HAWAU-S-99-001

AN ANALYSIS OF THE FISH COMMUNITIES ALONG THE BARBERS POINT OCEAN OUTFALL, ‘EWA BEACH, O‘AHU, HAWAI‘I, USING REMOTE VIDEO—1999 DATA

Richard E. Brock

PROJECT REPORT PR-99-14

June 1999

WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF HAWAI‘I AT MĀNOA
Honolulu, Hawai‘i 96822

REPORT DOCUMENTATION FORM
WATER RESOURCES RESEARCH CENTER
University of Hawai'i at Mānoa

1 SERIES NUMBER: Project Report PR-99-14	2 COWRR FIELD-GROUP: 05-C
3 TITLE: An analysis of the fish communities along the Barbers Point Ocean Outfall, Ewa Beach, Oahu, Hawaii, using remote video—1999 data	4 REPORT DATE: June 1999 5 NO. OF PAGES: vii + 20 6 NO. OF TABLES: 2 — 7 NO. OF FIGURES: 1
8 AUTHORS: Richard E. Brock	9 GRANT AGENCY: City and County of Honolulu Department of Environmental Services 10 CONTRACT NUMBER: C54997

11 DESCRIPTORS: fish, macroinvertebrates, monitoring, wastewater outfall

IDENTIFIERS: Barbers Point Ocean Outfall, transect survey, impacts to marine communities, remotely controlled video, Oahu, Hawaii

12 ABSTRACT (PURPOSE, METHOD, RESULTS, CONCLUSIONS)

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. Previous video samplings of the diffuser fish communities were carried out in January of 1992 through 1995 and 1998, in March of 1996, and in April of 1997 and 1999. The results of the eight 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, differing angles of the camera, 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, only one parameter showed any statistical change over the eight annual survey years. This parameter is the mean size of the area sampled to find an individual fish using the nonparametric Kruskal–Wallis analysis of variance. This statistical difference is related to the lower number of individual fish and macroinvertebrates encountered during the 1997 survey, which is related to the lowered ability to see fish due to poor visibility, camera resolution, and camera angle. 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.

2540 Dole Street • Honolulu, Hawai'i 96822 • U.S.A. • (808) 956-7847

AUTHOR:

Dr. Richard E. Brock
Associate Researcher and Fisheries Specialist
Sea Grant Extension Service
Hawaii Institute of Geophysics 213
University of Hawai'i at Mānoa
Honolulu, Hawai'i 96822
Tel.: 808/956-2859
FAX: 808/956-2858
Email: brockr@hawaii.edu

$10.00/copy

Please make remittance in U.S. dollars from a U.S. bank
or international money order to:
Research Corporation of the University of Hawaii

Mail to: Water Resources Research Center
University of Hawai'i at Mānoa
2540 Dole St., Holmes Hall 283
Honolulu, Hawai'i 96822 • U.S.A.
Attn: Publications Office

NOTE: Please indicate **PR-99-14** on check or money order for our reference.

AN ANALYSIS OF THE FISH COMMUNITIES ALONG THE BARBERS POINT OCEAN OUTFALL, ‘EWA BEACH, O‘AHU, HAWAI‘I, USING REMOTE VIDEO—1999 DATA

Richard E. Brock

Project Report PR-99-14

June 1999

PREPARED FOR
City and County of Honolulu
Department of Environmental Services
Project Report
for
“A Five-Year Biological and Sediment Monitoring Program on the Marine Communities Near the City's Ocean Sewer Outfalls”
Project No.: C54997
Project Period: 1 January 1997–30 September 2002
Principal Investigator: James E.T. Moncur

WATER RESOURCES RESEARCH CENTER
University of Hawai‘i at Mānoa
Honolulu, Hawai‘i 96822

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. Previous video samplings of the diffuser fish communities were carried out in January of 1992 through 1995 and 1998, in March of 1996, and in April of 1997 and 1999. The results of the eight 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, differing angles of the camera, 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, only one parameter showed any statistical change over the eight annual survey years. This parameter is the mean size of the area sampled to find an individual fish using the nonparametric Kruskal–Wallis analysis of variance. This statistical difference is related to the lower number of individual fish and macroinvertebrates encountered during the 1997 survey, which is related to the lowered ability to see fish due to poor visibility, camera resolution, and camera angle. 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.

CONTENTS

Figure

Tables

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 26 mgd (1.14 m^3/s) of a mixture of primary and secondary treated sewage through a 2,670-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 m 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 eighth annual sampling effort carried out on 19 April 1999.

