AN ANALYSIS OF THE FISH COMMUNITIES ALONG THE BARBERS POINT OCEAN OUTFALL, ‘EWA BEACH, O‘AHU, HAWAI‘I, USING REMOTE VIDEO—1993 DATA

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PROJECT REPORT PR-94-17

April 1994

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ABSTRACT

Because the diffuser of the Barbers Point Ocean Outfall lies below safe diving depths, a remotely controlled video camera system was used to determine the status of the marine fish communities and selected diurnally exposed macroinvertebrate species residing on the diffuser. Video reconnaissance was completed over the entire 534-m length. Three visual "transects," which "sampled" approximately 31% of the total diffuser length, were established on the diffuser pipe. Video sampling of the diffuser fish communities was carried out in January 1992 and January 1993. The results of the two annual surveys indicate that the diffuser fish communities are dominated by species that are either small as adults or juveniles of larger species, probably as a result of the presence of only small-scale shelter created by small armor rock and gravel used in constructing the discharge pipe. Because of poor camera resolution, small fish sizes, and the fishes' nature to flee from the approaching camera, the fish census data are highly variable and should be viewed as more qualitative than quantitative in nature. Despite this variability from transect to transect and year to year, there was no statistically significant change in the diffuser fish community from 1992 to 1993. Little significance should be attached to any change noted in the fish or macrobenthic communities residing on the Barbers Point diffuser because of the variable quality of the data generated by use of the remotely controlled video system.

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INTRODUCTION

In recent years controversy has arisen regarding the impact that sewage effluent from the Honouliuli Wastewater Treatment Plant may have on marine communities resident in the receiving waters. The Barbers Point Ocean Outfall, which has been operational since 1982, currently releases roughly 25 mgd (1.10 m^3/s) of primary treated sewage through a 2670-m-long pipe with a diffuser situated at a depth of 61 m offshore of ‘Ewa Beach, O‘ahu, Hawai‘i. The diffuser is comprised of reinforced concrete pipe of three diameters: 146.3 m of 1.98-m-diameter pipe having 40 discharge ports that are 8.67 cm in diameter on the shoreward end of the diffuser, 176.5 m of 1.68-m-diameter pipe equipped with 50 ports that are 9.09 cm in diameter in the central part, and 197.5 m of 1.22-m-diameter pipe outfitted with 58 ports that are 9.50 cm in diameter at the seaward end. Together these are comprised of 71 7.3-m sections of the diffuser. Reducers make up the other two 7.3-m sections; one reduces the diameter from 1.98 to 1.68 m and the second from 1.68 m to 1.22 m. At the terminus of the diffuser are two 15.24-cm-diameter ports. In all, there are 148 ports (two per pipe section) spread along the 534 m length of the diffuser. The diffuser rests on a gravel pad and has some ballast rock placed at the junctures between sections as well as along both sides of each pipe section up to the midline (springline). Fishes and invertebrates have taken up residence along most of the length of the deep ocean outfall. This study has been undertaken in an attempt to semiquantitatively ascertain the impacts that may be occurring to the communities residing on the diffuser. This report presents a synopsis of the data from the second annual sampling effort carried out on 20 January 1993.

MATERIALS AND METHODS

Because the fish and diurnally exposed macroinvertebrate communities of interest to this study reside in waters below safe diving depths, a remote controlled video camera system was used. There are a number of drawbacks as well as positive aspects to using a video camera system to visually census fishes and diurnally exposed macroinvertebrates. The drawbacks include problems with camera resolution, making species and size identifications difficult, and the problem of adequately controlling the camera to focus-in on rapidly fleeing fishes, adding further difficulty to identification problems. On the positive side, a permanent record of the organisms in the path of the camera is obtained. An additional benefit of using a video system is that it eliminates the need for diving to great depths.

There are some well-known problems with using visual census methods to assess coral reef fish populations, regardless of whether a camera or diver is in the water conducting the census. One of these is the simple frightening of wary fishes on the approach of the diver or camera. Another is 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). Use of a remotely controlled video system to obtain census data compounds many of the above problems, but it is probably one of the most cost-effective methods available for assessing fish communities at depths below safe diving limits.

