

**COMMUNITY STRUCTURE OF FISH AND MACROBENTHOS  
AT SELECTED SHALLOW-WATER SITES IN RELATION  
TO THE BARBERS POINT OCEAN OUTFALL, 1994**

Richard E. Brock

PROJECT REPORT PR-95-03

October 1994

**WATER RESOURCES RESEARCH CENTER  
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## ABSTRACT

This report provides the results of the third 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. The third field survey, completed in March and April 1994, sampled all of the stations. These 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 three surveys (1991, 1993, and 1994) indicated that no statistically significant change has taken place at these permanent stations, despite the imposition of a major hurricane on these marine communities in September 1992. 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 25 mgd (1.10 m<sup>3</sup>/s) of primary 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, beginning 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 third survey carried out on 2–4 March and 25 and 27 April 1994.

### 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 (such as storm drains and streams) and nonpoint source 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

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 which would probably manifest themselves as a slow decline in the communities so impacted. Gradients of "stress" or "impact" should be evident with distance from impact source(s). Thus, to quantitatively define these impacts, one should monitor these communities through time in areas suspected of being impacted as well as in similar communities at varying distances away from the suspected source(s). This rationale has been used in developing the sampling strategy for this study.

## MATERIALS AND METHODS

The quantitative sampling of macrofauna of marine communities presents a number of problems, many of 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 station 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. 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" distribution across it. Coral coverage may locally exceed 70%. Occasionally shallow sand areas located in depressions are found.

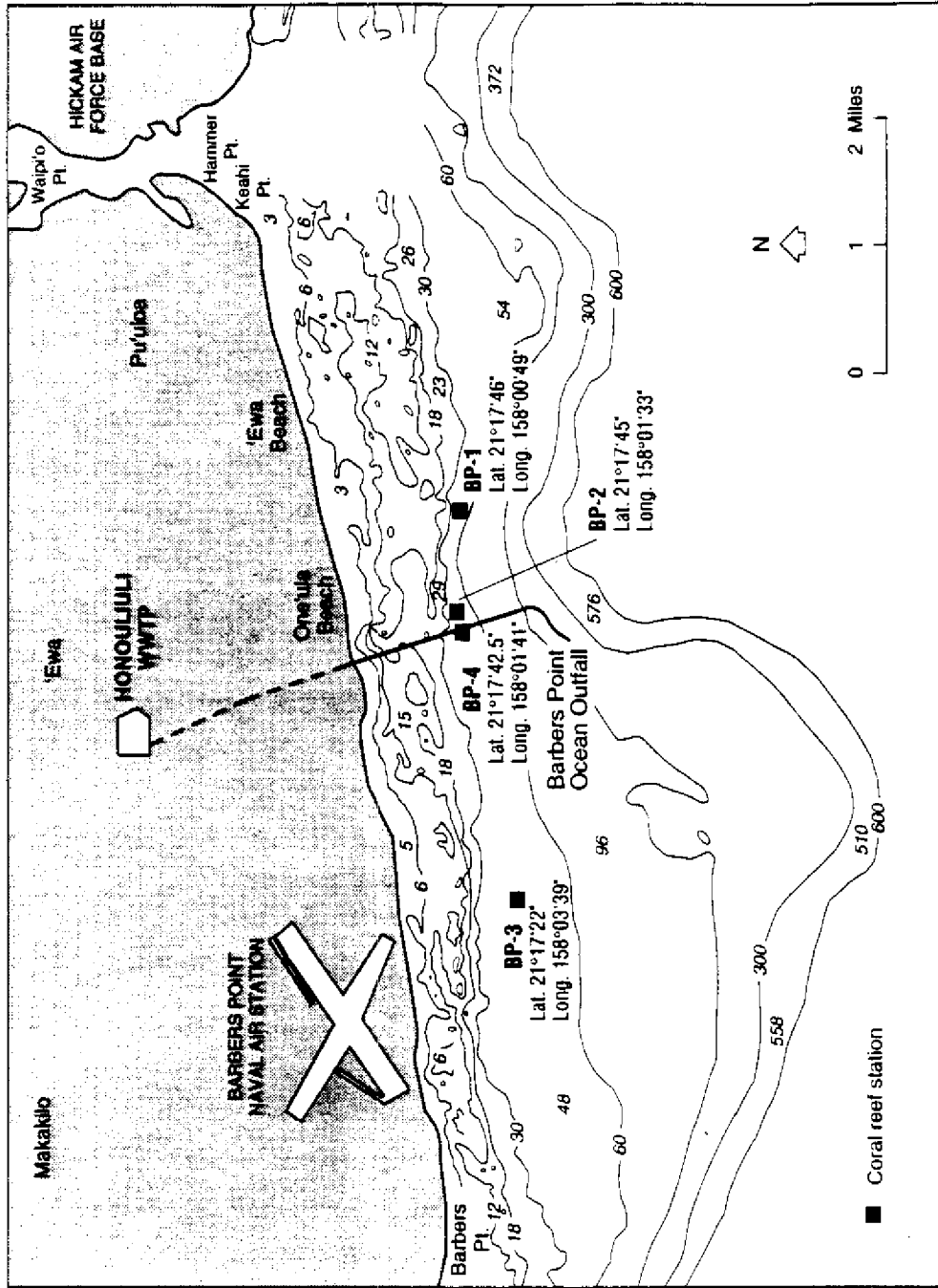


FIGURE 1. General locations of four permanent stations (two transects per station) sampled in the coral reef survey at the Barbers Point Ocean Outfall, O'ahu, Hawaii. These stations are the eastern station (BP-1) where the first two transects are located (BP-1-A and BP-2-B), the middle station (BP-2) 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.

- Station BP-2 Located about 0.25 km east of the sewer line and approximately 1.5 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 12 to 13 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 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 3.35 m<sup>2</sup> 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 using the photo-quadrat method, such as recently recruited benthic species. These changes have made both the photo- and visual quadrat assessment methods the same as those used at 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 Hawaiian benthic communities (see Brock 1982; Brock and Norris 1989), was 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 Hawai'i, the Naval Undersea Center (see Evans 1974), and the Hawai'i 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 the underestimation of cryptic species such as moray eels (family Muraenidae) and nocturnal species such as squirrelfishes (family Holocentridae) and bigeyes or 'āweoweo (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<sup>2</sup>). 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 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 were encountered in the quadrats, they were 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.

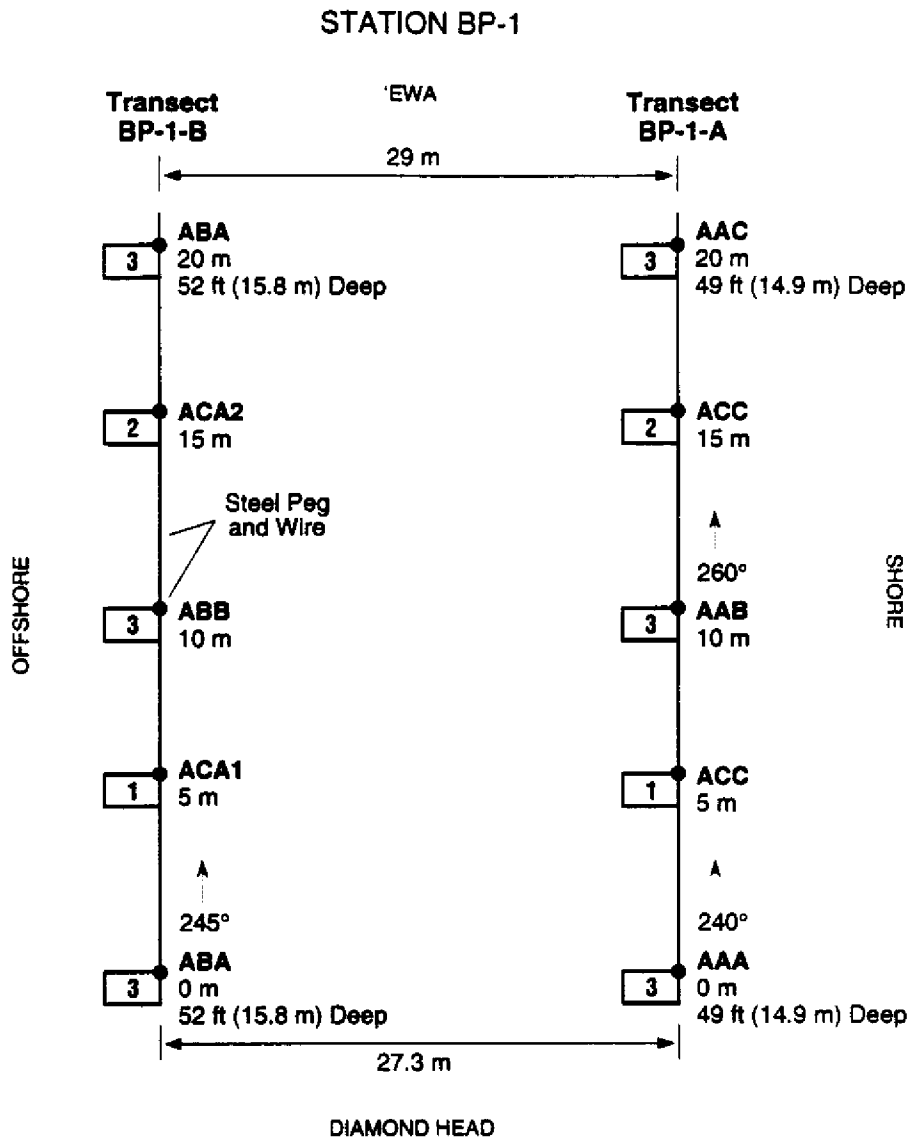
As requested by permit agencies, divers made simple physical measurements at the four stations. Measurements of percent oxygen concentration and temperature were made with a YSI Model 57 Oxygen meter, salinity was taken with a hand-held refractometer, and water clarity was determined using a 12-inch secchi disk. Oxygen measurements were taken approximately 1 m below the water surface and 1 m above the bottom.

