation)		Salinity (‰)	Temperature (°C)		Depth to Secchi Extinction (m)
	Top	Bottom		Top	Bottom	
27 FEBRUARY 1997						
Station BP-1						
1000 hr	103	103	34	25.4	25.0	>15.0
Station BP-2						
1030 hr	102	103	34	25.5	25.3	>11.0
Station BP-3						
1215 hr	103	101	34	25.3	25.2	>16.5
Station BP-4						
1100 hr	103	102	34	25.4	25.1	>13.0
5 FEBRUARY 1998						
Station BP-1						
0930 hr	101	102	34	24.4	24.4	>15.0
Station BP-2						
1000 hr	102	103	34	24.2	24.1	>11.0
Station BP-3						
1100 hr	103	102	34	24.5	24.3	>16.5
Station BP-4						
1030 hr	101	102	34	24.1	24.2	>13.0
27 JANUARY 1999						
Station BP-1						
0810 hr	100	100	34	25.1	24.8	>15.0
Station BP-2						
0840 hr	102	100	34	24.6	24.5	>11.0
Station BP-3						
0925 hr	100	102	34	24.9	24.8	>16.5
Station BP-4						
1010 hr	101	101	34	24.8	24.4	>13.0
16 MAY 2000						
Station BP-1						
0830 hr	100	101	34	25.5	25.2	>15.0
Station BP-2						
0850 hr	101	101	34	25.6	25.3	>11.0
Station BP-3						
0925 hr	102	100	34	25.3	25.3	>16.5
Station BP-4						
1010 hr	101	101	34	25.4	25.3	>13.0
9 JULY 2001						
Station BP-1						
0910 hr	100	101	34	25.2	25.2	>15.0
Station BP-2						
0945 hr	102	102	34	25.3	25.1	>11.0
Station BP-3						
1100 hr	101	102	34	25.4	25.2	>16.5
Station BP-4						
1015 hr	101	101	34	25.2	25.3	>13.0

TABLE 10—*Continued*

Location and Time	Oxygen (% of Saturation)		Salinity (‰)	Temperature (°C)		Depth to Secchi Extinction (m)
	Top	Bottom		Top	Bottom	
30 MAY 2002						
Station BP-1						
1400 hr	101	99	34	24.9	25.0	>15.0
Station BP-2						
1430 hr	102	101	34	24.9	25.1	>11.0
Station BP-3						
1500 hr	100	100	34	25.0	25.0	>16.5
Station BP-4						
1555 hr	97	101	34	24.9	24.9	>13.0
19 MARCH 2003						
Station BP-1						
0920 hr	100	100	34	23.9	23.6	>15.0
Station BP-2						
0940 hr	101	99	34	23.7	23.5	>11.0
Station BP-3						
1040 hr	96	100	34	23.8	23.2	>16.5
Station BP-4						
1005 hr	97	101	34	23.5	23.3	>13.0
17 MARCH 2004						
Station BP-1						
0905 hr	100	101	34	23.1	23.0	>15.0
Station BP-2						
0930 hr	100	100	34	23.0	22.9	>11.0
Station BP-3						
1025 hr	99	98	34	24.0	23.4	>16.5
Station BP-4						
1000 hr	98	100	34	23.6	23.2	>13.0
27 MAY 2005						
Station BP-1						
0810 hr	99	100	34	24.9	24.9	>15.0
Station BP-2						
0840 hr	100	97	34	25.0	25.0	>11.0
Station BP-3						
1020 hr	100	99	34	25.1	24.7	>16.5
Station BP-4						
0915 hr	98	96	34	25.0	24.8	>13.0

NOTE: Oxygen and temperature measurements were made approximately 1 m below the surface and 1 m above the bottom; water clarity at all stations was greater than the depth, thus extinction could not be directly measured.

TABLE 11. Summary of the Biological Parameters Measured at Stations Sampled in August 1991, May and September 1993, April 1994, June 1995, May 1996, February 1997, January 1998, January 1999, May 2000, July 2001, May 2002, March 2003, February 2004, and May 2005

Transect	% Algal Cover						
	1991	1993	1994	1995	1996	1997	1998
BP-1-A	4.2	0.5	1.3	0.7	0.4	1.7	0.0
BP-1-B	6.1	0.4	0.3	0.6	0.3	0.1	1.6
BP-2-A	0.5	0.9	0.1	0.9	0.6	0.5	2.0
BP-2-B	0.3	0.9	0.3	1.3	0.6	1.0	0.9
BP-3-A	3.0	0.0	0.0	0.0	0.0	0.8	0.0
BP-3-B	0.3	0.0	0.0	0.0	0.0	0.0	0.0
BP-4-A		0.0	3.5	2.0	1.2	0.7	1.2
BP-4-B		0.7	0.0	0.0	0.1	0.0	0.5
Mean	2.4	0.4	0.7	0.7	0.4	0.6	0.8