MATERIALS AND METHODS

Because the fish and diurnally exposed macroinvertebrate communities of interest to this study reside in waters below safe diving depths, a remotely 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 poor 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 ʻāweoweo (family Priacanthidae). This problem is compounded in areas of high relief and coral coverage that afford 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 Environmental Services, City and County of Honolulu. In the 1992 and 1993 annual surveys 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 the pipe. The camera usually viewed a path from about 1.5 to 3.0 m in width. For data analysis purposes in all surveys, we assumed that the camera path was approximately 2.0 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). In the 1994 survey the camera was usually maintained at a position on top of the diffuser to allow viewing ahead down the pipe. In 1994, due to exceptional water clarity, fishes could be seen as far as three pipe lengths ahead of the camera; hence many more larger fishes were censused than in previous surveys. In the 1995 survey the camera first traveled along one side of the discharge pipe and then crossed over for its return toward shore along the opposite side of the pipe. Only the counts for the offshore side of the discharge pipe (viewed by the camera on its return toward shore) were used in the 1995 annual assessment because resolution was deemed to be better on that segment. In 1996 two runs were made with the video camera, both starting at the shoreward end of the diffuser. The camera traveled down the middle about 1.0 to 1.5 m above the pipe in the first run and down the seaward side of the pipe in the second run. The videotape from the second run was utilized for the 1996 census of organisms. In 1997 the run in which the camera again travel principally along the seaward side of the pipe was used for the annual assessment. Camera resolution was poor in 1997, and often the camera was too high above the substratum to allow an accurate census to be made. In 1998 the videotape from the first run, in which the camera traveled along the seaward side of the pipe, was used for the census. In 1999, again the videotape from the run made along the seaward side of the diffuser, from the diffuser terminus working back toward the shoreward end of the diffuser, was used.

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 using 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 Hawai'i, the Naval Undersea Center (see Evans 1974), and the Hawai'i 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 Kruskal–Wallis analysis of variance (ANOVA) was used to compare means of parameters among the annual surveys, and the Student–Newman–Keuls test was used to discern which means were statistically significant (SAS Institute Inc. 1985).

RESULTS

The first video survey was carried out in January 1992 (see Brock 1993b). The 1992 videotape, which covered the entire length of the 534-m diffuser, was viewed several times to determine where representative "transects" could 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 through 1998 surveys (Brock 1994a, 1994b, 1995, 1996, 1997, 1998).

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 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 entire diffuser length.

Collectively, approximately 336 m^2 of substratum were sampled. The results of all fish censuses for the 19 April 1999 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 was counted as being comprised of a single species, even though more than one species may have been in the group.

The 1999 census results for Transect 1 are given in Table 1. Eleven species of fishes representing 39 individuals were censused. This amounts to one new fish species encountered for every 6.6 m^2 of substratum examined or one new individual fish seen for every 1.9 m^2 of bottom sampled on this transect. The most abundant species on this transect include the anthias *Pseudanthias* sp. (23% of the total counted), the damselfish *Chromis* sp. (21% of the total), and unidentified wrasses or labrids (15% of the total). The standing crop was estimated at

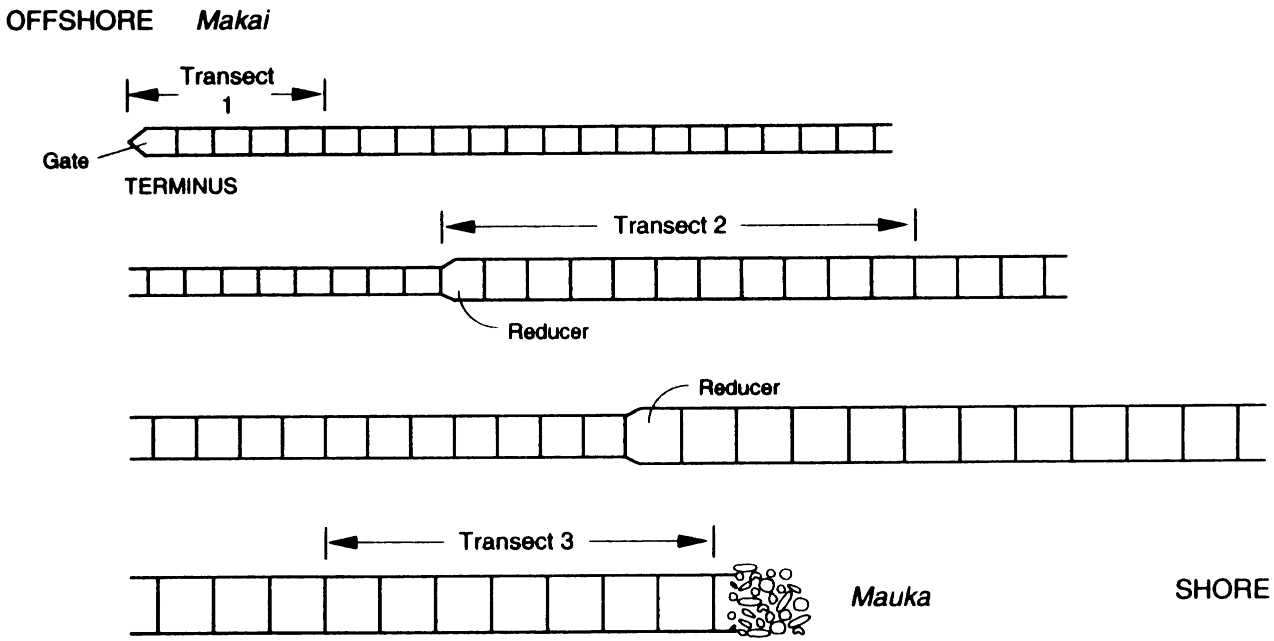

FIGURE 1. Rough schematic of the 534-m-long Barbers Point deep-ocean outfall diffuser pipe showing the approximate locations of three fish census transects (Transects 1 through 3) surveyed by a remotely controlled video recording system on 12 January 1992, 20 January 1993, 27 January 1994, 4 January 1995, 5 March 1996, 15 April 1997, 23 January 1998, and 19 April 1999. 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)