Data were subjected to simple nonparametric statistical procedures provided in the SAS Institute statistical package (SAS Institute 1985). Nonparametric methods were used to avoid meeting requirements of normal distribution and homogeneity of variance in the data. Data were analyzed using the Wilcoxon two-sample test to discern statistically significant differences among ranked means for each transect site and sample period; this procedure is outlined in Siegel (1956) and Sokal and Rohlf (1981).

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

## RESULTS

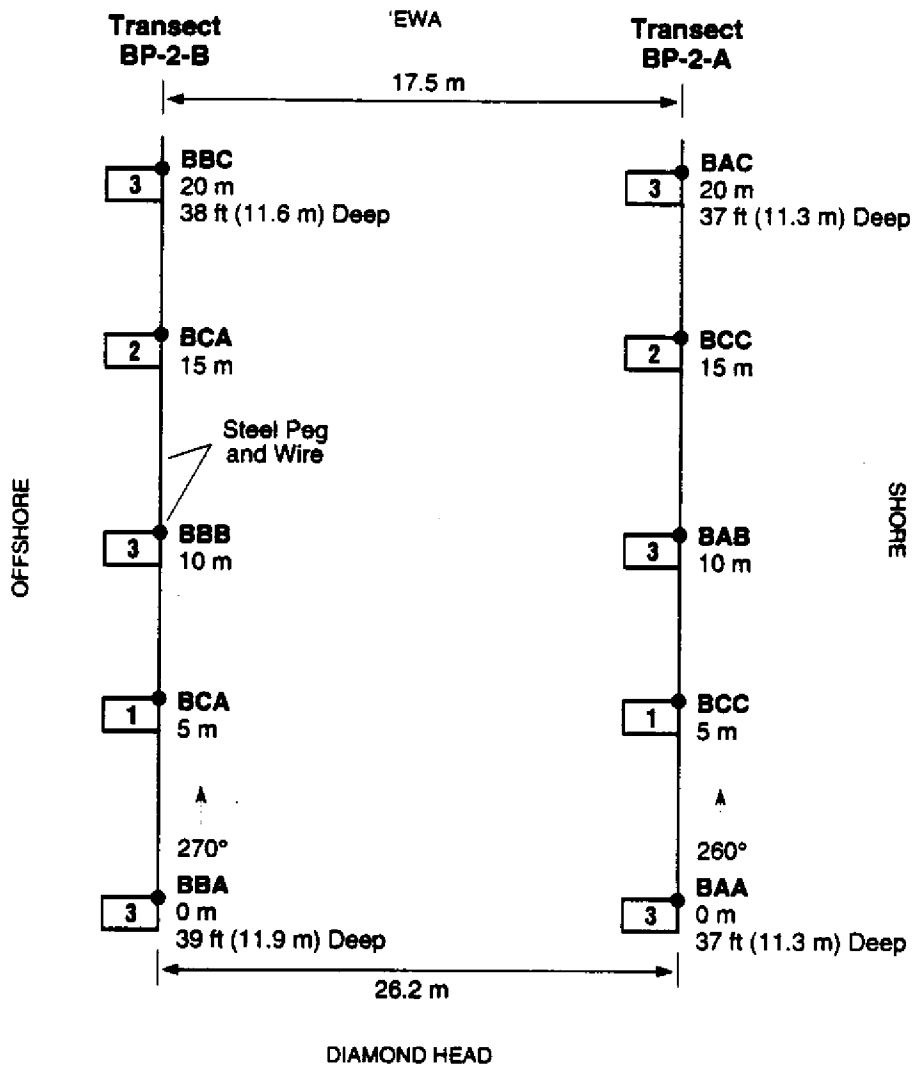
Field sampling was undertaken on 25 and 27 April 1994, and the photographs were taken by members of the Oceanographic Team, Department of Wastewater Management, City and County of Honolulu, on 2–4 March 1994. The physical measurements (temperature, salinity, and oxygen) were made on the morning of 28 April 1994. 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.



Photographic quadrat (0.67 m × 1 m)

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, Hawaii

STATION BP-2

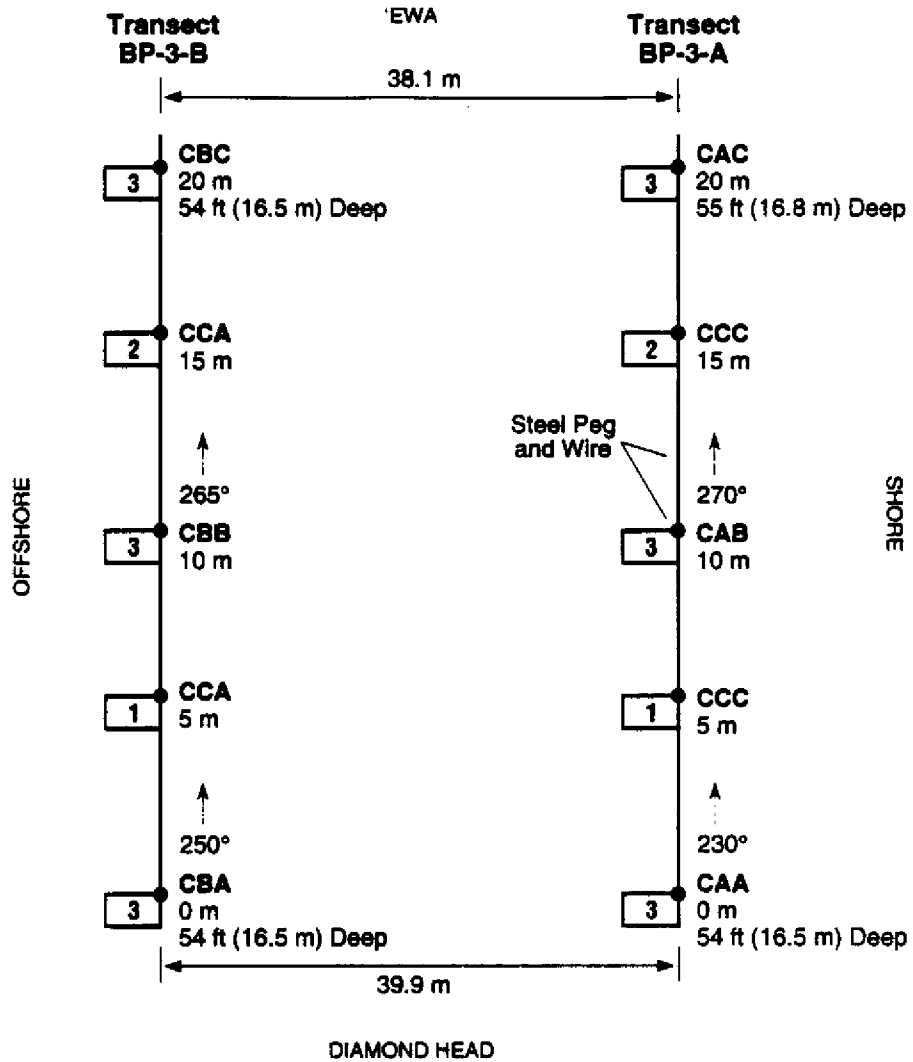


 Photographic quadrat (0.67 m x 1 m)

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 'Ewa Beach, O'ahu, Hawaii'