Transect	% Algal Cover						
	1999	2000	2001	2002	2003	2004	2005
BP-1-A	1.9	1.0	2.2	2.4	3.7	7.6	5.8
BP-1-B	0.7	0.8	1.2	2.1	1.2	3.3	0.8
BP-2-A	0.0	0.0	3.0	0.1	1.0	0.2	1.5
BP-2-B	0.3	0.2	5.9	0.6	0.5	0.7	0.9
BP-3-A	0.4	0.0	0.5	0.5	1.9	1.3	0.8
BP-3-B	0.0	0.0	0.0	0.2	0.4	0.2	0.0
BP-4-A	2.4	2.4	1.5	2.9	1.8	4.5	4.5
BP-4-B	0.1	0.0	0.0	0.5	0.4	0.0	0.9
Mean	0.7	0.6	1.8	1.2	1.4	2.2	1.9

Transect	% Coral Cover						
	1991	1993	1994	1995	1996	1997	1998
BP-1-A	23.3	15.5	17.4	17.0	15.0	14.6	15.7
BP-1-B	29.4	7.1	22.0	25.3	23.7	13.6	16.5
BP-2-A	3.6	2.2	0.9	1.0	1.0	1.0	0.7
BP-2-B	2.7	1.1	0.9	0.6	0.5	0.6	1.3
BP-3-A	8.0	4.6	8.1	6.5	5.2	4.0	5.2
BP-3-B	11.6	3.2	3.3	2.4	2.6	7.1	7.0
BP-4-A		19.7	26.9	28.1	27.8	27.3	21.6
BP-4-B		0.1	3.7	4.3	6.2	5.8	5.7
Mean	13.1	6.7	10.4	10.7	10.3	9.3	9.2

TABLE 11—*Continued*

Transect	% Coral Cover						
	1999	2000	2001	2002	2003	2004	2005
BP-1-A	18.7	18.5	12.2	13.3	15.8	11.7	14.8
BP-1-B	13.1	11.1	10.8	11.4	9.7	8.7	14.4
BP-2-A	1.4	3.2	1.4	4.9	4.2	4.6	3.7
BP-2-B	1.1	2.4	1.7	2.0	1.7	2.9	2.9
BP-3-A	9.2	6.7	9.7	5.9	6.3	8.2	8.1
BP-3-B	5.2	5.9	5.3	7.7	7.5	10.0	8.4
BP-4-A	40.0	31.3	28.6	32.9	33.6	27.5	36.8
BP-4-B	8.0	7.7	9.6	11.1	11.9	11.9	12.6
Mean	12.1	10.9	9.9	11.2	11.3	10.7	12.7

Transect	No. of Coral Species													
	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
BP-1-A	3	5	5	6	5	6	7	5	5	5	6	6	5	5
BP-1-B	3	4	5	6	6	7	5	6	7	8	7	7	6	8
BP-2-A	3	2	1	2	2	3	3	5	5	5	6	5	6	4
BP-2-B	3	3	4	2	2	3	3	4	6	4	4	5	4	5
BP-3-A	4	5	4	5	4	4	5	5	5	3	5	5	2	4
BP-3-B	5	4	5	4	5	5	5	5	5	6	5	6	5	6
BP-4-A		4	3	1	2	3	2	2	2	2	3	3	3	2
BP-4-B		2	3	3	4	3	4	4	6	5	6	5	5	5
Mean	4	4	4	4	4	4	4	5	5	5	5	5	5	5

Transect	No. of Macroinvertebrate Species													
	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
BP-1-A	4	4	8	7	6	5	5	8	7	10	8	8	8	7
BP-1-B	2	4	4	6	6	6	7	7	5	6	6	8	6	5
BP-2-A	6	7	3	6	5	5	7	5	6	7	7	8	8	8
BP-2-B	4	4	6	7	7	4	5	6	7	8	11	8	5	6
BP-3-A	8	9	6	6	8	7	6	9	10	12	13	9	3	9
BP-3-B	6	6	8	6	7	6	9	8	10	9	10	8	8	6
BP-4-A		6	7	9	7	6	8	7	7	7	3	3	4	4
BP-4-B		2	2	4	4	3	5	8	7	7	10	6	7	6
Mean	5	5	6	6	6	5	7	7	7	8	9	7	6	6

TABLE 11—*Continued*

Transect	No. of Fish Species						
	1991	1993	1994	1995	1996	1997	1998
BP-1-A	47	41	39	38	34	38	35
BP-1-B	42	44	42	38	40	34	33
BP-2-A	10	6	5	9	7	8	19
BP-2-B	6	12	11	15	12	15	7
BP-3-A	38	28	26	35	26	33	27
BP-3-B	30	17	18	29	27	26	30
BP-4-A		49	51	48	52	42	50
BP-4-B		2	10	10	12	13	17
Mean	29	25	25	28	26	26	27

Transect	No. of Fish Species						
	1999	2000	2001	2002	2003	2004	2005
BP-1-A	34	41	43	36	31	28	23
BP-1-B	41	37	48	42	39	32	28
BP-2-A	6	9	8	9	10	7	9
BP-2-B	11	14	12	9	10	17	12
BP-3-A	28	31	30	26	25	30	25
BP-3-B	29	23	25	30	25	28	19
BP-4-A	38	41	40	37	35	37	33
BP-4-B	18	20	13	18	12	10	11
Mean	26	27	27	26	23	24	20