TABLE 1. Family and Species of Fishes Censused at 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 19 April 1999. (Areas sampled at 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
MURAENIDAE			
Gymnothorax sp.			1
SERRANIDAE			
Pseudanthias sp.	9	23	8
LUTJANIDAE			
Lutjanus sp.		15	1
MULLIDAE			
Parupeneus multifasciatus		7	4
CHAETODONTIDAE			
Chaetodon sp.			4
POMACANTHIDAE			
Holocanthus arcuatus	1	1	1
POMACENTRIDAE			
Chromis hanui		7	11
Chromis sp.	8	14	61
LABRIDAE			
Coris flavovittata	2		
Pseudojuloides cerasinus	3		
Anampses chrysocephalus	1		
Labrid unidentified	6	7	14
ACANTHURIDAE			
Acanthurus olivaceus		1	5
Acanthurus xanthopterus	3	5	
Acanthurus sp.			1
Acanthurid unidentified			5
BALISTIDAE			
Sufflamen fraenatus	4	2	4
TETRAODONTIDAE			
Canthigaster jactator	1		
Canthigaster sp.		2	
DIODONTIDAE			
Diodon hystrix	1		
Total No. of Species	11	11	13
Total No. of Individuals	39	84	120
Estimated Biomass (g/m^2)	65	31	17

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

65 g/m^2, and the largest contributors to this biomass were the yellowfin surgeonfish or pualu *Acanthurus xanthopterus* and the bridled triggerfish or humuhumu mimi *Sufflamen fraenatus.*

One macroinvertebrate species (6 individuals) was noted during the census at Transect 1 in April 1999. The species present was the brown sea cucumber *Holothuria* sp.

The results 1998 census carried out at Transect 1 noted 11 species of fishes representing 402 individuals (Brock 1998). This is equivalent to one new fish species encountered for every 6.6 m^2 of bottom examined or one fish seen for every 0.2 m^2 of substratum sampled. The most abundant fish species were the bluelined snapper or ta'ape (*Lutjanus kasmira*) and the orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*). The standing crop of fishes on Transect 1 was estimated at 70 g/m^2, with *L. kasmira* comprising 71% of the total and *A. olivaceus* contributing 18% to the total.

The 1997 survey of Transect 1 noted 11 species of fishes representing 25 individuals (Brock 1997). The most common species were the damselfishes *Chromis hanui* and *Chromis* sp. and the orangebar surgeonfish *Acanthurus olivaceus*. The standing crop was estimated at 60 g/m^2, with *A. olivaceus* and *A. xanthopterus* being the largest contributors. As in the 1998 survey, one new fish species was encountered for every 6.6 m^2 of substratum examined or one fish was seen for every 2.9 m^2 of bottom examined.

In the 1996 census at Transect 1, 14 species of fishes representing 43 individuals were noted (Brock 1996). This is equivalent to one new fish species encountered for every 5.2 m^2 of bottom sampled or one new fish seen for every 1.7 m^2 of substratum sampled. The most abundant fish species was the category of *Chromis* sp., comprising 28% of the total number counted. The standing crop of fishes on Transect 1 was estimated at 8 g/m^2, with *Acanthurus dussumieri* comprising 29% of the total and *Bodianus bilunulatus* making up 26% of the total.

In the 1995 survey at Transect 1, 16 species of fishes representing 106 individuals were counted (Brock 1995). This is equivalent to one new fish species encountered for every 4.6 m^2 of bottom examined or one fish seen for every 0.7 m^2 of substratum sampled. The most abundant species was *Chromis* sp. The standing crop was estimated at 27 g/m^2, with *Acanthurus dussumieri* comprising 34% of the total and *Acanthurus olivaceus* making up 22% of the total.

In the 1994 survey of this transect, 14 species of fishes representing 127 individuals were seen (Brock 1994b). This amounts to one new fish species encountered for every 5.2 m^2 of substratum sampled or one fish seen for every 0.6 m^2 of bottom on the transect. The most abundant fish species were juvenile *Lutjanus* sp. (probably *L. kasmira*), which comprised 44% of the total, and *Chromis hanui* and *Chromis* sp., which contributed 29% to the total. Standing crop was estimated at 67 g/m^2, with the most important contributors being *Acanthurus* *olivaceus*, comprising 36% of the total, and *Parupeneus multifasciatus*, accounting for 41% of the total.