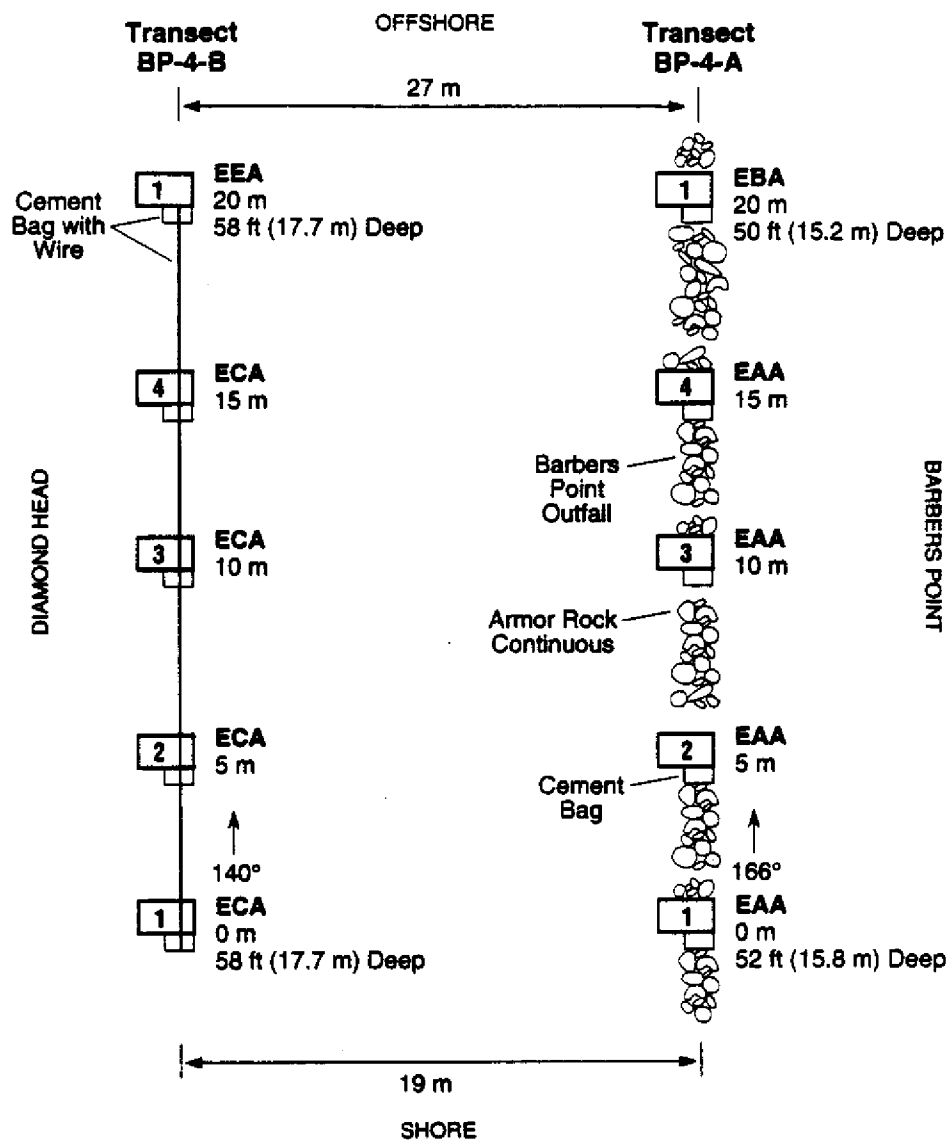
STATION BP-3



Photographic quadrat (0.67 m × 1 m)

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

### STATION BP-4



□ Photographic quadrat (0.67 m x 1 m)

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 'Ewa Beach, O'ahu, Hawai'i

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 situated about 2.2 km inshore and to the east (northeast) of the deep ocean outfall terminus. This station 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 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 from 27.3 to 29 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 at Transect BP-1-A in April 1994 is presented in Table 1. In the visually assessed quadrat survey one coralline algal species (*Porolithon onkodes*), two sponge species (*Spirastrella coccinea* and *Chondrosia chucalla*), one soft coral species (*Anthelia edmondsoni*), and five coral species (*Porites lobata*, *P. compressa*, *Montipora verrucosa*, *M. patula*, and *Pocillopora meandrina*) were encountered. *Porites lobata* continues to be the dominant coral at this transect, where mean coral coverage for all species combined was 17.4%. In the macroinvertebrate census the rock oyster *Spondylus tenebrosus*, the boring bivalve *Lithophaga* sp., the octopus *Octopus cyanea*, two polychaete species (*Loimia medusa* and *Sabellastarte sanctijosephi*), the brown hermit crab *Aniculus strigatus*, and two echinoderm species (*Linckia diplox* and *Echinometra mathaei*) were noted.

The results of the fish census are presented in the Appendix. Thirty-nine species representing 386 individuals were counted at Transect BP-1-A. The most abundant species included the brick soldierfish or menpachi (*Myripristis amaenus*), the damselfish *Chromis ovalis*, the brown surgeonfish or ma'i'i'i (*Acanthurus nigrofuscus*), and the goldring surgeonfish or kole (*Ctenochaetus strigosus*). The standing crop of fishes was estimated at

TABLE 1. Summary of Biological Observations Made at Transect BP-1-A, 2.2 km Inshore and Northeast of Barbers Point Ocean Outfall Terminus on 27 April 1994

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Algae					
<i>Porolithon onkodes</i>	4	1.5	1		
Sponges					
<i>Spirastrella coccinea</i>			0.7		
<i>Chondrosia chucalla</i>				1	
Soft Corals					
<i>Anthelia edmondsoni</i>	0.5		0.3	0.5	2.2
Corals					
<i>Porites lobata</i>	19	51	1.2	0.8	12
<i>Porites compressa</i>		0.9	0.6	0.3	
<i>Pocillopora meandrina</i>		0.5			
<i>Montipora verrucosa</i>				0.1	0.1
<i>Montipora patula</i>				0.4	
Sand			7	3	13
Rubble	22	38	48.2	85.9	41.7
Hard Substratum	54.5		41	8	31
<hr/>					
II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals				
<hr/>					
Phylum Mollusca					
<i>Spondylus tenebrosus</i>		1			
<i>Octopus cyanea</i>		1			
<i>Lithophaga</i> sp.		1			
Phylum Annelida					
<i>Loimia medusa</i>		5			
<i>Sabellastarte sanctijosephi</i>		1			
Phylum Arthropoda					
<i>Aniculus strigatus</i>		1			
Phylum Echinodermata					
<i>Linckia diplax</i>		1			
<i>Echinometra mathaei</i>		2			
<hr/>					
III. Fish Census (4 m × 20 m)					
<hr/>					
39 Species					
386 Individuals					
Estimated Standing Crop = 222 g/m <sup>2</sup>					
<hr/>					

NOTE: Results of the 5-m<sup>2</sup> 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 14.9 to 15.8 m; mean coral coverage is 17.4% (visual quadrat method).

222 g/m<sup>2</sup>, with the largest contributors including the emperor fish or mu (*Monotaxis grandoculis*—15% of the total), *Ctenochaetus strigosus* (13% of the total), and a single broomtail filefish or 'ō'ili lepa (*Alutera scripta*—14% of the total).

The results of the photo-quadrat survey made at the four stations are presented in Table 2. At Transect BP-1-A, two coral species having a mean coverage of 27.2% were recorded. Also recorded were two algal species (*Porolithon onkodes* and *Hydrolithon rienboldii*) with a mean coverage of 6.3%. Other benthic organisms present included two sponge species.

#### **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 are presented in Table 3. The quadrat survey noted two algal species (*Desmia hornemannii* and *Porolithon onkodes*), the sponge *Chondrosia chucalla*, the soft coral *Anthelia edmondsoni*, and five corals (*Porites lobata*, *P. compressa*, *Montipora patula*, *M. verrilli*, and *Pocillopora meandrina*). The dominant coral species was *Porites lobata*, and mean coral coverage was 22%. In the 4 m × 20 m census area four macroinvertebrate species were seen: the rock oyster *Spondylus tenebrosus*, the octopus *Octopus cyanea*, the terebellid worm *Loimia medusa*, and the sea urchin *Echinometra mathaei*.

The results of the photo-quadrat survey for Transect BP-1-B are given in Table 2. Three coral species (*Porites lobata*, *P. compressa*, and *Pocillopora meandrina*) having a mean coverage of 25.4% were noted. Also encountered were two algal species (*Porolithon onkodes* and *Hydrolithon rienboldii*) and two encrusting sponge species (*Chondrosia chucalla* and *Spirastrella coccinea*).

The results of the fish census are presented in the Appendix. Forty-two species representing 371 individuals were censused at Transect BP-1-B, where the most common species present were two damselfishes (*Chromis ovalis* and *C. hanui*), the brown surgeonfish or ma'i'i'i (*Acanthurus nigrofuscus*), and the goldring surgeonfish or kole (*Ctenochaetus strigosus*). The standing crop of fish was estimated at 202 g/m<sup>2</sup>, with the largest contributors being the emperor fish or mu (*Monotaxis grandoculis*—28% of the total) and the goldring surgeonfish or kole (*Ctenochaetus strigosus*—9% of the total).