Transect	No. of Fish Individuals						
	1991	1993	1994	1995	1996	1997	1998
BP-1-A	745	375	386	355	293	382	463
BP-1-B	453	488	371	410	370	428	608
BP-2-A	21	6	7	22	11	10	87
BP-2-B	12	21	36	68	43	118	13
BP-3-A	367	82	191	189	320	213	224
BP-3-B	187	161	109	156	393	302	473
BP-4-A		537	1,563	943	1,247	1,081	2,137
BP-4-B		3	15	96	67	52	123
Mean	298	209	335	280	343	323	516

TABLE 11—*Continued*

Transect	No. of Fish Individuals						
	1999	2000	2001	2002	2003	2004	2005
BP-1-A	558	548	384	358	175	576	183
BP-1-B	419	725	320	273	627	1,165	704
BP-2-A	13	18	14	19	16	15	33
BP-2-B	33	37	27	27	22	48	34
BP-3-A	192	193	146	162	173	157	122
BP-3-B	199	145	135	247	167	342	130
BP-4-A	971	892	718	597	1,222	640	1,080
BP-4-B	57	149	83	144	89	104	60
Mean	305	338	228	228	311	381	293

Transect	Fish Biomass (g/m^2)						
	1991	1993	1994	1995	1996	1997	1998
BP-1-A	406	249	222	108	115	251	325
BP-1-B	374	490	202	109	290	471	141
BP-2-A	7	9	2	11	9	12	44
BP-2-B	2	11	25	26	56	168	9
BP-3-A	343	70	255	157	176	236	231
BP-3-B	121	311	445	128	282	550	499
BP-4-A		374	1,305	440	685	821	1,263
BP-4-B		1	12	16	27	1,027	115
Mean	209	189	309	124	205	442	328

Transect	Fish Biomass (g/m^2)						
	1999	2000	2001	2002	2003	2004	2005
BP-1-A	124	393	321	117	116	665	79
BP-1-B	211	427	330	161	828	1,573	800
BP-2-A	15	12	3	9	5	6	5
BP-2-B	31	41	16	9	11	40	22
BP-3-A	358	155	236	84	102	51	75
BP-3-B	359	213	111	118	218	497	79
BP-4-A	893	701	579	703	1,457	413	1,239
BP-4-B	62	280	22	73	42	62	34
Mean	257	278	202	159	347	413	292

NOTE: Coral and algal percent cover as well as the number of coral species are from the photo-quadrats in the 1991 dataset; all other data are from the 4 m × 20 m area visually assessed at each transect site. Transects BP-4-A and BP-4-B were first sampled in September 1993.

percent algal and coral cover; number of coral, other macroinvertebrate, and fish species; number of individual fish; and biomass of fishes) showed a general decline between the 1991 and 1993 surveys and an increasing or leveling off trend since 1993. The early decreases in means may have been related to impacts created by Hurricane Iniki in September 1992, and the increases since the 1993 survey may be related to the recovery in these communities. The changes in fish biomass means are probably not related to impacts from the hurricane. The low means may be related to greater fishing pressure, whereas the higher means are probably related to chance encounters with large (heavy) roving predators or large schools of certain fish species. The fish biomass mean peaked in 1997, when a large subadult sandbar shark (*Carcharhinus milberti*) accounted for 83% of the biomass at Transect BP-4-B. The Kruskal–Wallis analysis of variance (ANOVA) applied to the annual mean data (combining all transects during an annual sampling period for each parameter; see Table 11) showed that there have been no statistically significant changes (where significance is given at $p = 0.05$ or less) in the mean percent cover by algae ($p > 0.37$, not significant), the mean percent cover by coral ($p > 0.98$, not significant), the mean number of coral species ($p > 0.13$, not significant), the mean number of fish species ($p > 0.99$, not significant), the mean number of individual fish ($p > 0.99$, not significant), and the mean standing crop of fish expressed in grams per square meter ($p > 0.89$, not significant). The Kruskal–Wallis ANOVA noted significant differences in the mean number of macroinvertebrate species per transect among the fourteen annual surveys ($p > 0.01$, significant). The Student–Newman–Keuls (SNK) test separates means that are statistically significantly from those that are not; in this case, the mean number of macroinvertebrate species per transect was significantly greater in 2002 (mean = 8.5 species/transect) than in 1991 (mean = 5.0 species/transect). However, this statistical separation is not strong because the means of the other years are related to these two extremes in the test.