Noted in the January 1993 survey of Transect 1 were 10 species of fishes representing 52 individuals (Brock 1994a). This amounts to one new fish species encountered for every 7.3 m^2 of substratum sampled or one individual fish seen for every 1.4 m^2 of bottom on the transect. Of the identifiable species, the most abundant were *Chromis hanui* and *Chromis* sp., which comprised 63% of the total number of fishes present. The most important contributors to the estimated standing crop of 18 g/m^2 were a single *Acanthurus olivaceus*, comprising 44% of the total; two *Naso unicornis*, making up 13% of the total; and a single *Cantherhines dumerilii*, accounting for 23% of the total.

In the January 1992 survey at Transect 1, 11 species of fishes representing 294 individuals were censused (Brock 1993b). 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 were *Lutjanus* sp., which comprised 86% of the fishes censused, and *Chromis hanui* and *Chromis* sp. In terms of standing crop, which was estimated at 13 g/m^2, juvenile snappers (*Lutjanus* sp.) comprised 57% of the total and *Acanthurus olivaceus* accounted for 22% of the total.

Transect 2 sampled 161 m^2 of substratum over 11 sections of pipe (Figure 1). In the April 1999 census, 11 species representing 84 individual fishes were counted. One new species was encountered for every 14.6 m^2 of substratum examined, and one new individual was seen for every 1.9 m^2 of bottom surveyed. The anthias *Pseudanthias* sp. and the juvenile snapper *Lutjanus* sp. were again included among the most abundant species this year. *Pseudanthias* sp. made up 27% of the total, juvenile *Lutjanus* sp. comprised 18% of the total, and the damselfish *Chromis* sp. contributed 17% to the total. The standing crop of fishes at Transect 2 was estimated at 31 g/m^2, with the species contributing the most to this estimate including the pualu or yellowfin surgeonfish (*Acanthurus xanthopterus*) at 71% of the total and the na'ena'e or orangebar surgeonfish (*Acanthurus olivaceus*) at 11% of the total.

The April 1999 survey noted four recognizable macroinvertebrate species on Transect 2, including a single spiny lobster or ula (*Panulirus marginatus*) estimated at 0.8 kg in weight, one rock oyster (*Spondylus tenebrosus*), two Holothuria sp., and eight serrated slate-pencil sea urchin (*Chondrocidaris gigantea*).

In the January 1998 survey 15 species of fishes representing 489 individuals were encountered at Transect 2. The most common species was the juvenile snapper *Lutjanus* sp. (probably *Lutjanus kasmira*) and *Pseudanthias* sp. In the 1998 survey 10.7 m^2 of substratum was examined to find one new species and for every fish seen, 0.3 m^2 of bottom was surveyed. The standing crop of fish was estimated at 30 g/m^2, with *Acanthurus xanthopterus* contributing 23% to the total and the juvenile *Lutjanus kasmira* making up an additional 17% of the total.

The April 1997 survey at Transect 2 censused 8 species of fishes representing 32 individuals (Brock 1997). One new fish species was encountered for every 20.1 m^2 of substratum examined or one new fish was seen for every 5.0 m^2 of bottom surveyed. The most abundant fish species at this transect was the group of unidentified pomacentrids, which comprised 47% of the total, followed by *Abudefduf abdominalis*, which made up 19% of the total. The standing crop of fish was estimated at 8 g/m^2, with *A. abdominalis* comprising 41% of the total and a single unidentified unicornfish (*Naso* sp.) making up another 43%.

The March 1996 survey at Transect 2 noted 15 species of fishes representing 127 individuals (Brock 1996). This amounts to one new species encountered for every 10.7 m^2 of substratum sampled or one new individual fish seen for every 1.3 m^2 sampled. The most abundant species were *Chromis hanui* (17% of the total), *Chromis* sp. (22% of the total), and *Lutjanus* sp. (18% of the total). In terms of the estimated standing crop, 67% was comprised of *Acanthurus dussumieri* and 18% of *Parupeneus multifasciatus*.

The January 1995 survey at Transect 2 resulted in 12 species representing 191 individuals being censused (Brock 1995). This amounts to one new fish species encountered for every 13.4 m^2 of substratum sampled or one new individual fish seen for every 0.8 m^2 of bottom on this transect. The most abundant species were *Chromis hanui*, making up 8% of the total; *Chromis* sp., comprising 56% of the total; and unidentified labrids, contributing 24% to the total. The standing crop was estimated at 29 g/m^2, with *Acanthurus xanthopterus* comprising 29% of the total and both *Acanthurus dussumieri* and *A. olivaceus* each contributing 18% to the total.