Other than exposed sessile species (corals in shallow water and some sponges in deeper waters), most tropical marine invertebrates are cryptic, remaining under shelter until darkness when they emerge to feed. Only a few motile macroinvertebrates remain fully exposed during the day; among these are some holothurian (sea cucumber) and echinoid (sea urchin) species. Problems with species identification preclude the enumeration of most diurnally exposed invertebrates. Identification of holothurians is based on skin spicule configuration, and spicules are also used for identification of sponges. Thus, in this study, the identification and enumeration of exposed macroinvertebrates are confined to large arthropods (spiny lobsters) and sea urchins, and educated guesses are made as to species of holothurians present along the Barbers Point diffuser pipe.

The video "transect" of fish and macroinvertebrate populations resident to the diffuser pipe along predetermined transects was undertaken by the Oceanographic Team of the Department of Wastewater Management, City and County of Honolulu. In general, the video camera traveled from 0.5 to 1.5 m above the diffuser pipe, occasionally moving to the right or left side (and down) to survey the substratum alongside of the pipe. The camera usually viewed a path from about 1.5 to 3 m in width. For data analysis purposes, we assumed that the camera path was approximately 2 m in width and attempted to count only fishes and invertebrates seen in this path. At times, the camera would tilt up (toward the horizon) to allow a viewing ahead down the pipe. Visibility under these circumstances ranged from about 1 m (in a discharge plume) to about 8 m, which is approximately the length of one pipe section. Because the camera grossly underestimates the number of fishes and invertebrates, we counted everything in the arbitrary 2-m-wide path, regardless of whether it was encountered directly below the camera (as when viewing from above) or several meters ahead (as when the camera is in a horizontal position).

The fish census involved not only the counting of populations but also the estimating of the lengths of all fishes for later use in calculating standing crop. The standing crop of all fishes was estimated by use of linear regression techniques (Ricker 1975). Commencing about 30 years ago, species-specific regression coefficients have been developed by the author and others at the University of Hawaii, the Naval Undersea Center (see Evans 1974), and the Hawaii Division of Aquatic Resources from weight and body length measurements of captured fishes; for many species, sample sizes were in excess of a hundred individuals.

Simple nonparametric statistical procedures were utilized in analyzing the data. Specifically, the Wilcoxon 2-Sample Test was used to compare means of parameters between the two annual surveys (SAS Institute, Inc. 1985).

RESULTS

The first video survey was carried out in January 1992 (see Brock 1993b). The videotape, which covered the entire length of the 534-m diffuser, was viewed several times to determine where representative "transects" could be best be established. Three transect sites selected as being representative of different parts of the diffuser pipe were sampled using the visual census technique. These transects were established using known points on the pipe and counting sections of pipe from those points. Establishing transects at known points ensures that these same sites can again be sampled in subsequent annual surveys, thus making data comparable. These same sites were sampled in the 1993 survey.

The location of each transect is shown in Figure 1. Transect 1 commences at the outfall terminus and continues shoreward for 36.5 m. It "samples" 73 m^2 of substratum at the terminal five sections of the 1.22-m-diameter diffuser pipe at a depth of 61 m. Transect 2 is situated near the middle of the diffuser and commences 212 m down from the beginning of the diffuser pipe in about 61 m of water and continues for 80 m along the pipe from that point. This transect samples 11 sections of the 1.68-m-diameter diffuser pipe, or 161 m^2 of substratum. Transect 3 was established approximately 197.5 m from the end of Transect 2 (or 490 m from the outfall terminus). Comprised of the seven most landward sections of the