From 1993 through the most recent survey years, 5 m^2 of substratum were visually assessed with a 1 m × 1 m quadrat on each transect. In 1991, 8.1 m^2 (2.7 m^2 at three locations on each transect) of substratum were surveyed using photography. A summary of the coral cover data collected using these methods is presented in Appendix Table A.2. Has there been any significant change in mean coral cover on each of the individual transects over the period of this study? Using the Kruskal–Wallis ANOVA, mean coral cover as measured at each transect over time was shown to have not changed significantly at Transects BP-1-A ($p > 0.99$, not significant), BP-1-B ($p > 0.94$, not significant), BP-2-A ($p > 0.61$, not significant), BP-2-B ($p > 0.11$, not significant), BP-3-A ($p > 0.96$, not significant), BP-3-B ($p > 0.54$, not significant), and BP-4-A ($p > 0.41$, not significant) using the Kruskal–Wallis ANOVA. The mean coral cover was shown to have changed significantly at Transect BP-4-B

($p > 0.02$, significant), but the SNK test did not show mean coral cover for any year at this transect as being significantly different. However, the change in mean coral cover through time at Transect BP-4-B probably does have some biological meaning. The lowest mean coral cover there (0.1%) was recorded in 1993 (after the hurricane) and the highest (12.6%) in 2005. This increase through the years (see Appendix Table A.2) supports the contention that the operation of the Barbers Point outfall has had no detrimental impact on the coral community inshore of the outfall. The conclusion is that coral cover has varied on each transect and quadrat but has not changed significantly through the course of this study, despite the imposition of a hurricane in 1992 and the continuous operation of the outfall.

In general, the topographic complexity of the substratum is much greater at Transects BP-1-A and -B, BP-3-A and -B, and BP-4-A than at the other transects (i.e., BP-2-A and -B, and BP-4-B) surveyed in this study. The low diversity of fishes at the latter transects is not surprising in view of the little topographical relief present at those locations.

From a commercial fisheries standpoint, a number of important species have been encountered at several of the transect sites during the different survey years; this group includes the brick soldierfish or mempachi (*Myripristis amaena*), the bigeye or ‘āweoweo (*Priacanthus cruentatus*), the grey snapper or uku (*Aprion virescens*), the emperor fish or mu (*Monotaxis grandoculis*), the sidespot goatfish or malu (*Parupeneus pleurostigma*), the manybar goatfish or moano (*Parupeneus multifasciatus*), the blue goatfish or moano kea (*Parupeneus cyclostomus*), the yellowfin goatfish or weke‘ula (*Mulloidichthys vanicolensis*), the spiny lobsters or ula (*Panulirus penicillatus* and *P. marginatus*), and the octopus or he‘e (*Octopus cyanea*).

Green Sea Turtle Observations

Two green turtles (*Chelonia mydas*) were encountered during the 2005 field survey. Both of these individuals were seen resting on the bottom at Transect BP-1-B on 20 May, and both had an estimated straight-line carapace length of 75 cm. Neither turtle appeared to have a tag or any tumors. In general, individual turtles are commonly seen surfacing for air while transiting from Honolulu Harbor to ‘Ewa Beach. Most of the individuals seen appear to be subadults. Also seen at Station BP-1 was a pod of about 40 spinner porpoises (*Stenella longirostris*) moving in an easterly direction at 0740 hours on 20 May. At 0830 hours on 23 May, a smaller pod of spinner porpoises, also moving in an easterly direction, was seen at Station BP-3.

DISCUSSION

On 11 September 1992, Hurricane Iniki struck the Hawaiian islands. The hurricane passed directly over Kaua‘i, with sustained winds of 144 mph and gusts to 172 mph causing considerable damage to improvements and forests on that island and the west (leeward) coast of O‘ahu. To a lesser extent, high surf caused damage to marine communities along the southern, eastern, and western shores of O‘ahu, Kaua‘i, Maui, Lāna‘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 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; Connell 1978; Walsh 1983), and the occasional storm event generating high surf is one of the most important parameters that determine the structure of Hawai‘i coral communities (Dollar 1982). Because Hawai‘i corals are relatively slow growing, storm events need only to occur infrequently (ca. every 20 to 50 years) to be a major structuring force (Grigg 1983). Corals may provide the topographical relief and shelter necessary for fish community development. Numerous studies have shown that storm-generated surf may keep coral reefs in a nonequilibrium or subclimactic state (Grigg and Maragos 1974; Connell 1978; Woodley et al. 1981; Grigg 1983). The large expanses of near-featureless lava or limestone substratum present around much of the Hawaiian islands at less than 30 m depths attest to the force and frequency of these events (Brock and Norris 1989). These wave forces also impinge upon and impact fish communities (Walsh 1983).

Hurricane Iniki caused damage to coral communities at all four study sites. The greatest impact occurred to the benthic communities at Station BP-3, where many coral colonies completely disappeared or were reduced to rubble. 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 of rubble buried coral colonies or killed the lower portions of larger colonies. The hurricane broke many coral colonies into pieces; some of these have survived where they have been lodged into the substratum. These live fragments are responsible for local increases in the diversity of species, and this fragmentation serves as a viable means of reproduction and dispersal for some coral species (Highsmith 1982). Coral rubble and live fragments fill in depressions and holes that otherwise serve as shelter for cryptic fish and invertebrates, thus reducing the complexity of the habitat. This usually results in a decrease in the diversity of species present and may explain some of the declines seen between the 1991 and 1993 surveys. Despite the large changes that occurred in the coral communities of the Barbers Point region, many of the benthic components survived and the communities are well into the process of recovery, as evidenced by the new coral recruits seen at all stations. However, since Hawaiʻi corals are relatively slow growing, it will be years before the impact of Hurricane Iniki will no longer be evident in the benthic communities at the study sites.