Noted in the January 1994 survey at Transect 2 were 17 species representing 303 individual fishes (Brock 1994b). The most abundant species were juvenile *Lutjanus* sp. (24% of the total), the damselfishes *Chromis hanui* and *Chromis* sp. (33% of the total), and a group of unidentified labrids (19% of the total). From a comparative standpoint, the 17 species of fishes translates to one new fish species encountered for every 9.5 m^2 of substratum sampled or one individual fish seen for every 0.5 m^2 of bottom on the transect. The standing crop of fishes at Transect 2 was estimated at 206 g/m^2; the important contributors to this high standing crop were six *Seriola dumerili* that wandered through the census area (making up 49% of the total), ten *Acanthurus olivaceus* (comprising 15% of the total), fifteen *A. dussumieri* (contributing 12% to the total), and eight *A. mata* (comprising 8% of the total).

In the January 1993 survey at Transect 2, 16 species of fishes representing 97 individuals were censused (Brock 1994a). The most abundant species at this transect were juvenile

Lutjanus kasmira, which comprised 29% of the total numbers counted, and *Chromis hanui*, which made up 32% of the total. 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, with the species contributing most heavily including two *Acanthurus xanthopterus* (38% of the total), one *Sufflamen fraenatus* (16% of the total), and one *Cantherhines dumerilii* (21% of the total).

In the January 1992 survey of Transect 2, 13 species of fishes representing 413 individuals were censused (Brock 1993b). 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 *Lutjanus kasmira*, *Chromis hanui*, and *Parupeneus multifasciatus*. The biomass of fishes was estimated at 41 g/m^2. Important species by weight included one *Caranx melampygus* (42% of the total), three *Sufflamen fraenatus* (24% of the total), 341 juvenile *Lutjanus* sp. (11% of the total), and one *Arothron hispidus* (10% of the total).

Transect 3 was established on the first seven (most landward) sections of the diffuser pipe that are not fully covered with armor rock (see Figure 1). The fish census at this site noted 13 species representing 120 individuals. This amounts to one new species of fish seen for every 7.8 m^2 of substratum or one new individual fish encountered for every 0.9 m^2 of bottom examined on this transect. The most abundant fishes seen include the damselfish *Chromis* sp., comprising 51% of the total; unidentified wrasses or labrids, making up 12% of the total; and the chocolate-dip damselfish *Chromis hanui*, contributing 9% to the total. The standing crop of fishes at this site was estimated at 17 g/m^2, with the species contributing most heavily to this biomass including a single moray eel or puhi (*Gymnothorax* sp.) making up 29% of the total, four bridled triggerfish or humuhumu mimi (*Sufflamen fraenatus*) contributing 26% to the total, and the orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*) contributing 11% to the total.

Seven individuals of one macroinvertebrate species, the serrated slate-pencil sea urchin or *Chondrocidaris gigantea*, was encountered at this transect site in the April 1999 survey.

The January 1998 survey noted 11 species representing 90 individual fishes. This amounts to one new fish species encountered every 9.3 m^2 or one individual fish seen for every 1.1 m^2 sampled. The most common fish species present were *Chromis hanui*, unidentified pomacentrids, and unidentified labrids. The standing crop was estimated at 34 g/m^2, with a single *Gymnothorax flavimarginatus* contributing 65% to the total and four *Sufflamen fraenatus* making up 12% of the total.

The April 1997 survey at Transect 3 noted 9 species of fishes representing 132 individuals (Brock 1997). This corresponds to one new fish species encountered for every

11.3 m^2 of substratum sampled or one individual fish seen for every 0.8 m^2 of bottom surveyed. The most common species on this transect were unidentified pomacentrids (33% of the total), unidentified labrids (16% of the total), and *Chromis* sp. (26% of the total). The standing crop was estimated at 12 g/m^2. The most important contributors to the standing crop were *Parupeneus multifasciatus* (22% of the total), unidentified pomacentrids (24% of the total), and *Sufflamen fraenatus* (24% of the total).

The March 1996 survey of this transect noted 13 species of fishes representing 212 individuals (Brock 1996). This translates into one new fish species encountered for every 7.8 m^2 of substratum sampled or one new individual fish seen for every 0.5 m^2 of bottom censused. The dominant species were *Chromis hanui* (32% of the total) and *Chromis* sp. (41% of the total). The standing crop of fishes was estimated at 13 g/m^2, with *Parupeneus multifasciatus* making up 32% of the total and *Bodianus bilunulatus* contributing 26% to the total.

In the January 1995 survey at Transect 3, 10 species representing 207 individual fishes were noted (Brock 1995). The amount of substratum sampled to encounter one new fish species was 10.2 m^2, and 0.5 m^2 of bottom was sampled for each new individual fish seen on this transect. The most common species were *Chromis hanui* (16% of the total), *Chromis* sp. (55% of the total), and unidentified labrids (20% of the total). The group of unidentified labrids was probably comprised of *Thalassoma duperrey*, *Cheilinus bimaculatus*, and *Pseudojuloides cerasinus*. The standing crop of fishes was estimated at 16 g/m^2, with the unidentified labrids comprising 53% of the total and *Acanthurus xanthopterus* contributing 21% to the total.