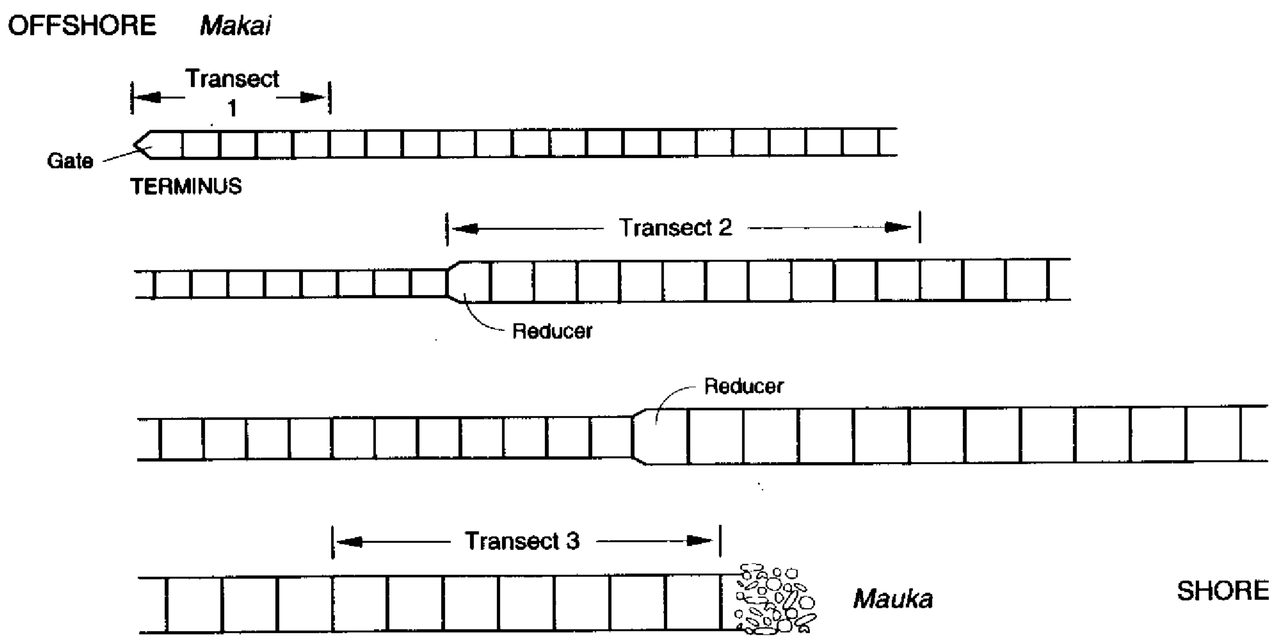

FIGURE 1. Rough schematic of the 534-m-long Barbers Point deep ocean outfall diffuser pipe showing the approximate locations of three fish census transects (Transects 1 through 3) first surveyed by a remotely controlled video recording system on 12 January 1992 and 20 January 1993. Transects are numbered, and the length of diffuser pipe covered by each is shown with arrows. Transect 1 covers the gate plus 4 of 27 sections of 1.22-m-diameter pipe. Transect 2 covers 11 of 24 sections of 1.68-m-diameter pipe, and Transect 3 covers 7 of 20 sections of 1.98-m-diameter pipe. Each of the 71 pipe sections and the reducers is 7.3 m in length. (Drawing not to scale)

1.98-m-diameter diffuser pipe, this transect, which is located at a depth of about 61 m, samples 102 m^2 of substratum. It commences at the shoreward end of the diffuser (where the pipe emerges from the armor rock cap and discharge ports are evident) and continues for 51 m in a seaward direction. In total, these transects sampled 31% of the total diffuser length.

Collectively, approximately 336 m^2 of substratum were sampled. The results of all fish censuses for the 20 January 1993 survey are presented in Table 1, and the data for each transect are discussed below. In tallying the number of species seen on a given transect, all fishes that could not be positively assigned to a given species were lumped into groups such as "labrid unidentified"; in the tally of species, each of these groups were counted as being comprised of a single species, even though more than one species may have been in the group.

In the 1993 survey at Transect 1, 10 species of fishes representing 52 individuals were seen (Table 1). This amounts to one new fish species encountered for every 7.3 m^2 of substratum sampled or one fish seen for every 1.4 m^2 of bottom on the transect. The most abundant fish species were the damselfish *Chromis hanui* and *Chromis* sp. (probably a mix of *C. hanui* and *C. agilis*), which comprised 63% of the total number of fishes present. In terms of standing crop, which was estimated at 18 g/m^2, the most important contributors were a single orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*) comprising 44% of the total, two bluespine unicornfish or kala (*Naso unicornis*) making up 13%, and a single barred filefish or 'ō'ili (*Cantherhines dumerilii*) accounting for 23%.