#### **Station Observation**

In the vicinity of Station BP-1 were seen the corals *Pocillopora meandrina*, *Pavona varians*, *P. duerdeni*, and *Montipora flabellata*.

#### **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

TABLE 2. Summary of the Results of the Photographic Quadrat Survey for Stations BP-1 Through BP-4, Barbers Point Ocean Outfall, 'Ewa Beach, O'ahu, Hawai'i, 2-4 March 1994

Transect BP-1-A	Percent Cover				
	Photographic Quadrat				
	AAA3 (0 m)	ACC1 (5 m)	AAB3 (10 m)	ACC2 (15 m)	AAC3 (20 m)
Algae					
<i>Hydrolithon rienboldii</i>	3.9	16.0			3.1
<i>Porolithon onkodes</i>	1.4	5.6			1.4
Sponges					
<i>Spirastrella coccinea</i>			0.3		
<i>Chondrosia chucalla</i>				0.3	0.6
Corals					
<i>Porites lobata</i>	67.5	40.6			18.8
<i>Porites compressa</i>	5.0	2.8		0.8	0.6
Sand			17.9	3.6	
Rubble			74.8	95.2	43.7
Hard Substratum	22.1	35.0	7.0		31.9
Mean Coral Coverage = 27.2%					

Transect BP-1-B	Percent Cover				
	Photographic Quadrat				
	ABA3 (0 m)	ACA1 (5 m)	ABB3 (10 m)	ACA2 (15 m)	ABC3 (20 m)
Algae					
<i>Hydrolithon rienboldii</i>	6.7	1.1	1.7	1.1	3.6
<i>Porolithon onkodes</i>	1.4	0.6			
Sponges					
<i>Spirastrella coccinea</i>		0.1			
<i>Chondrosia chucalla</i>	0.6	0.3	0.3		
Corals					
<i>Porites lobata</i>	21.8	11.2	8.1	15.1	55.7
<i>Porites compressa</i>	2.5	0.6	2.0	5.6	3.1
<i>Pocillopora meandrina</i>					1.1
Sand		0.3	0.3	2.5	
Rubble	11.2	33.3	11.2	16.5	
Hard Substratum	55.7	52.6	76.5	59.1	34.2
Mean Coral Coverage = 25.4%					

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					
<i>Spirastrella coccinea</i>		0.1	0.3	0.3	0.1
<i>Chondrosia chucalla</i>	0.6	0.1		1.7	0.1
Corals					
<i>Porites lobata</i>	0.6		0.1	2.2	0.3
<i>Pocillopora meandrina</i>			0.6	1.4	
Sand	10.1	51.3	58.5	9.2	77.0
Hard Substratum	88.8	48.5	40.6	85.2	22.4
Mean Coral Coverage = 1.2%					

Transect BP-2-B	Percent Cover				
	Photographic Quadrat				
	BBA3 (0 m)	BCA1 (5 m)	BBB3 (10 m)	BCA2 (15 m)	BBC3 (20 m)
Sponges					
<i>Spirastrella coccinea</i>	0.3	0.3			
<i>Chondrosia chucalla</i>	0.3	0.3		0.3	0.1
Corals					
<i>Porites lobata</i>	0.6	3.4	0.3		
<i>Pocillopora meandrina</i>		0.6			
Sand	73.7	65.3	79.8	45.7	67.8
Hard Substratum	25.2	30.3	19.9	4.1	31.9
Mean Coral Coverage = 1.0%					

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)
<b>Algae</b>					
<i>Porolithon onkodes</i>				0.3	
<b>Sponges</b>					
<i>Spirastrella coccinea</i>		0.3	0.1	0.3	
<i>Chondrosia chucalla</i>		0.3	0.3	2.2	
<b>Corals</b>					
<i>Porites lobata</i>	1.4			3.1	
<i>Porites compressa</i>				0.8	
<i>Pocillopora meandrina</i>				1.4	
<i>Montipora verrucosa</i>			0.1		
Sand	2.0	4.5	2.2		5.3
Rubble	72.3	29.7	97.2	65.2	94.7
Hard Substratum	24.4	65.3		26.6	
Mean Coral Coverage = 1.4%					

Transect BP-3-B	Percent Cover				
	Photographic Quadrat				
	CBA3 (0 m)	CCA1 (5 m)	CBB3 (10 m)	CCA2 (15 m)	CBC3 (20 m)
<b>Algae</b>					
<i>Porolithon onkodes</i>	0.8	1.7		0.6	0.1
<i>Hydrolithon rienboldii</i>	2.2	7.8		1.7	
<b>Sponges</b>					
<i>Spirastrella coccinea</i>	0.4	0.3	0.1	0.8	0.8
<i>Chondrosia chucalla</i>					0.1
<b>Corals</b>					
<i>Porites lobata</i>	9.8	20.2		16.2	
<i>Porites compressa</i>				0.6	
<i>Pocillopora meandrina</i>				0.3	
<i>Montipora verrucosa</i>				0.3	
Sand			0.6		0.6
Rubble	40.9	61.3	99.3	44.8	98.3
Hard Substratum	45.8	8.7		34.7	
Mean Coral Coverage = 9.5%					



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					
<i>Porolithon onkodes</i>			0.6		0.6
Sponges					
<i>Spirastrella coccinea</i>	3.9	0.3	0.8	0.6	0.3
Corals					
<i>Porites lobata</i>	3.4	27.5	19.6	23.8	18.5
<i>Pocillopora meandrina</i>	3.6	0.1			
Rubble	30.0		20.0	1.4	
Hard Substratum	59.1	72.1	59.0	74.2	80.7
Mean Coral Coverage = 19.3%					
Transect BP-4-B	Percent Cover				
	Photographic Quadrat				
	ECA1 (0 m)	ECA2 (5 m)	ECA3 (10 m)	EAC4 (15 m)	EEA1 (20 m)
Sponges					
<i>Spirastrella coccinea</i>					0.1
<i>Chondrosia chucalla</i>	0.3			0.3	1.1
Corals					
<i>Porites lobata</i>	0.8	0.3	1.1	0.6	
<i>Pocillopora meandrina</i>	12.8		0.8		
Sand	1.1	4.2	2.8	1.4	1.4
Hard Substratum	85.4	95.5	95.2	97.8	97.2
Mean Coral Coverage = 3.3%					

NOTE: Presented in the body of the table are the percent cover of species and substrate types for each transect. Note that for Stations BP-1, BP-2 and BP-3 the 5 m and 15 m data are based on one 0.67-m<sup>2</sup> photo-quadrat and the 0 m, 10 m, and 20 m data on the mean from four 0.67-m<sup>2</sup> quadrats at each location. Data for Station BP-4 are based on one 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 27 April 1994

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Algae					
<i>Desmia hornemannii</i>			0.5		
<i>Porolithon onkodes</i>	0.1				0.6
Sponges					
<i>Chondrosia chucalla</i>				0.2	
Soft Corals					
<i>Anthelia edmondsoni</i>		1.2	0.1		
Corals					
<i>Porites lobata</i>	7.5	4.5		1.3	84.1
<i>Porites compressa</i>	1	1	1.3	2.2	2.3
<i>Pocillopora meandrina</i>		0.6			1.0
<i>Montipora patula</i>		1	0.8	0.9	
<i>Montipora verrilli</i>		0.2		0.1	
Sand	2	6	12		
Rubble	75.4	47.5	14	80.3	
Hard Substratum	14	38	71.3	15	12
<hr/>					
II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals				
<hr/>					
Phylum Mollusca					
<i>Spondylus tenebrosus</i>	3				
<i>Octopus cyanea</i>	1				
Phylum Annelida					
<i>Loimia medusa</i>	1				
Phylum Echinodermata					
<i>Echinometra mathaei</i>	2				
<hr/>					
III. Fish Census (4 m × 20 m)					
<hr/>					
42 Species					
371 Individuals					
Estimated Standing Crop = 202 g/m <sup>2</sup>					
<hr/>					

NOTE: Results of the 5-m<sup>2</sup> 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 14.9 to 15.8 m; mean coral coverage is 22.0% (visual quadrat method).

relief present. Common corals seen include *Pocillopora meandrina* and *Porites lobata*; other species seen include *Montipora verrilli* and *M. verrucosa*. Two of the common algal species in the area were limu kohu or *Asparagopsis taxiformis* and the recently introduced *Avrainvillea amadelpha*.

The two permanently marked transect lines at this station have an orientation that approximately parallels 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 noted two algal species (*Asparagopsis taxiformis* and *Avrainvillea amadelpha*), four sponge species (*Chondrosia chucalla*, *Callyspongia diffusa*, *Spirastrella coccinea*, and *Microciona maunaloa*), one soft coral (*Anthelia edmondsoni*), and one coral species (*Porites lobata*). Mean coral coverage at this station was estimated at 0.9%. The macroinvertebrate census carried out over the 4 m × 20 m area noted three species: the cone shells *Conus lividus* and *C. miles* and the rock boring urchin *Echinostrephus aciculatum*.