The January 1994 visual census conducted on Transect 3 yielded 11 species of fishes representing 86 individuals (Brock 1994b). This amounts to one new fish species seen for every 9.3 m^2 of substratum sampled or one individual fish seen for every 1.2 m^2 of bottom on the transect. The most abundant species were *Chromis* sp., which made up 40% of the total number present, and the unidentified wrasses (categorized as labrid unidentified), which made up 27% of the total. The estimated standing crop of fishes was 46 g/m^2, with the species contributing the greatest amount including *Acanthurus xanthopterus* and *A. mata* (each contributing 21% to the total) and *A. dussumieri* (28% of the total).

Seven species of fishes representing 48 individuals were censused in the January 1993 survey at Transect 3 (Brock 1994a). This amounts to one new fish species encountered for every 14.6 m^2 of substratum sampled or one fish seen for every 2.1 m^2 of bottom on the transect. The most abundant identifiable fish species was *Chromis* sp., 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 *Naso hexacanthus* contributed 75% to this amount.

In the January 1992 survey at Transect 3, 13 species of fishes were seen, or one new fish species was encountered for every 7.8 m^2 of substratum sampled (Brock 1993b). The number of individual fishes encountered at this transect was 221, or one fish for every 0.5 m^2 of bottom sampled. The most abundant fish species appeared to be juvenile snappers (*Lutjanus* sp.), which made up 53% of the total number censused. Other common species included *Chromis* sp. and *Parupeneus multifasciatus*. The standing crop of fishes, estimated at 51 g/m^2, was comprised of three *Acanthurus xanthopterus* (43% of the total), one *Acanthurus olivaceus* (21% of the total), and ten *Parupeneus multifasciatus* (8% of the total).

The physical characteristics and survey results for the three transects annually censused from 1992 through 1999 are summarized in Table 2. In general, the number of fish species counted was similar for all survey years except 1997, when a slight decrease occurred. The number of individual fishes has fluctuated between years, with the 1998 survey having the highest number recorded. This is attributed to the large number of juvenile *Lutjanus kasmira* and *Lutjanus* sp. encountered at Transects 1 and 2, respectively. The estimated biomass was similar for all years except 1994, when higher numbers were recorded for all three transects. Other than the higher 1994 biomass estimate, the physical characteristics and survey results for the Barbers Point deep-ocean outfall diffuser are similar to those obtained for 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 various parameters over the eight years using the Kruskal–Wallis ANOVA suggests that despite the changes among the survey periods (as shown in Table 2), only one parameter has changed significantly. Specifically, the mean amount of substratum censused to find an individual fish changed significantly among the eight survey years ($p > 0.03$). In this case the mean amount of substratum examined to find an individual fish was significantly greater in 1997 (mean = 2.9 m^2) than in other years (range from 0.4 to 1.7 m^2). There were no significant changes on the three transects for the mean number of fish species encountered ($p > 0.34$, not significant), the mean number of individual fish censused ($p > 0.09$, not significant), and the mean estimated biomass of fishes ($p > 0.18$, not significant). The mean amount of substratum covered to encounter a new fish species also did not change significantly ($p > 0.98$, not significant). Further analysis using the nonparametric Student–Newman–Keuls (SNK) test supported the Kruskal–Wallis ANOVA where the mean amount of substratum censused to encounter an individual fish was significantly greater in 1997 (mean = 2.9 m^2) than in any other year; the other years showed no statistical separation. The mean number of invertebrate species censused did not change significantly among the eight survey years ($p > 0.19$, not significant), nor did the mean number of invertebrates censused change

TABLE 2. Summary of the Physical Characteristics at Three Transects Carried Out at Various Points Along the 534-m-Long Barbers Point Ocean Outfall Diffuser for 1992 Through 1999

Parameter	1992 Transect			1993 Transect			1994 Transect			1995 Transect		
	1	2	3	1	2	3	1	2	3	1	2	3
Transect Length (m)	36.5	80	51	36.5	80	51	36.5	80	51	36.5	80	51
Area Sampled (m^2)	73	161	102	73	161	102	73	161	102	73	161	102
No. of Fish Species	11	13	13	10	16	7	14	17	11	16	12	10
No. of Fish Individuals	294	413	221	52	97	48	127	303	86	106	191	207
No. of m^2 Sampled/ New Fish Species	6.6	12.4	7.8	7.3	10.1	14.6	5.2	9.5	9.3	4.6	13.4	10.2
No. of m^2 Sampled/ Individual Fish	0.2	0.4	0.5	1.4	1.7	2.1	0.6	0.5	1.2	0.7	0.8	0.5
Fish Biomass (g/m^2)	13	41	51	18	13	12	67	206	46	27	29	16
No. of Macroinvertebrate Species	5	4	5	5	5	4	4	2	3	4	4	3
No. of Macroinvertebrate Individuals	8	13	22	14	28	16	7	9	12	11	9	14