The results from the fourteen annual surveys showed that the coral and fish communities are better developed at the eastern (BP-1) and western (BP-3) stations relative to the middle station (BP-2). The relatively scoured appearance of the substratum and poor coral development at Station BP-2 suggest that this area receives occasional wave impact, which curtails the development of the coral community. The poor coral development results in a lack of topographical complexity. This lack of appropriate shelter translates into poor development of the fish community at that location. From the shoreline to a depth of about 20 m, the Barbers Point discharge pipe is buried in a trench and covered with armor rock. This armor rock cover is very incomplete from the shoreline to a depth of about 12 m; from that point seaward, it forms low mounds (up to 1.5 m above the surrounding substratum) that overlie the buried pipe. If the movement of sand over the relatively flat and featureless limestone substratum is causing sand scour that retards the development of the coral community, it follows that corals should be common on the armor rock that rises above the substratum. In this setting, benthic species (such as corals) settling on this rock would be elevated above and out of the influence of the abrasion and scour that otherwise occurs on the surrounding substratum. Similarly, if sewage effluent is playing a role in preventing corals from growing on the limestone and armor rock, then corals should be rare or absent at both locations.

To test these hypotheses Station BP-4 was established in 1993, with Transect BP-4-A on the basalt armor rock of the discharge alignment and Transect BP-4-B approximately 19 to 27 m to the east on the flat limestone substratum. As noted in the Results section, the survey data show that the benthic and fish communities are well developed on the elevated armor rock and less well developed on the adjacent limestone flat that is subjected to periodic scouring. Also apparent is the fact that the corals at Transect BP-4-A show a considerable range in size on the armor rock; the largest corals are no older than the time of outfall construction when the armor rock was placed, and the smaller corals represent more recent recruitment events. Thus the range in sizes of corals shows that their recruitment has continued despite the operation of the outfall.

The working hypothesis is that all four study sites, being situated in relatively shallow water, are outside of the zone of influence of the present Barbers Point deep-water outfall. However, if impacts from the present outfall are occurring on 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 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 nonpoint sources of pollution for years. In general, the nearshore currents parallel the shoreline and have a net westerly movement along the coastline (Laevastu et al. 1964); thus stream and industrial inputs from Honolulu Harbor, Keʻehi Lagoon, and Pearl Harbor situated to the east would be carried in a westerly direction toward the area offshore of ʻEwa Beach. Also, from 1955 to 1977 the old Honolulu sewer outfall (located 15 km to the east of the present study area) released 62 mgd (3 m^3/s) of raw sewage in 10 m of water offshore of Sand Island. This material was undoubtedly diluted and was probably advected primarily in a west-southwest direction.

Presumably, the present Barbers Point outfall releases sewage well offshore at a 61 m depth, and little interaction occurs with the inshore biota. However, if the material was carried into inshore waters, impacts would probably occur to shallow marine communities situated primarily to the west of the outfall—if the information on nearshore currents is correct (see Laevastu et al. 1964; Bathen 1978; Hamilton et al. 1996). Thus the eastern station (BP-1) is viewed as a control site, and the station inshore and adjacent to the discharge pipe (BP-2) as well as the station to the west (BP-3) serve as experimental sites. The spatial separation of the stations precludes direct comparison of data among stations. Comparison of the biological data for each station showed that there were no statistically significant changes among the sampling periods other than an increase in the number of macroinvertebrate species in 2005 over the 1991 data, suggesting that the operation of the outfall has not resulted in measurable negative impacts.

Relative to many other locations in Hawaiʻi, the fish communities are well developed at the eastern (BP-1) and western (BP-3) stations and at the pipe-armor rock transect (BP-4-A). The high standing crop estimates are much greater than those for 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). Two explanations for the high standing crop of fishes censused at the study stations are (1) the shelter created by the natural topographical relief serves to attract many fishes, thus locally enhancing the fish community, and (2) chance encounters with roving predators or planktivorous schooling species during censuses serve 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. Thus Brock (1954), using visual techniques on Hawaiʻi reefs, estimated the standing crop of fishes to range from 4 g/m^2 on sand flats to 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 Hawaiʻi waters may serve to increase fish standing crops to more than 1 kg/m^2 (Brock and Norris 1989).

Chance encounters with large roving predators (such as emperor fish or mu [*Monotaxis grandoculis*] and the grey snapper or uku [*Aprion virescens*]) or schools of planktivorous fishes (such as the mackerel scad or ʻōpelu [*Decapterus macarellus*], the sleek unicornfish or kala holo [*Naso hexacanthus*], the milletseed butterflyfish or lau wiliwili [*Chaetodon miliaris*], and the sergeant major or mamo [*Abudefduf abdominalis*]) may greatly increase the counts and biomass on a particular transect. The presence of natural topographical relief in the vicinity of Stations BP-1 and BP-3 as well as Transect BP-4-A serves to focus numerous predators and planktivorous fishes near 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.