Five species of macroinvertebrates were noted during the census at Transect 1 in January 1993 (Table 2). The most abundant identifiable macroinvertebrate was the long-spined black sea urchin or wana (*Diadema setosum*—six individuals), followed by the black sea cucumber *Holothuria atra* (four individuals), the spotted sea cucumber *Bohadschia vitiensis* (two individuals), the cushion starfish *Culcita novaeguineae* (one individual), and the serrated sea urchin *Chondrocidaris gigantea* (one individual).

In the January 1992 survey at Transect 1 (Brock 1993b), 11 species of fishes representing 294 individuals with an estimated biomass of 13 g/m^2 were censused. This amounts to one new fish species encountered for every 6.6 m^2 of substratum sampled or one individual fish seen for every 0.2 m^2 of bottom on the transect. Of the species that could be identified, the most abundant fishes were the snapper (*Lutjanus* sp.; probably juvenile bluelined snapper or ta'ape [*Lutjanus kasmira*]), which comprised 86% of the fishes censused, and the damselfishes *Chromis hanui* and *Chromis* sp. (probably *C. hanui* or *C. agilis*, or both). In terms of standing crop, juvenile snappers (*Lutjanus* sp.) contributed 57% of the total and the orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*) accounted for 22%.

Five identifiable macroinvertebrate species were seen at Transect 1 in the January 1992 survey. These species were the cushion starfish *Culcita novaeguineae* (one individual), the

TABLE 1. Family and Species of Fishes Censused on Three Transects Along the 534-m-Long Diffuser Pipe of the Barbers Point Ocean Outfall as Delineated By Use of a Remotely Controlled Video Camera System on 20 January 1993. Areas Sampled on the Three Transects Varied: 73 m^2 for Transect 1, 161 m^2 for Transect 2, and 102 m^2 for Transect 3.

FAMILY and Species	Transect		
	1	2	3
SERRANIDAE			
Pseudanthias thompsoni		1	
LUTJANIDAE			
Lutjanus kasmira		28	
MULLIDAE			
Parupeneus multifasciatus		3	1
CHAETODONTIDAE			
Chaetodon miliaris		1	
Chaetodon sp.	1	1	
POMACANTHIDAE			
Holocanthus arcuatus	1		1
POMACENTRIDAE			
Chromis hanui	15	31	
Chromis sp.	18	9	29
Pomacentrid sp.		2	6
LABRIDAE			
Thalassoma duperrey			2
Thalassoma sp.	8	3	
Bodianus bilunulatus	1		
Labrid unidentified	4	3	8
ACANTHURIDAE			
Acanthurus xanthopterus			
A. olivaceus	1	2	
Acanthurid sp.		1	
Naso unicornis	2		
N. hexacanthus			1
BALISTIDAE			
Sufflamen fraenatus		1	
MONACANTHIDAE			
Cantherhines dumerilii	1	1	
CANTHIGASTERIDAE			
Canthigaster jactator		1	
Unidentified fish sp.		9	
Total No. of Species	10	16	7
Total No. of Individuals	52	97	48
Estimated Biomass (g/m^2)	18	13	12

NOTE: In the body of the table are given the numbers of each species censused. At the foot of the table are given totals and an estimate of biomass for each transect.

TABLE 2. Summary of the Physical Characteristics of Three Transects Carried Out at Various Points Along the 534-m Barbers Point Ocean Outfall Diffuser

Parameter	1992 Transect			1993 Transect		
	1	2	3	1	2	3
Transect Length (m)	36.5	80	51	36.5	80	51
Area Sampled (m^2)	73	161	102	73	161	102
No. of Fish Species	11	13	13	10	16	7
No. of Fish Individuals	294	413	221	52	97	48
No. of m^2 Sampled/New Fish Species	6.6	12.4	7.8	7.3	10.1	14.6
No. of m^2 Sampled/Individual Fish	0.2	0.4	0.5	1.4	1.7	2.1
Fish Biomass (g/m^2)	13	41	51	18	13	12
No. of Macroinvertebrate Species	5	4	5	5	5	4
No. of Macroinvertebrate Individuals	8	13	22	14	28	16

NOTE: Included are summary data from the fish and invertebrate censuses carried out at each transect location in January 1992 (from Brock 1993b) and January 1993.

long-spined black sea urchin or wana (*Diadema setosum*—three individuals), the serrated sea urchin *Chondrocidaris gigantea* (one individual), the spotted sea cucumber *Bohadschia vitiensis* (one individual), and the common black sea cucumber *Holothuria atra* (two individuals).