The photo-quadrat survey noted two sponge species (*Spirastrella coccinea* and *Chondrosia chucalla*) and two coral species (*Porites lobata* and *Pocillopora meandrina*). Coral coverage was estimated at 1.2%.

The results of the fish census are presented in the Appendix. In total five fish species representing seven individuals were censused at Transect BP-2-A. The biomass of fishes on this transect was estimated at 2 g/m<sup>2</sup>, with the largest contributor being a single bridled triggerfish or humuhumu mimi (*Sufflamen fraenatus*—80% of the total).

#### ***Transect BP-2-B***

Transect BP-2-B was established at a distance varying from 17 to 26 m seaward of Transect BP-2-A (Figure 3). Table 5 presents the results of the visual quadrat survey carried out at Transect BP-2-B. Four algal species (*Amansia glomerata*, *Asparagopsis taxiformis*, *Avrainvillea amadelpha*, and *Lyngbya majuscula*), three encrusting sponge species (*Spirastrella coccinea*, *Callyspongia diffusa*, and *Chondrosia chucalla*), and four coral species (*Porites lobata*, *Pocillopora meandrina*, *Montipora verrucosa*, and *M. patula*) were noted. Mean coral coverage was estimated at 8.1%. Noncolonial macroinvertebrates censused in the 4 m × 20 m transect include three cone shell species (*Conus lividus*, *C. leopardus*, and *Terebra maculata*), the banded shrimp *Stenopus hispidus*, and two sea urchin species (the rock boring urchin *Echinostrephus aciculatum* and the black urchin *Tripneustes gratilla*).

The results of the photo-quadrat survey for Transect BP-2-B are given in Table 2. Two sponge species (*Chondrosia chucalla* and *Spirastrella coccinea*) provided a mean coverage of

TABLE 4. Summary of Biological Observations Made at Transect BP-2-A, 0.25 km East of the Discharge Pipe and 1.5 km Inshore and Northeast of Barbers Point Ocean Outfall Terminus on 25 April 1994

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Algae					
<i>Avrainvillea amadelpha</i>	0.1				
<i>Asparagopsis taxiformis</i>				0.1	
<i>Asparagopsis taxiformis</i>		0.5			
Sponges					
<i>Chondrosia chucalla</i>	0.9	0.2	1.0	1.1	1.1
<i>Callyspongia diffusa</i>		0.1			
<i>Spirastrella coccinea</i>		0.8			
<i>Microciona maunaloa</i>	0.1				
Soft Corals					
<i>Anthelia edmondsoni</i>	0.3	0.1	0.5	0.2	
Corals					
<i>Porites lobata</i>	2.4		0.6	1	1.3
Sand		31	62	4	37
Hard Substratum	96.2	67.8	35.5	93.6	57.3

II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals
Phylum Mollusca	
<i>Conus lividus</i>	1
<i>Conus miles</i>	1
Phylum Echinodermata	
<i>Echinostrephus aciculatum</i>	1

III. Fish Census (4 m × 20 m)

5 Species  
 7 Individuals  
 Estimated Standing Crop = 2 g/m<sup>2</sup>

NOTE: Results of the 5-m<sup>2</sup> 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 11.3 to 11.9 m; mean coral coverage is 0.9% (visual quadrat method).

TABLE 5. Summary of Biological Observations Made at Transect BP-2-B, 0.25 km East of the Discharge Pipe and 1.5 km Inshore and Northeast of Barbers Point Ocean Outfall Terminus on 25 April 1994

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Algae					
<i>Amansia glomerata</i>	0.3				0.2
<i>Asparagopsis taxiformis</i>		0.1			
<i>Avrainvillea amadelpa</i>			0.3		
<i>Lyngbya majuscula</i>			0.2	0.1	0.3
Sponges					
<i>Chondrosia chucalla</i>		0.1	1.1		0.6
<i>Spirastrella coccinea</i>	0.9			0.1	0.4
<i>Callyspongia diffusa</i>			0.1	0.1	
Soft Corals					
<i>Anthelia edmondsoni</i>	0.1	0.2	0.6	0.3	0.2
Corals					
<i>Porites lobata</i>		1.3	2.3		0.5
<i>Pocillopora meandrina</i>			0.1	0.1	
<i>Montipora patula</i>			0.3		
<i>Montipora verrucosa</i>					0.1
Sand	46	1	4	12	2
Hard Substratum	52.7	97.3	91	87.3	95.7
<hr/>					
II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals				
<hr/>					
Phylum Mollusca					
<i>Conus lividus</i>	1				
<i>Conus leopardus</i>	1				
<i>Terebra maculata</i>	1				
Phylum Arthropoda					
<i>Stenopus hispidus</i>	1				
Phylum Echinodermata					
<i>Tripneustes gratilla</i>	1				
<i>Echinostrephus aciculatum</i>	5				
<hr/>					
III. Fish Census (4 m × 20 m)					
<hr/>					
11 Species					
36 Individuals					
Estimated Standing Crop = 25 g/m <sup>2</sup>					

NOTE: Results of the 5-m<sup>2</sup> 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 11.3 to 11.9 m; mean coral coverage is 8.1% (visual quadrat method).

0.3% and two coral species (*Porites lobata* and *Pocillopora meandrina*) contributed a mean coverage of 1.0% at this transect.

The fish census noted 11 species of fishes representing 36 individuals (Appendix). The most common fish on this transect was the damselfish or 'ālo'ilo'i (*Dascyllus albisella*). Fish standing crop was estimated at 25 g/m<sup>2</sup>, with the orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*) contributing 75% of the total.

### **Station Observations**

The low numbers and 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 an easier task.

In the vicinity of Station BP-2 was seen the coral *Pavona varians*, the abbreviated cone shell *Conus miliaris*, the reef crab *Thalamita edwardsi*, and the belted wrasse or 'omaka (*Stethojulis balteata*).

### **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 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 have an orientation that is approximately perpendicular to the shoreline and are from 2 to 15 m in width, 4 to 40 m in length, and up to 0.75 m in height. The ridges are spaced from 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 was between 12 and 15 m, which is the usual measurement for this location.

### **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 given in Figure 4) noted two encrusting sponge species (*Spirastrella coccinea* and *Chondrosia chucalla*) and four coral species (*Porites lobata*, *P. compressa*, *Pocillopora meandrina*, and *Montipora patula*). Mean coral coverage at this location was estimated at 8.1% (visual quadrat method), and the dominant species was *Porites lobata*. Six macroinvertebrate species were censused, including the rock oyster *Spondylus*

TABLE 6. Summary of Biological Observations Made at Transect BP-3-A, 3.3 km West and Inshore of Barbers Point Ocean Outfall Terminus on 25 April 1994

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Sponges					
<i>Chondrosia chucalla</i>			0.3		
<i>Spirastrella coccinea</i>		1.4		3.2	
Corals					
<i>Porites lobata</i>	0.1	1.2	0.3	27	
<i>Porites compressa</i>		0.1		6	
<i>Pocillopora meandrina</i>			0.4	4.5	
<i>Montipora patula</i>	0.6		0.2		
Sand	2				5
Rubble	97.3	82.3	80.8	47.3	64
Hard Substratum		15	18	12	31
<hr/>					
II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals				
<hr/>					
Phylum Mollusca					
<i>Conus lividus</i>		1			
<i>Spondylus tenebrosus</i>		3			
Phylum Echinodermata					
<i>Echinometra mathaei</i>		3			
<i>Echinothrix diadema</i>		9			
<i>Tripneustes gratilla</i>		2			
<i>Heterocentrotus mammillatus</i>		2			
<hr/>					
III. Fish Census (4 m × 20 m)					
<hr/>					
26 Species					
191 Individuals					
Estimated Standing Crop = 255 g/m <sup>2</sup>					

NOTE: Results of the 5-m<sup>2</sup> 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).

*tenebrosus*, the cone shell *Conus lividus*, and four sea urchin species (*Echinothrix diadema*, *Echinometra mathaei*, *Tripneustes gratilla*, and *Heterocentrotus mammillatus*).

The results of the photo-quadrat survey for Transect BP-3-A are presented in Table 2. Noted were one coralline algal species (*Porolithon onkodes*) having a mean coverage of 0.06%, two sponge species (*Chondrosia chucalla* and *Spirastrella coccinea*) with a mean coverage of 0.7%, and four coral species (*Porites lobata*, *P. compressa*, *Montipora verrucosa*, and *Pocillopora meandrina*) having a mean coverage of 1.4%.