In the 2005 survey, schooling species such as the bluelined snapper or taʻape (*Lutjanus kasmira*) and the orangebar surgeonfish or naʻenaʻe (*Acanthurus olivaceus*) contributed substantially to the standing crop at several transects. *A. olivaceus* was an important contributor to the standing crop at Transects BP-2-B (32% of the total) and BP-4-B (54%). Similarly, *L. kasmira* contributed to the standing crop at Transects BP-1-B (88%) and BP-4-A (67%). In some annual surveys migratory coastal predatory species such as the jacks (family Carangidae) were encountered and may have added substantially to the standing crop at a transect site.

CONCLUSION

The siting of the permanent stations near the Barbers Point Ocean Outfall to capitalize on presumed gradient(s) of impact that may be created by the discharge and movement of treated sewage effluent toward the shore and the annual quantitative survey of the marine communities at these stations should allow a delineation of changes that may be caused by the effluent. A comparison of the data from the fourteen annual surveys indicated that no statistically significant change has occurred in the biological parameters measured at the four permanent stations that would suggest an impact from the operation of the sewage outfall, despite the imposition of a major hurricane on these marine communities in September 1992. Despite the continuous operation of the outfall, the 2002 survey noted significant increase in the number of macroinvertebrate species seen per transect over the earliest year (1991). Additionally, coral coverage at Transect BP-4-B, which is located directly adjacent to the outfall pipe, has shown a steady increase from the first survey there (1993 mean = 0.1%) to the most recent survey (2005 mean = 12.6%). If sewage was having a negative impact on these communities, increases in coral coverage or invertebrate species diversity would not be expected to increase as has occurred here. Thus the data to date support the contention that the operation of the Barbers Point deep-ocean outfall is not having a quantifiable impact on the coral reef resources situated inshore of the outfall terminus.

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APPENDIX

TABLE A.1. Results of Quantitative Visual Fish Censuses Conducted on Two Transects Each at Four Stations Offshore of ‘Ewa Beach, O‘ahu, Hawai‘i, 20 and 23 May 2005

FAMILY and Species	Transect (BP-)							
	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B
MURAENIDAE								
Gymnothorax flavimarginatus							1	
Gymnothorax meleagris		1						
HOLOCENTRIDAE								
Myripristis amaena							70	
SERRANIDAE								
Cephalopholis argus						1		
Pseudanthias thompsoni							1	
APOGONIDAE								
Apogon kallopterus	1							
LUTJANIDAE								
Aprion virescens					1		1	
Lutjanus kasmira		512					525	
LETHRINIDAE								
Monotaxis grandoculis	16	1					1	
MULLIDAE								
Parupeneus cyclostomus						1		
Parupeneus multifasciatus	5	2			26	5	3	
Parupeneus pleurostigma					3		1	
CHAETODONTIDAE								
Chaetodon fremblii							1	
Chaetodon kleinii		3					25	3
Chaetodon lunula					2			
Chaetodon miliaris							60	
Chaetodon multicinctus	4	2			2			2
Chaetodon unimaculatus					2			
Forcipiger flavissimus		2			2	1	3	
Heniochus diphreutes							9	
POMACANTHIDAE								
Centropyge potteri	2	1						
POMACENTRIDAE								
Abudefduf abdominalis	10						113	
Chromis hanui	4	6						
Chromis ovalis		23			3		30	
Chromis vanderbilti			3					
Dascyllus albisella	23	6			2	14	67	21
Plectroglyphidodon johnstonianus		1	3	1	2	5		
Stegastes fasciolatus	1				1		1	
CIRRHITIDAE								
Cirrhitops fasciatus				1		1		
Paracirrhites arcatus	1		1	1		2		5
Paracirrhites forsteri							2	

TABLE A.1—*Continued*

FAMILY and Species	Transect (BP-)							
	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B
LABRIDAE								
Bodianus bilunulatus		1						
Coris ballieui							1	
Coris gaimard		1			2	1	1	
Gomphosus varius	2							
Halichoeres ornatissimus					2			
Labroides phthirophagus					1		2	
Macropharyngodon geoffroy		4			1			
Oxycheilinus bimaculatus			12	8				
Pseudocheilinus octotaenia		5			3	2		
Pseudojuloides cerasinus			4	6	4			3
Stethojulis balteata		3	3	3		4		1
Thalassoma ballieui							1	
Thalassoma duperrey	3	7	5	6	6	10	5	3
SCARIDAE								
Calotomus carolinus					1			
Scarus psittacus		1			6	28	4	
Scarus sordidus	1							
BLENNIIDAE								
Exallias brevis	1							
ACANTHURIDAE								
Acanthurus nigrofuscus	22	44			39	35	20	
Acanthurus olivaceus	5			2	5		15	9
Acanthurus triostegus							15	
Ctenochaetus strigosus	50	55				13	35	
Naso hexacanthus	25						56	
Naso unicornis						1		
Zanclus cornutus	1	1					3	
Zebrasoma flavescens	1	6						
BALISTIDAE								
Melichthys niger	1	12						
Melichthys vidua		1		1	1	1	3	
Sufflamen bursa	2	1	1	1	2	2	4	2
Xanthichthys auromarginatus								9
MONACANTHIDAE								
Cantherhines dumerilii		1	1	2			1	
TETRAODONTIDAE								
Canthigaster jactator	2	1		2	3	3		2
Total No. of Species	23	28	9	12	25	19	33	11
Total No. of Individuals	183	704	33	34	122	130	1,080	60
Estimated Standing Crop (g/m^2)	79	800	5	22	75	79	1,239	34

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 of fishes present at each location. All censuses were carried out by the author.