Parameter	1996 Transect			1997 Transect			1998 Transect			1999 Transect		
	1	2	3	1	2	3	1	2	3	1	2	3
Transect Length (m)	36.5	80	51	36.5	80	51	36.5	80	51	36.5	80	51
Area Sampled (m^2)	73	161	102	73	161	102	73	161	102	73	161	102
No. of Fish Species	14	15	13	11	8	9	11	15	11	11	11	13
No. of Fish Individuals	43	127	212	25	32	132	402	489	90	39	84	120
No. of m^2 Sampled/ New Fish Species	5.2	10.7	7.8	6.6	20.1	11.3	6.6	10.7	9.3	6.6	14.6	7.8
No. of m^2 Sampled/ Individual Fish	1.7	1.3	0.5	2.9	5.0	0.8	0.2	0.3	1.1	1.9	1.9	0.9
Fish Biomass (g/m^2)	8	56	13	60	8	12	70	30	34	65	31	17
No. of Macroinvertebrate Species	3	4	14	1	5	1	4	3	3	1	4	1
No. of Macroinvertebrate Individuals	5	17	14	2	10	1	7	12	11	6	12	7

NOTE: Included are summary data from the fish and invertebrate censuses carried out at each transect location. The 1992 through 1998 data are from Brock (1993b, 1994a, 1994b, 1995, 1996, 1997, 1998).

significantly among the eight survey years ($p > 0.13$, not significant). However, the SNK test did note that the mean number of invertebrate individuals censused per transect was significantly less in 1997 than in other years and significantly greater in 1993 than in all other years. Other years showed no statistical separation.

DISCUSSION

Despite the changes in the number of species and abundance of fishes on each transect among the eight annual survey years, the Kruskal–Wallis ANOVA found that only the mean number of square meters examined to find an individual fish showed a statistically significant change. The SNK analysis noted several significant changes—all of which relate to the lower number of individual fish and lower number of individual invertebrates seen in 1997 as compared to all other years. However, the application of statistical procedures to the data derived using a video camera to census the transects is probably not appropriate because of a number of drawbacks inherent with the method. These drawbacks, which are discussed below, result in data that are more qualitative than quantitative in nature, thus making comparisons among years tenuous.

The identification of a number of species of fishes in this study has not been difficult because of their size (adult pualu or *Acanthurus xanthopterus* and kala or *Naso unicornis)*, color (moano or *Parupeneus multifasciatus* and masked angelfish or *Holacanthus arcuatus)*, extreme abundance (ta'ape or *Lutjanus kasmira)*, or diurnal habits (damselfish or *Chromis hanui*). Despite this, a number of the fishes have been 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 seeking cover, (3) small size of fishes, or (4) fishes being on the periphery of the camera's field of view. Some of these fishes are 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 are important but, in general, have 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 sea cucumbers (e.g., *Holothuria atra*) is tentative because accurate identification requires examination of skin spicules with a microscope.

Most of the fishes encountered on the transects at 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 assessment difficult. In the surveys, these small fishes are usually only seen when the video camera is 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 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.

Through the survey years, changes were made in the operation of the video camera. One videotape was generated in 1999. The camera traveled from the discharge terminus toward shore, first along one side of the diffuser pipe then along the other side. As noted above, census work is carried out along the seaward side of the diffuser; in 1999 the camera traversed this area from 0.3 to about 3.0 m above the substratum alongside of the diffuser and armor rock. In general, visibility was reasonable, but the camera angle tended to focus more toward the horizontal, thereby increasing our ability to see larger fishes ahead but decreasing our opportunity to view small fishes directly below the camera. Overall, resolution was not good in the 1999 videotape.

In 1998 two videotapes were generated. For the first videotape the camera traveled about 1.5 to 2.0 m above the centerline of the discharge pipe, focusing primarily on the substratum below. Because of the camera height and angle, the resolution for viewing small fish was poor. For the second videotape, the camera commenced at the discharge pipe terminus and traveled toward shore along the seaward side of the discharge pipe, moving primarily about 0.3 to 3.0 m above the substratum while focusing on the substratum directly below. This second tape was used in making our visual census of organisms. Both the good water clarity and the relatively close position of the camera to the substratum were factors that probably contributed to the higher estimates of abundance in 1998.

In 1997 two videotapes were also generated. The one selected for census work was made with the camera traveling about 1 to 15 m above the substratum while focusing on the substratum directly below. Because of the distance above the substratum, the resolution was poor and the resulting fish counts probably low. In the 1996 survey the camera first traveled down the centerline of the discharge pipe about 1.0 to 1.5 m above the pipe. This run commenced at the point where the discharge ports first appear and moved toward the terminus. The second run also commenced at the shallow side of the diffuser and moved toward the discharge terminus, but this time the camera was situated alongside the seaward side of the pipe. Because the camera was held in reasonably close proximity to the substratum, the videotape of the latter run was used for our survey. In 1995 the camera was primarily operated along one side of the diffuser pipe heading toward the terminus; upon reaching the terminus, the camera moved to the opposite side for the return trip toward shore. For the January 1994 survey, the camera was kept principally on a track that ran down the middle of the top of the diffuser pipe and was primarily focused ahead rather than straight down. During the 1992 and 1993 surveys, the camera was focused primarily downward and moved on a track that went along one side of the pipe and crossed over to the other side.