The results of the fish census at Transect BP-3-A are presented in the Appendix. Twenty-six fish species representing 191 individuals were censused. The most abundant fish species were the manybar goatfish or moano (*Parupeneus multifasciatus*) and the orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*). The standing crop of fishes was estimated at 255 g/m<sup>2</sup>, and the species contributing most heavily included a single tableboss or 'a'awa (*Bodianus bilunulatus*—7% of the total), *Parupeneus multifasciatus* (16% of the total), and *Acanthurus olivaceus* (63% of the total).

### **Transect BP-3-B**

Transect BP-3-B is located approximately 38 m seaward of Transect BP-3-A (Figure 4). It has an orientation that is parallel to Transect BP-3-A and is located at a water depth of 16.5 m. Table 7 presents the results of the quantitative survey carried out at this transect. Three sponge species (*Spirastrella coccinea*, *Chondrosia chucalla*, and *Asteropus kaena*) and five coral species (*Porites lobata*, *P. compressa*, *Pocillopora meandrina*, *Montipora patula*, and *Pavona varians*) were noted. Coral coverage at this transect is estimated at 3.3% (visual quadrat method). Eight species of macroinvertebrates were censused in the 4 m × 20 m area, including the rock oyster *Spondylus tenebrosus*, the hairy triton *Cymatium pileare*, the slate pencil sea urchin *Heterocentrotus mammillatus*, the black sea urchin *Tripneustes gratilla*, the banded sea urchin *Echinothrix calamaris*, the long-spined black urchins or wana (*Echinothrix diadema* and *Diadema setosum*), and the green sea urchin *Echinometra mathaei*. The most abundant macroinvertebrate present was the green sea urchin.

Table 2 presents the results of the photo-quadrat survey carried out at Transect BP-3-B. Noted were two coralline algal species (*Porolithon onkodes* and *Hydrolithon rienboldii*) having a mean coverage of 3%, two sponge species (*Chondrosia chucalla* and *Spirastrella coccinea*) with a mean coverage of 0.5%, and four coral species (*Montipora verrucosa*, *Pocillopora meandrina*, *Porites compressa*, and *P. lobata*) having a mean coverage of 9.5%.

The results of the fish census carried out at Transect BP-3-B are presented in the Appendix. In total 18 species representing 109 individuals were counted, with the most abundant fishes including the manybar goatfish or moano (*Parupeneus multifasciatus*), the smalltail wrasse *Pseudojuloides cerasinus*, and the orangebar surgeonfish or na'ena'e



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 25 April 1994

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Sponges					
<i>Spirastrella coccinea</i>		2.5		1.3	0.8
<i>Chondrosia chucalla</i>		0.1			
<i>Asteropus kaena</i> (?)			0.4		
Soft Corals					
<i>Anthelia edmondsoni</i>	0.1				
Corals					
<i>Porites lobata</i>		6		6.3	
<i>Porites compressa</i>				0.8	0.9
<i>Pocillopora meandrina</i>	0.3	0.1		0.5	0.4
<i>Montipora patula</i>	0.1	0.5	0.1	0.1	0.3
<i>Pavona varians</i>				0.2	
Sand				3	
Rubble	74.5	82.8	99.5	89.1	78.6
Hard Substratum	25	8			19
II. Macroinvertebrate Census (4 m × 20 m)					
	No. of Individuals				
Phylum Mollusca					
<i>Spondylus tenebrosus</i>	2				
<i>Cymatium pileare</i>	1				
Phylum Echinodermata					
<i>Tripneustes gratilla</i>	3				
<i>Echinothrix calamaris</i>	1				
<i>Echinothrix diadema</i>	3				
<i>Echinometra mathaei</i>	8				
<i>Heterocentrotus mammillatus</i>	2				
<i>Diadema setosum</i>	1				
III. Fish Census (4 m × 20 m)					
18 Species					
109 Individuals					
Estimated Standing Crop = 445 g/m <sup>2</sup>					

NOTE: Results of the 5-m<sup>2</sup> 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 3.3% (visual quadrat method).

(*Acanthurus olivaceus*). The standing crop of fish on Transect BP-3-B was estimated at 445 g/m<sup>2</sup>, and the species contributing most heavily were the blue goatfish or moano kea (*Parupeneus cyclostomus*—16% of the total) and *Acanthurus olivaceus* (64% of the total).

### **Station Observations**

In the vicinity of Station BP-3 were seen the corals *Fungia scutaria* and *Pavona varians*, as well as the yellowmargin moray eel or puhi paka (*Gymnothorax flavimarginatus*), the undulate moray eel or puhi laumilo (*Gymnothorax undulatus*), and the slipper lobster or ula pāpapa (*Paribaccus antarcticus*).

## **Station BP-4**

Station BP-4 was established on 10 September 1993 with two transects (BP-4-A and BP-4-B) placed on and adjacent to the basalt caprock shield that covers and protects the discharge pipe approximately 250 m west of BP-2 in 12 to 13 m of water. Station BP-4 is located 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 BP-4-B is located approximately 15 m to the east on the adjacent flat natural limestone substratum.

### **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 m in dimension 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 thus is 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 noted three algal species (*Neomeris annulata*, *Velonia ventricosa*, and *Porolithon onkodes*) with a mean coverage of 3.5%, one soft coral species (*Palythoa tuberculosa*) having a mean coverage of 0.02%, and three coral species (*Porites lobata*, *P. (Synarea) convexa*, and *Montipora verrucosa*) having a mean coverage of 26.9%. The census of macroinvertebrates noted seven species: the rock oyster *Spondylus tenebrosus*, two polychaete species (*Loimia medusa* and *Sabellastarte sanctijosephi*), the black sea cucumber *Holothuria atra*, and three sea urchin species (*Tripneustes gratilla*, *Echinothrix diadema*, and *E. calamaris*).

The results of the photo-quadrat survey are given in Table 2. In the photo-quadrat analysis, the coralline alga *Porolithon onkodes* had a mean coverage of 0.2%, the encrusting

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 25 April 1994

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Algae					
<i>Neomeris annulata</i>	0.1				
<i>Velonia ventricosa</i>			0.1		
<i>Porolithon onkodes</i>				4.5	13
Soft Corals					
<i>Palythoa tuberculosa</i>		0.1			
Corals					
<i>Porites lobata</i>	13	52	19	31	19
<i>Porites (Synarea) convexa</i>			0.6		
<i>Montipora verrucosa</i>	0.1				
Rubble	13	14	21	19	3
Hard Substratum	73.8	22.9	59.3	45.5	65
<hr/>					
II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals				
<hr/>					
Phylum Mollusca					
<i>Spondylus tenebrosus</i>	1				
Phylum Annelida					
<i>Loimia medusa</i>	1				
<i>Sabellastarte sanctijosephi</i>	2				
Phylum Echinodermata					
<i>Tripneustes gratilla</i>	2				
<i>Echinothrix calamaris</i>	2				
<i>Echinothrix diadema</i>	121				
<i>Holothuria atra</i>	2				
<hr/>					
III. Fish Census (4 m × 20 m)					
<hr/>					
51 Species					
1,563 Individuals					
Estimated Standing Crop = 1,305 g/m <sup>2</sup>					

NOTE: Results of the 5-m<sup>2</sup> 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 12.2 m; mean coral coverage is 26.9% (visual quadrat method).

sponge *Spirastrella coccinea* had a mean coverage of 1.2%, and two coral species (*Porites lobata* and *Pocillopora meandrina*) had an estimated coverage of 19.3%.

The results of the fish census carried out at Transect BP-4-A are presented in the Appendix. Fifty-one fish species representing 1,563 individuals having an estimated biomass of 1,305 g/m<sup>2</sup> were censused. The most abundant fish species included the black damselfish or 'ālo'ilo'i (*Dascyllus albisella*—18% of the total number), the bluelined snapper or ta'ape (*Lutjanus kasmira*—39% of the total), and the goldring surgeonfish or kole (*Ctenochaetus strigosus*—7% of the total). Species contributing most to the estimated standing crop included the undulate moray eel or puhi laumilo (*Gymnothorax undulatus*—3% of the total), the orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*—11% of the total), and *Lutjanus kasmira* (50% of the total).

#### **Transect BP-4-B**

Transect BP-4-B was established approximately 15 m to the east of Transect BP-4-A in 13.1 m to 13.4 m of water (Figure 4). 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<sup>2</sup>. These patches of sand are spaced from 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 noted three encrusting sponge species (*Spirastrella coccinea*, *Chondrosia chucalla*, and *Asteropus kaena*) having a mean coverage of 0.6%, one soft coral species (*Anthelia edmondsoni*) having a mean coverage of 0.02%, and three coral species (*Porites lobata*, *Pocillopora meandrina*, and *Montipora patula*) with a mean coverage of 3.7%. The macroinvertebrate census noted the cone shell *Conus miles* and the rock boring urchin *Echinostrephus aciculatum*.