TABLE A.2. Summary of Coral Cover Data for Each Visually Assessed Quadrat on Each Transect for 1991 and 1993 Through 2005

Site	Quadrat Location	Coral Cover (%)						
		1991	1993	1994	1995	1996	1997	1998
Transect BP-1-A	0 m	40.7	19.0	19.0	19.0	8.3	7.3	10.6
	5 m		32.5	52.4	41.9	39.4	30.7	4.5
	10 m	17.1	0.6	1.8	1.4	0.9	1.5	1.9
	15 m		2.2	1.6	0.6	1.4	1.6	41.2
	20 m	12.3	23.0	12.1	21.7	25.1	32.0	20.5
	Mean	23.4	15.5	17.4	16.9	15.0	14.6	15.7
		1999	2000	2001	2002	2003	2004	2005
	0 m	2.0	2.8	2.0	1.1	2.3	2.3	2.0
	5 m	48.4	55.8	25.4	37.0	42.7	29.0	42.0
	10 m	3.3	2.7	3.9	2.5	8.0	8.2	6.7
	15 m	4.6	3.2	3.8	12.0	5.2	4.7	2.3
	20 m	35.4	28.1	26.1	13.7	21.0	14.2	21.1
	Mean	18.7	18.5	12.2	13.3	15.8	11.7	14.8
		1991	1993	1994	1995	1996	1997	1998
Transect BP-1-B	0 m	37.9	7.5	8.5	16.0	8.2	8.7	8.2
	5 m		8.1	7.3	4.6	2.7	4.2	37.3
	10 m	1.8	1.0	2.1	6.4	15.3	3.9	0.9
	15 m		6.9	4.5	9.4	6.1	7.2	2.1
	20 m	48.5	12.1	87.4	90.0	86.0	44.2	33.9
	Mean	29.4	7.1	22.0	25.3	23.7	13.6	16.5
		1999	2000	2001	2002	2003	2004	2005
	0 m	14.1	9.1	11.3	9.4	5.4	8.8	12.8
	5 m	6.9	3.0	2.8	6.9	2.8	2.2	16.2
	10 m	4.6	8.4	9.3	9.4	11.7	8.6	8.7
	15 m	7.6	8.2	6.0	13.3	11.6	10.6	11.3
	20 m	32.2	27.0	24.7	17.8	17.2	13.2	22.8
	Mean	13.1	11.1	10.8	11.4	9.7	8.7	14.4

TABLE A.2—*Continued*

Site	Quadrat Location	Coral Cover (%)						
		1991	1993	1994	1995	1996	1997	1998
Transect BP-2-A	0 m	3.6	4.5	2.4	2.6	2.3	2.1	0.5
	5 m		0.1	0	0.8	0	0.1	0.2
	10 m	2.4	0.5	0.6	0.6	0.7	0.9	1.8
	15 m		5.0	1.0	0.7	1.4	0.6	1.0
	20 m	4.9	0.9	1.3	1.0	0.7	1.3	0.2
	Mean	3.6	2.2	1.1	1.1	1.0	1.0	0.7
		1999	2000	2001	2002	2003	2004	2005
	0 m	1.2	0.9	1.4	3.9	1.3	1.7	1.8
	5 m	0.6	0.2	0	0.1	1.1	0.3	0.1
	10 m	1.0	1.1	1.4	0.3	1.9	0.1	0.3
	15 m	2.6	12.0	1.7	17.7	13.0	16.5	15.0
	20 m	1.8	1.7	2.5	2.5	3.8	4.5	1.6
	Mean	1.4	3.2	1.4	4.9	4.2	4.6	3.8
		1991	1993	1994	1995	1996	1997	1998
Transect BP-2-B	0 m	0.8	0.1	0	0.4	0.5	0.6	1.4
	5 m		3.0	1.3	1.1	0.4	0.5	0.3
	10 m	5.6	1.9	2.7	0.7	1.1	0.9	1.2
	15 m		0.3	0.1	0.5	0.2	0.5	1.1
	20 m	1.9	0.2	0.6	0	0.3	0.5	2.3
	Mean	0.8	0.1	0	0.4	0.5	0.6	1.4
		1999	2000	2001	2002	2003	2004	2005
	0 m	1.0	1.3	1.4	1.6	2.2	3.0	2.6
	5 m	1.1	0.9	1.3	2.4	1.7	2.8	3.0
	10 m	2.0	6.7	3.2	4.2	3.4	1.9	8.6
	15 m	1.2	2.3	1.3	1.0	1.2	0.3	0.3
	20 m	0.4	0.8	1.1	0.8	0.1	6.3	0.1
	Mean	1.1	2.4	1.7	2.0	1.7	2.9	2.9