The census of small fishes was probably better in 1992 and 1993 than in 1994. The change in camera operation in 1994 resulted in a better viewing of the larger fishes that were present ahead of the camera, but the time that the video camera was focused on the small armor rock adjacent to the diffuser where many of the small fishes reside was decreased. Thus the 1994 census not only probably reflects a more accurate assessment of the few larger (high biomass) fishes present (these fishes usually leave the area prior to the arrival of the camera), but it also reflects a greater underestimate of the small fishes in the transect area. The emphasis in the 1995, 1996, and 1998 surveys on the small-scale cover of the caprock alongside the diffuser probably resulted in a better estimate of the small fishes resident to the area, making these data comparable with the 1992 and 1993 data. Due to problems with water clarity and distance of the camera above the substratum, the 1997 census data are not comparable with data from any of the earlier surveys. Again, these changes have all added to the variability in the resulting data.

The estimated standing crop of fishes ranged from 13 to 51 g/m^2 in the January 1992 survey, from 12 to 18 g/m^2 in the January 1993 census, from 46 to 206 g/m^2 in the January 1994 survey, from 16 to 29 g/m^2 in the January 1995 census, from 8 to 56 g/m^2 in the March 1996 sampling effort, from 8 to 60 g/m^2 in the April 1997 survey, and from 30 to 70 g/m^2 in the January 1998 survey. In many cases, just a few individual large fish contributed heavily to the estimates. Major contributors to the biomass in the censuses undertaken in 1992, 1993, 1995, and 1997 were the orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*) at Transect 1, the bridled triggerfish or humuhumu mimi (*Sufflamen fraenatus*) at Transect 2, and the yellowfin surgeonfish or pualu (*Acanthurus xanthopterus*) at Transect 3. In 1994, besides the above species, six amberjacks or kahala (*Seriola dumerili*), with an estimated weight of more than 16 kg, were encountered at Transect 2, and at both Transects 2 and 3 were seen a number of eye-stripe surgeonfish or palani (*Acanthurus dussumieri*) that added substantially to the estimated standing crop at each site. In 1995 and 1996 *A. dussumieri* contributed heavily to the estimated standing crop at Transects 1 and 2, and in 1997 *A. xanthopterus* was an important contributor to the standing crop at Transect 2. The high abundance of juvenile *Lutjanus kasmira* at Transect 1 and *Lutjanus* sp. at Transect 2 gave these species importance to the 1998 biomass estimates. Other important species in 1998 were *Acanthurus olivaceus* at Transect 1, *A. xanthopterus* at Transect 2, and *Sufflamen fraenatus* at Transect 3. In 1999 *A. xanthopterus* was the most important contributor to the estimates for Transects 1 and 2, and the other same species (i.e., *A. olivaceus* and *Sufflamen fraenatus*) were important on all three transects.

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 Hawai'i 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 of the evidence suggests that both 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 is favorable for species that are either small as adults or juveniles of larger species. The average size of the fishes censused in the 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 Environmental Services 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. 1994a. An analysis of the fish communities along the Barbers Point deep ocean outfall, 'Ewa Beach, O'ahu, Hawai'i, using remote video—1993 data. Project Rep. PR-94-17, Water Resources Research Center, University of Hawai'i at Mānoa, Honolulu. 13 pp.

Brock, R.E. 1994b. An analysis of the fish communities along the Barbers Point Ocean Outfall, 'Ewa Beach, O'ahu, Hawai'i, using remote video—1994 data. Project Rep. PR-94-19, Water Resources Research Center, University of Hawai'i at Mānoa, Honolulu. 15 pp.

Brock, R.E. 1995. An analysis of the fish communities along the Barbers Point Ocean Outfall, 'Ewa Beach, O'ahu, Hawai'i, using remote video—1995 data. Project Rep. PR-95-10, Water Resources Research Center, University of Hawai'i at Mānoa, Honolulu. 15 pp.

Brock, R.E. 1996. An analysis of the fish communities along the Barbers Point Ocean Outfall, 'Ewa Beach, O'ahu, Hawai'i, using remote video—1996 data. Project Rep. PR-97-01, Water Resources Research Center, University of Hawai'i at Mānoa, Honolulu. 16 pp.

Brock, R.E. 1997. An analysis of the fish communities along the Barbers Point Ocean Outfall, 'Ewa Beach, O'ahu, Hawai'i, using remote video—1997 data. Project Rep. PR-98-01, Water Resources Research Center, University of Hawai'i at Mānoa, Honolulu. 17 pp.

Brock, R.E. 1998. An analysis of the fish communities along the Barbers Point Ocean Outfall, 'Ewa Beach, O'ahu, Hawai'i, using remote video—1998 data. Project Rep. PR-98-14, Water Resources Research Center, University of Hawai'i at Mānoa, Honolulu. 19 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, North Carolina. 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.