The results of the photo-quadrat survey carried out at Transect BP-4-B are given in Table 2. In this survey, two sponge species (*Spirastrella coccinea* and *Chondrosia chucalla*) had a mean coverage of 0.4% and two coral species (*Pocillopora meandrina* and *Porites lobata*) had a mean coverage of 3.3%.

The results of the fish census carried out at Transect BP-4-B are presented in the Appendix. Ten species of fishes representing 15 individuals having an estimated standing crop of 12 g/m<sup>2</sup> were encountered. The most abundant fish species at this transect was the hawkfish or pili ko'a (*Paracirrhites arcatus*), and 57% of the standing crop was due to a single orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*) that passed through the transect area during the census.

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 on 25 April 1994

I. Quadrat Survey	Percent Cover				
	Quadrat Distance Along Transect				
	0 m	5 m	10 m	15 m	20 m
Sponges					
<i>Asteropus kaena</i>		0.3			
<i>Chondrosia chucalla</i>	0.4			1.1	1.2
<i>Callyspongia diffusa</i>		0.1			
Soft Corals					
<i>Anthelia edmondsoni</i>					0.1
Corals					
<i>Porites lobata</i>	0.7	0.2	1.2	1.2	0.8
<i>Pocillopora meandrina</i>	7.5		0.3	4.5	
<i>Montipora panula</i>	2.3				
Sand		6	89.5		
Hard Substratum	89.1	93.4	9	93.2	97.9
<hr/>					
II. Macroinvertebrate Census (4 m × 20 m)	No. of Individuals				
<hr/>					
Phylum Mollusca					
<i>Conus miles</i>	1				
Phylum Echinodermata					
<i>Echinostrephus aciculatum</i>	5				
<hr/>					
III. Fish Census (4 m × 20 m)					
<hr/>					
10 Species					
15 Individuals					
Estimated Standing Crop = 12 g/m <sup>2</sup>					

NOTE: Results of the 5-m<sup>2</sup> 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 13.1m to 13.4 m; mean coral coverage is 3.7% (visual quadrat method).

## Physical Measurements and Biological Parameters

Physical measurements made in the morning on 28 April 1994 are presented in Table 10. Little variation was noted in temperature (22.7 to 23.1°C), percent oxygen saturation (101% to 103%), and salinity (all 34‰) despite the fact that measurements for oxygen and temperature were made both at 1 m below the water surface and about 1 m above the bottom. In all cases the secchi disk measurements did not yield an extinction value; water clarity was such that from the surface 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 nephelometer in the laboratory.

The biological data for the 1991, 1993, and 1994 annual surveys are summarized as means for each transect in Table 11. The means of all biological parameters measured in these surveys (i.e., 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 to the recovery in these communities since the storm. The Kruskal–Wallis analysis of variance applied to the annual mean data (combining all transects during an annual sample 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 ( $p > 0.56$ , not significant), the mean number of coral species ( $p > 0.20$ , not significant), the mean number of macroinvertebrate species ( $p > 0.90$ , not significant), the mean number of fish species ( $p > 0.95$ , not significant), the mean number of individual fish ( $p > 0.85$ , not significant), and the mean standing crop of fish expressed in grams per square meter ( $p > 0.94$ , not significant).

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 transects.

From a commercial fisheries standpoint, a number of important species have been encountered at several of the transect sites, including the brick soldierfish or menpachi (*Myripristis amaenus*), bigeye or 'āweoweo (*Priacanthus cruentatus*), grey snapper or uku (*Aprion virescens*), emperor fish or mu (*Monotaxis grandoculis*), yellowfin goatfish or weke'ula (*Mulloidichthys vanicolensis*), yellowstripe goatfish or weke (*Mulloidichthys flavolineatus*), sidespot goatfish or malu (*Parupeneus pleurostigma*), manybar goatfish or

TABLE 10. Summary of Physical Measurements Made at Each Station in the Vicinity of Transect Pairs, 2 October 1991, 16 September 1993, and 28 April 1994

Location and Time	Oxygen (% of Saturation)		Salinity (‰)	Temperature (°C)		Depth to Secchi Extinction (m)
	Top	Bottom		Top	Bottom	
<b>2 OCTOBER 1991</b>						
Station BP-1 1000 hr	103	102	34	25.3	25.1	>15
Station BP-2 1025 hr	101	101	34	25.0	24.9	>11
Station BP-3 1110 hr	102	102	34	25.4	25.2	>16.5
<b>16 SEPTEMBER 1993</b>						
Station BP-1 0945 hr	102	101	34	25.4	25.1	>15
Station BP-2 1020 hr	103	102	34	25.5	25.2	>11
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
<b>28 APRIL 1994</b>						
Station BP-1 0930 hr	103	102	34	23.1	23.0	>15
Station BP-2 1010 hr	102	101	34	22.7	23.0	>11
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

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, and April 1994

Transect	% Algal Cover		% Coral Cover		No. of Coral Species		No. of Invert. Species		No. of Fish Species		No. of Fish Individuals		Biomass (g/m <sup>2</sup> )									
	1991	1993	1994	1994	1991	1993	1994	1991	1993	1994	1991	1993	1994	1993	1994							
BP-1-A	4.2	6.4	6.3	23.9	20.9	27.2	3	5	2	4	4	4	8	47	41	39	745	375	387	406	249	222
BP-1-B	6.1	3.7	3.2	29.4	27.2	25.4	3	3	3	2	4	4	4	42	44	42	453	488	371	374	490	202
BP-2-A	0.5	0	0	3.6	1.8	1.2	3	2	2	6	7	3	3	10	6	5	21	6	7	7	9	2
BP-2-B	0.3	0	0	2.7	1.3	1.0	3	2	2	4	4	6	6	6	12	11	12	21	36	2	11	25
BP-3-A	3.0	0.1	0.1	8.0	1.2	1.4	4	3	4	8	9	6	6	38	28	26	367	82	191	343	70	255
BP-3-B	0.3	1.8	3.0	11.6	8.3	9.5	5	4	4	6	6	8	8	30	17	18	187	161	109	121	311	445
BP-4-A		0.3	0.2		17.9	19.3	3	2	2		6	7	7		49	51		537	1,563		374	1,305
BP-4-B		0.7	0		0.2	3.3	2	2	2		2	2	2		2	10		3	15		1	12
Mean	2.4	1.6	1.6	13.2	9.9	11.0	4	3	3	5	5	5	6	29	25	25	298	209	335	209	189	309

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



moano (*Parupeneus multifasciatus*), blue goatfish or moano kea (*Parupeneus cyclostomus*), and the octopus or he'e (*Octopus cyanea*).

### Green Sea Turtle Observations

Two green turtles (*Chelonia mydas*) were encountered on the bottom directly adjacent to Station BP-3. Both were resting on the bottom in a depression located about 15 m from Transect BP-3-B. The estimated straight line carapace lengths of these two individuals were 70 cm and 90 cm. In general, individual turtles are commonly seen surfacing for air while transiting from Honolulu Harbor to 'Ewa Beach. Most of the individuals seen are juveniles (i.e., they are less than 80 cm in straight line carapace length).

## DISCUSSION

On 11 September 1992 the Hawaiian islands were struck by Hurricane Iniki. The hurricane passed directly over Kaua'i, with sustained winds of 144 mph and gusts to 172 mph resulting in considerable damage to improvements and forests of that island and the west (leeward) coast of O'ahu. To a lesser extent, high surf caused damage to marine communities along the 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 Hawaiian coral communities (Dollar 1982). Because Hawaiian 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<sup>2</sup> to over 30 m<sup>2</sup>. 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 Hawaiian corals are relatively slow growing, it will be years before the impact of Hurricane Iniki will no longer be evident in the benthic communities of the study sites.

The results from the three 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 suggests 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 stone 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 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 continues to play a role in eliminating corals from the limestone and armor rock, then corals should be rare or absent from 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 15 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 poorly 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 to the shallow-water coral reef areas shoreward of the outfall, our monitoring should be able to quantitatively discern these impacts. Because of bottom time constraints, potential dangers with deep diving, and the fact that coral community development is usually greatest in water less than 30 m 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, Keehi Lagoon, and Pearl Harbor situated to the east would be carried in a westerly direction toward the area offshore of 'Ewa 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<sup>3</sup>/sec) of raw sewage in 10 m of water offshore of Sand Island. This material was undoubtedly diluted but 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). 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 statistical changes between the 1991, 1993 and 1994 sampling periods, suggesting that the operation of the outfall has not resulted in measurable negative impacts.