In the January 1993 survey at Transect 2, 16 species of fishes representing 97 individuals were censused (Table 1). The most abundant species at this transect were juvenile bluelined snapper or ta'ape (*Lutjanus kasmira*), which comprised 29% of the total numbers counted, and the damselfish *Chromis hanui*, which made up 32%. This amounts to one new species encountered for every 10.1 m^2 of substratum sampled or one fish seen for every 1.7 m^2 of bottom on the transect. The standing crop of fishes was estimated at 13 g/m^2, and the species contributing most heavily included two yellowfin surgeonfish or pualu (*Acanthurus xanthopterus*—38% of the total) and single individuals of the bridled triggerfish or humuhumu mimi (*Sufflamen fraenatus*—16% of the total) and the barred filefish or 'ō'ili (*Cantherhines dumerilii*—21% of the total).

In the January 1993 census five species of macroinvertebrates representing 28 individuals were noted at Transect 2 (Table 2). These species were the black sea cucumber *Holothuria atra* (eight individuals), the long-spined black sea urchin or wana (*Diadema setosum*—eight individuals), the cushion starfish *Culcita novaeguineae* (six individuals), the spotted sea cucumber *Bohadschia vitiensis* (five individuals), and the serrated sea urchin *Chondrocidaris gigantea* (one individual).

In the January 1992 survey of Transect 2 (Brock 1993b), 13 species of fishes representing 413 individuals were censused. This translates to one new species seen for every 12.4 m^2 of substratum sampled, or one fish seen for every 0.4 m^2 sampled. The most common species of fishes seen were the bluelined snapper or ta'ape (*Lutjanus kasmira*), the damselfish *Chromis hanui*, and the manybar goatfish or moano (*Parupeneus multifasciatus*). Important species by weight included a single blue trevally or 'ōmilu (*Caranx melampygus*—42% of the total), the bridled triggerfish or humuhumu mimi (*Sufflamen fraenatus*—24% of the total), the juvenile snapper (*Lutjanus* sp.—11% of the total), and the smooth puffer or kēkē (*Arothron hispidus*—10% of the total). The biomass of fishes was estimated at 41 g/m^2.

In the January 1992 macroinvertebrate census 4 species representing 13 individuals were encountered. These species included the common black sea cucumber *Holothuria atra* (nine individuals), the spotted sea cucumber *Bohadschia vitiensis* (two individuals), the long-spined black sea urchin or wana (*Diadema setosum* —one individual), and the cushion starfish *Culcita novaeguineae* (one individual).

Seven species of fishes representing 48 individuals were censused in the January 1993 survey on Transect 3 (Table 1). This amounts to one new fish species encountered for every 14.6 m^2 of bottom sampled or one fish seen for every 2.1 m^2 of substratum surveyed. The most abundant identifiable fish species was the damselfish *Chromis* sp. (probably a mix of *C. hanui* and *C. agilis*), which comprised 60% of the total number of individuals at this site. The standing crop of fishes was estimated at 12 g/m^2; a single sleek unicornfish or kala holo (*Naso hexacanthus*) contributed 75% of this amount.

In the January 1993 macroinvertebrate census 4 species representing 16 individuals were noted (Table 2). These species included the cushion starfish *Culcita novaeguineae* (three individuals), the black sea cucumber *Holothuria atra* (nine individuals), the long-spined black sea urchin or wana (*Diadema setosum*—two individuals), and the spotted sea cucumber *Bohadschia vitiensis* (two individuals).