TABLE A.2—*Continued*

Site	Quadrat Location	Coral Cover (%)						
		1991	1993	1994	1995	1996	1997	1998
Transect BP-3-A	0 m	7.2	0.7	0.7	0	0.1	0	4.2
	5 m		1.5	1.3	1.6	1.8	1.7	6.4
	10 m	1.0	0.6	0.9	0	0	0.4	0.1
	15 m		19.8	37.5	31.2	24.0	17.5	13.0
	20 m	15.8	0.2	0	0.1	0.1	0.4	2.2
	Mean	8.0	4.6	8.1	6.6	5.2	4.0	5.2
		1999	2000	2001	2002	2003	2004	2005
	0 m	0.5	0.6	0.2	0.9	1.9	0.0	0.0
	5 m	7.2	2.7	18.0	6.1	2.7	10.0	17.8
	10 m	0.1	0.4	0.2	0.7	1.1	0.1	0.0
	15 m	37.5	29.5	28.7	20.3	25.8	30.5	21.0
	20 m	0.9	0.5	1.3	1.7	0.2	0.6	1.7
	Mean	9.2	6.7	9.7	5.9	6.3	8.2	8.1
		1991	1993	1994	1995	1996	1997	1998
Transect BP-3-B	0 m	22.4	4.4	0.4	3.4	4.8	5.2	0.6
	5 m		2.7	6.6	3.1	1.5	7.9	2.3
	10 m	9.2	0.3	0.1	0.6	0.1	0.2	0.2
	15 m		6.0	7.9	4.6	5.5	20.1	31.4
	20 m	3.5	2.7	1.6	0.1	1.2	2.3	0.4
	Mean	11.7	3.2	3.3	2.4	2.6	7.1	7.0
		1999	2000	2001	2002	2003	2004	2005
	0 m	6.9	5.6	7.9	5.3	7.3	10.5	10.7
	5 m	5.3	10.0	13.6	19.0	12.5	19.0	15.0
	10 m	0.3	0.9	1.6	1.8	0.6	0.4	0.2
	15 m	10.7	9.7	2.1	10.4	12.5	17.4	14.7
	20 m	2.8	3.5	1.5	1.9	4.8	2.9	1.5
	Mean	5.2	5.9	5.3	7.7	7.5	10.0	8.4

TABLE A.2—*Continued*

Site	Quadrat Location	Coral Cover (%)						
		1991	1993	1994	1995	1996	1997	1998
Transect BP-4-A	0 m	6.0	13.1	19.0	27.0	9.2	21.0	6.0
	5 m	13.8	52.0	46.0	42.8	40.0	29.1	13.8
	10 m	56.1	19.6	26.0	21.0	31.3	26.0	56.1
	15 m	15.2	31.0	27.0	29.3	28.0	11.1	15.2
	20 m	7.6	19.0	22.0	19.0	28.0	21.0	7.6
	Mean	19.7	26.9	28.0	27.8	27.3	21.6	19.7
		1999	2000	2001	2002	2003	2004	2005
	0 m	41.7	23.0	26.0	57.0	27.0	11.0	49.0
	5 m	47.0	42.1	51.0	29.0	58.1	48.0	39.0
	10 m	31.0	36.0	23.0	27.7	27.0	23.0	44.0
	15 m	24.3	21.5	26.1	23.5	43.0	37.2	19.0
	20 m	56.0	34.0	17.0	27.1	13.0	18.3	33.0
	Mean	40.0	31.3	28.6	32.9	33.6	27.5	36.8
		1991	1993	1994	1995	1996	1997	1998
Transect BP-4-B	0 m	0.1	10.5	11.7	19.3	17.6	13.4	0.1
	5 m	0.2	0.2	0.3	0.4	3.9	1.1	0.2
	10 m	0.2	1.5	2.3	2.7	0.4	3.7	0.2
	15 m	0.1	5.7	5.8	6.5	2.6	7.5	0.1
	20 m	0.1	0.8	1.6	2.2	4.6	2.6	0.1
	Mean	0.1	3.7	4.3	6.2	5.8	5.7	0.1
		1999	2000	2001	2002	2003	2004	2005
	0 m	28.6	21.8	28.7	29.5	29.2	33.8	30.6
	5 m	0.8	1.5	2.4	4.8	3.0	3.4	4.4
	10 m	1.9	2.2	7.1	6.6	5.3	8.4	6.9
	15 m	5.1	7.9	7.1	7.1	13.9	11.0	9.7
	20 m	3.6	5.0	2.8	7.5	8.0	2.7	11.2
	Mean	8.0	7.7	9.6	11.1	11.9	11.9	12.6

NOTE: Only three locations on each transect were sampled in 1991, and the transects at Station BP-4 were not established until 1993. Data for the years preceding 2005 are from earlier reports by the author.