Relative to many other locations in the Hawaiian Islands, the fish communities are well developed at the eastern (BP-1), western (BP-3), and pipe-armor rock (BP-4-A) stations. The

high-standing crop estimates are much greater than found on most coral reefs; the maximum fish standing crop encountered on natural coral reefs is about 200 g/m<sup>2</sup> (Goldman and Talbot 1975; Brock et al. 1979). Two explanations for the high biomass 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 serves 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 Hawaiian reefs, estimated the standing crop of fishes to range from 4 g/m<sup>2</sup> on sand flats to 186 g/m<sup>2</sup> in an area of considerable vertical relief. If structural complexity or topographical relief is important to coral reef fish communities, then the addition of materials to increase this relief in otherwise barren areas may serve to locally enhance the biomass of fish. Such manipulations are well known and usually take the form of artificial reefs. Artificial reefs in Hawaiian waters may serve to increase fish standing crops to more than 1 kg/m<sup>2</sup> (Brock and Norris 1989).

Chance encounters with large roving predators (such as emperor fish or mu, [*Monotaxis grandoculis*] and grey snappers or uku [*Aprion virescens*]) or schools of planktivorous fishes (such as the mackerel scad or opelu [*Decapterus macarellus*], the sleek unicornfish or kala holo, [*Naso hexacanthus*], the milletseed butterfly fish or lauwiwili [*Chaetodon miliaris*], and the sergeant major or mamo [*Abudefduf abdominalis*]) may greatly increase the counts and biomass on a particular transect. The presence of the 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 will result in higher biomass estimates.

Schooling species such as the bluelined snapper or ta'ape (*Lutjanus kasmira*), emperor fish or mu (*Monotaxis grandoculis*), and orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*) all contributed substantially to the standing crop on several transects. At Transect BP-1-A, *Monotaxis grandoculis* contributed 15% of the biomass and at Transect BP-1-B, 28%. At Transect BP-3-A *Acanthurus olivaceus* made up 63% of the biomass and at Transect BP-3-B, 64%. A large school of *Lutjanus kasmira* was present at Transect BP-4-A, contributing 50% of the fish biomass at this site. Relatively large solitary predators often

contributed to the estimated standing crop at a location; a single broomtail filefish or 'ō'ili lepa (*Alutera scripta*) made up 14% of the biomass at Transect BP-1-A and 7% at Transect BP-1-B.

## 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 shore and the annual quantitative survey of these stations should allow a delineation of changes that may be caused by the effluent. In the three annual surveys (1991, 1993, and 1994) no statistically significant change was detected at the permanent survey stations, despite the imposition of a major hurricane on the marine communities in September 1992. 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 discharge.

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## APPENDIX



Results of Quantitative Visual Fish Censuses Conducted on Two Transects Each at Four Stations Offshore of 'Ewa Beach, O'ahu, Hawai'i, 25 and 27 April 1994

FAMILY and Species	Transect (BP-)							
	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B
<b>MURAENIDAE</b>								
<i>Gymnothorax flavimarginatus</i>						1		
<i>Gymnothorax undulatus</i>							1	
<i>Gymnothorax meleagris</i>								1
<b>SYNODONTIDAE</b>								
<i>Saurida gracilis</i>		1						
<b>AULOSTOMIDAE</b>								
<i>Aulostomus chinensis</i>				1				1
<b>HOLOCENTRIDAE</b>								
<i>Myripristis amaenus</i>	28	12						63
<i>Adioryx xantherythrus</i>	5	2						
<i>Adioryx diadema</i>	6	8						
<b>SCORPAENIDAE</b>								
<i>Dendrochirus barberi</i>				1				
<b>PRIACANTHIDAE</b>								
<i>Priacanthus cruentatus</i>	1							
<b>FISTULARIIDAE</b>								
<i>Fistularia commersoni</i>	1	2						
<b>APOGONIDAE</b>								
<i>Apogon kallopterus</i>	3	9						2
<b>SERRANIDAE</b>								
<i>Cephalopholis argus</i>						1		
<b>LUTJANIDAE</b>								
<i>Lutjanus kasmira</i>								619
<i>Aprion virescens</i>								1
<b>SPARIDAE</b>								
<i>Monotaxis grandoculis</i>	6	14						
<b>MULLIDAE</b>								
<i>Mulloidichthys vanicolensis</i>								8
<i>Mulloidichthys flavolineatus</i>		16						
<i>Parupeneus pleurostigma</i>	1	1				1	1	1
<i>Parupeneus multifasciatus</i>	16	6				62	18	14
<i>Parupeneus cyclostomus</i>							5	
<b>CHAETODONTIDAE</b>								
<i>Forcipiger flavissimus</i>		3						9
<i>Chaetodon multicinctus</i>	4	5				2		4
<i>Chaetodon fremblii</i>								1
<i>Chaetodon kleinii</i>						1	1	23
<i>Chaetodon auriga</i>						2		
<i>Chaetodon quadrimaculatus</i>								2
<i>Chaetodon miliaris</i>		9						51
<b>POMACANTHIDAE</b>								
<i>Centropyge potteri</i>	4	13						1

## Results—Continued

FAMILY and Species	Transect (BP-)							
	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B
<b>POMACENTRIDAE</b>								
<i>Dascyllus albisella</i>	14	23		19	16		285	
<i>Plectroglyphidodon johnstonianus</i>	1	4					1	
<i>Abudefduf abdominalis</i>		1					14	
<i>Chromis vanderbilti</i>				3	1	3		2
<i>Chromis hanui</i>	21	24						
<i>Chromis verator</i>	9							
<i>Chromis ovalis</i>	44	55					1	
<i>Chromis agilis</i>	9							
<i>Stegastes fasciolatus</i>	1	3					21	
<b>CIRRHITIDAE</b>								
<i>Paracirrhinus arcatus</i>							1	4
<i>Paracirrhinus forsteri</i>		3					1	
<i>Cirrhitops fasciatus</i>						1	2	
<i>Cirrhitus pinnulatus</i>	1							
<b>LABRIDAE</b>								
<i>Bodianus bilunulatus</i>	1				1		1	
<i>Cheilinus bimaculatus</i>			1	1				
<i>Pseudocheilinus octotaenia</i>		4			1			
<i>Thalassoma duperrey</i>	9	4		3	16	4	39	
<i>Thalassoma ballieui</i>	1						2	
<i>Coris gaimard</i>					2			
<i>Coris venusta</i>			1					
<i>Coris flavovittata</i>							1	
<i>Pseudojuloides cerasinus</i>		3	1		8	18		1
<i>Stethojulis balteata</i>		1			2			
<i>Macropharyngodon geoffroy</i>								1
<i>Anampses chrysocephalus</i>	7	1					3	
<i>Gomphosus varius</i>							3	
<b>SCARIDAE</b>								
<i>Calotomus carolinus</i>					3		1	
<i>Scarus perspicillatus</i>	2			2				
<i>Scarus sordidus</i>	11	1			13		16	
<i>Scarus rubroviolaceus</i>						2		
<b>BLENNIIDAE</b>								
<i>Exallia brevis</i>							1	
<i>Plagiotremus ewaensis</i>				1	1			
<b>ACANTHURIDAE</b>								
<i>Acanthurus nigrofuscus</i>	36	25			12	4	91	
<i>Acanthurus nigroris</i>	10	4			3	9	23	
<i>Acanthurus olivaceus</i>	4	1		3	21	36	29	1
<i>Acanthurus triostegus</i>				1	1		45	
<i>Acanthurus dussumieri</i>							1	
<i>Acanthurus mata</i>							2	
<i>Acanthurus thompsoni</i>	14							
<i>Ctenochaetus strigosus</i>	99	82			13		107	
<i>Zebrasoma flavescens</i>	8	13						

## Results—Continued

FAMILY and Species	Transect (BP-)							
	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B
<i>Naso hexacanthus</i>		1					42	
<i>Naso unicornis</i>							13	
<i>Naso brevirostris</i>	1						1	
<i>Naso lituratus</i>						2		
<b>ZANCLIDAE</b>								
<i>Zanclus cornutus</i>	1	2					2	
<b>BALISTIDAE</b>								
<i>Melichthys niger</i>		3				1		
<i>Melichthys vidua</i>		1				1	2	
<i>Sufflamen bursa</i>	2	3			1	1	5	2
<i>Sufflamen fraenatus</i>	1		1	1			1	1
<i>Xanthichthys auromarginatus</i>							1	
<b>MONACANTHIDAE</b>								
<i>Pervagor melanocephalus</i>		1						
<i>Pervagor spilosoma</i>	1	1						
<i>Cantherhines dumerili</i>						1		
<i>Alutera scripta</i>	1	1					2	
<b>OSTRACIONTIDAE</b>								
<i>Ostracion meleagris</i>						1		
<b>CANTHIGASTERIDAE</b>								
<i>Canthigaster jactator</i>	1	4	3		4		1	1
<i>Canthigaster coronata</i>	1				2			1
<b>DIODONTIDAE</b>								
<i>Diodon holocanthus</i>		1					1	
Total No. of Species	39	42	5	11	26	18	51	10
Total No. of Individuals	386	371	7	36	191	109	1,563	15
Estimated Standing Crop (g/m <sup>2</sup> )	222	202	2	25	255	445	1,305	12

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