In the January 1992 survey of Transect 3 (Brock 1993b), 13 species of fishes were seen, or one new fish species was encountered for every 7.8 m^2 of substratum sampled. The number of individual fishes encountered at this transect was 221 individuals or one fish per 0.5 m^2 of bottom. The most abundant fish species appeared to be juvenile snappers (probably bluelined snapper or ta'ape [*Lutjanus kasmira*]), which made up 53% of the total number of fishes censused. Other common species included the damselfish (*Chromis* sp., again probably *C. hanui* or *C. agilis*, or both) and the manybar goatfish or moano (*Parupeneus multifasciatus*). The standing crop of fishes, estimated at 51 g/m^2, was comprised of 3 yellowtail surgeonfish or pualu (*Acanthurus xanthopterus*—43% of the total), 1 orangebar surgeonfish or na'ena'e

(*Acanthurus olivaceus*—21% of the total), and 10 manybar goatfish or moano (*Parupeneus multifasciatus*—8% of the total).

In the 1992 survey, 5 species of macroinvertebrates representing 22 individuals were censused on Transect 3. These species included *Bohadschia vitiensis* (11 individuals), *Holothuria atra* (3 individuals), *Chondrocidaris gigantea* (5 individuals), *Culcita novaeguineae* (2 individuals), and *Diadema setosum* (1 individual).

Physical characteristics and survey results for the three transects censused in January 1992 and January 1993 are summarized in Table 2. In general, the number of individual fish censused and the estimated biomass decreased at all transects from 1992 to 1993. However, these data are similar to those obtained on the Sand Island deep ocean outfall diffuser using the same methods (Brock 1992a, 1992b, 1993a).

A concern of this study is to address the question of change in the marine communities resident to the Barbers Point deep ocean outfall diffuser. A nonparametric statistical comparison of the 1992 with 1993 data (Wilcoxon 2-Sample Test) suggests that despite the changes between the two surveys (as shown in Table 2), none is statistically significant. Specifically, on the three transects there were no significant changes in the mean number of fishes encountered ($p > 0.65$, not significant), the mean number of individual fish censused ($p > 0.08$, not significant), and the mean estimated biomass of fishes ($p > 0.26$, not significant). The mean amount of substratum covered to encounter a new fish species also was not significantly changed ($p > 0.99$, not significant). Similarly, the mean amount of substratum censused to find an individual fish has not significantly changed between the two survey periods ($p > 0.08$, not significant). The mean number of invertebrate species censused between the two survey periods did not change significantly ($p > 0.79$, not significant), nor has the mean number of invertebrates censused changed significantly between the two survey periods ($p > 0.38$, not significant).

DISCUSSION

Despite the changes in the number of species and abundance of fishes on each transect between the two annual surveys, none is statistically significant. Even if the statistical test had shown a significant change from one survey to the next, there would be little reason for concern because of the many problems inherent with the use of the remotely controlled video camera system for assessing small fishes resident to the Barbers Point deep ocean diffuser. These drawbacks, which are discussed below, result in data that are more qualitative than quantitative in nature, thus making comparisons between years tenuous.

The identification of a number of species of fishes in this study was not difficult because of their size (adult pualu or *Acanthurus xanthopterus* and kala or *Naso unicornis*), color (moano or *Parupeneus multifasciatus* and masked angelfish or *Holocanthus arcatus*), extreme abundance (ta'ape or *Lutjanus kasmira*), or diurnal habits (damselfish or *Chromis hanui*). Despite this, a number of the fishes were difficult or impossible to identify because of (1) poor camera resolution due to a lack of water clarity or the camera's field of view, (2) rapid movement of the individual fishes to cover, (3) small size of fishes, or (4) fishes being on the periphery of the camera's field of view. Some of these fishes were small *Chromis* sp. (probably *C. hanui* or *C. agilis*), small *Lutjanus* sp. (probably juvenile *L. kasmira*), and small wrasses (family Labridae; possibly *Cheilinus bimaculatus*, *Pseudocheilinus* spp., *Thalassoma* spp., or *Pseudojuloides cerasinus*). In terms of abundance, these unidentified fishes were important but, in general, contributed little to the biomass estimates because of their small size.

Similarly, only large invertebrates can be seen with enough detail to allow identification and censusing. The identification of the two sea cucumbers (*Bohadschia vitiensis* and *Holothuria atra*) is tentative because accurate identification requires examination of skin spicules with a microscope.

Most of the fishes encountered on the transects on the Barbers Point deep ocean outfall diffuser are small (less than 8 cm) and usually seek shelter on the approach of the video camera, making visual assessments of these fishes difficult. In both the 1992 and 1993 surveys, these small fishes could usually only be seen when the video camera was held in a near-vertical position just above the rocky substratum adjacent to the diffuser pipe. Larger fishes are usually only seen when the camera is held in a near-horizontal position, and when seen these fishes are at a distance, leaving the area of the approaching camera. Thus it is evident that the camera angle plays a large role in the general sizes of fishes seen, and because the control of the camera is difficult, considerable variability in the field of view results. Manipulation of the remotely operated and tethered video camera is difficult, especially when considering that more than 60 m of electrical cable are between the camera and the operator on the surface vessel. Not only does wind create difficulties with keeping the surface vessel on station, but currents may interact with the cable and camera below—all impacting the field of view and fishes seen. Added to this is the fact that both large and small fishes can only be seen when the water clarity permits. Further, the effluent from the diffuser discharge ports often obscures the field of view (depending on the local currents), again adding variability to the resulting data.

The estimated standing crop of fishes ranged from 13 to 51 g/m^2 in the January 1992 survey and from 12 to 18 g/m^2 in the January 1993 census. In many cases, just a few individual large fish contributed heavily to the biomass estimates. Major contributors to the biomass in the censuses for both years were the orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*) on Transect 1, the bridled triggerfish or humuhumu mimi (*Sufflamen fraenatus*) on Transect 2 , and the yellowfin surgeonfish or pualu (*Acanthurus xanthopterus*) on Transect 3. Goldman and Talbot (1975) suggested that a reasonable maximum biomass of coral reef fish is about 200 g/m^2. Space and cover are important agents governing the distribution of coral reef fishes (Sale 1977). Similarly, the standing crop of fishes on a reef is correlated with the degree of vertical relief. Thus Brock (1954) using visual techniques on Hawaiian reefs estimated the standing crop of fishes to range from 4 g/m^2 on sand flats to a maximum of 186 g/m^2 in an area of considerable vertical relief. The large variation seen in standing crop of fishes on coral reefs is tied to the structural diversity of the habitat (Risk 1972). Some authors (Risk 1972; 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) view reef structure as an important factor in determining the species composition of coral reef fish communities. Thus some evidence suggests that both the biomass and species composition are influenced by the complexity of the local topography.

The substratum in the vicinity of the Barbers Point outfall diffuser appears to be a sandy plain. Sand habitats typically support a low diversity of fish species and biomass (i.e., biomass ranging from 0.5 to 20 g/m^2; Brock 1954; Brock et al. 1979; Brock and Norris 1989). The deployment of the diffuser pipe situated on a gravel pad with some ballast stone placed up to the midline of the pipe as well as at the ends of most pipe sections provides additional local topographical structure, which has probably influenced the development of the fish community. Because of the small graded sizes used, the ballast stone and gravel pad provide only small-scale shelter. Small-scale shelter favors species that are either small as adults or juveniles of larger species. The average size of the fishes censused in both the 1992 and 1993 surveys supports this contention. Thus the presence of a few adult fishes of species that attain some size (up to 30 cm) will add substantially to the biomass estimates.

Controlling all of the sources of variation inherent with the use of the remotely controlled video camera is difficult if not impossible. The remotely controlled video camera is used for the annual engineering inspection of the Barbers Point discharge pipe by Department of Wastewater Management personnel and probably provides sufficient resolution and information with respect to the physical status of the outfall and diffuser, but it appears to be inadequate for monitoring the status of fish and macrobenthos on the diffuser. Until an alternative can be found, the remotely controlled video system is the only low-cost means available to view the marine communities on the diffuser. Until a more accurate means of visual assessment is available, the biological data generated by the remotely controlled video camera should be viewed as qualitative, with little statistical rigor.

REFERENCES CITED

Alevizon, W., R. Richardson, P. Pitts, and G. Serviss. 1985. Coral zonation and patterns of community structure in Bahamian reef fishes. *Bull. Mar. Sci.* 36:304–318.

Anderson, G.R.V., A.H. Ehrlich, P.R. Ehrlich, J.D. Roughgarden, B.C. Russell, and F.H. Talbot. 1981. The community structure of coral reef fishes. *Am. Nat.* 117:476–495.

Brock, R.E. 1982. A critique on the visual census method for assessing coral reef fish populations. *Bull. Mar. Sci.* 32:269–276.

Brock, R.E. 1992a. An analysis of the fish communities along the Sand Island deep ocean outfall using remote video. I. 1990 data. Spec. Rep. 04.02:92, Water Resources Research Center, University of Hawaii at Manoa, Honolulu. 6 pp.

Brock, R.E. 1992b. An analysis of the fish communities along the Sand Island deep ocean outfall using remote video. II. 1991 data. Spec. Rep. 04.08:92, Water Resources Research Center, University of Hawaii at Manoa, Honolulu. 14 pp.

Brock, R.E. 1993a. An analysis of the fish communities along the Sand Island deep ocean outfall using remote video III. 1992 data. Spec. Rep. 01.15.93, Water Resources Research Center, University of Hawaii at Manoa, Honolulu. 15 pp.

Brock, R.E. 1993b. An analysis of the fish communities along the Barbers Point deep ocean outfall, O'ahu, Hawai'i, using remote video—1992 data. Project Rep. PR-94-02, Water Resources Research Center, University of Hawaii at Manoa, Honolulu. 10 pp.

Brock, R.E., C. Lewis, and R.C. Wass. 1979. Stability and structure of a fish community on a coral patch reef in Hawaii. *Mar. Biol.* 54:281–292.

Brock, R.E., and J.E. Norris. 1989. An analysis of the efficacy of four artificial reef designs in tropical waters. *Bull. Mar. Sci.* 44:934–941.

Brock, V.E. 1954. A preliminary report on a method of estimating reef fish populations. *J. Wildl. Mgmt.* 18:297–308.

Eckert, G.J. 1985. Settlement of coral reef fishes to different natural substrata and at different depths. In *Proc. 5th Int. Coral Reef Congress,* vol. 5, 385–390. Tahiti.

Evans, E.C., ed. 1974. Pearl Harbor biological survey—final report. Report No. NUC-TN-1128, Naval Undersea Center, Hawaii Laboratory.

Gladfelter, W.B., and E.H. Gladfelter. 1978. Fish community structure as a function of habitat structure on West Indian patch reefs. *Rev. Biol. Trop.* 26(Supplement 1):65–84.

Goldman, B., and F.H. Talbot. 1975. Aspects of the ecology of coral reef fishes. In *Biology and geology of coral reefs,* ed. O.A. Jones and R. Endean, vol. 3, Biology 2, 124–154. New York: Academic Press.

Ogden, J.C., and J.P. Ebersole. 1981. Scale and community structure of coral reef fishes: A long-term study of a large artificial reef. *Mar. Ecol. Prog. Ser.* 4:97–104.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Bd. Canada* 191. 382 pp.

Risk, M.J. 1972. Fish diversity on a coral reef in the Virgin Islands. *Atoll Res. Bull.* 153:1–6.

Sale, P.F. 1977. Maintenance of high diversity in coral reef fish communities. *Am. Nat.* 111:337–359.

SAS Institute, Inc. 1985. SAS user's guide: Basics, version 5 edition. SAS Institute Inc., Cary, N.C. 1,290 pp.

Shulman, M.J. 1984. Resource limitation and recruitment patterns in a coral reef fish assemblage. *J. Exp. Mar. Biol. Ecol.* 74:85–109.

Shulman, M.J., J.C. Ogden, J.P. Ebersole, W.N. McFarland, S.L. Miller, and N.G. Wolf. 1983. Priority effects in the recruitment of juvenile coral reef fishes. *Ecology* 64:1508–1513.

Walsh, W.J. 1985. Reef fish community dynamics on small artificial reefs: The influence of isolation, habitat structure, and biogeography. *Bull. Mar. Sci.* 36:357–376.