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An Analysis of the Fish Communities Along the Barbers Point Ocean Outfall, ‘Ewa Beach, O‘ahu, Hawai‘i, Using Remote Video—2005 Data

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May 2005

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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. Commencing in 1992, video samplings of the diffuser fish communities have been carried annually except in 2000 when the equipment malfunctioned. The results of the thirteen annual surveys to date 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, the mean number of individual fish per transect showed statistically significant changes over the fourteen-year period. Not unexpectedly, a related parameter, the mean number of square meters examined to find an individual fish, also showed statistically significant changes. The size of the area searched to find an individual fish is directly related only to the number of fishes counted because the area searched on a given transect does not vary among the different survey years. Thus, if the mean number of fishes censused per transect shows a statistically significant change, the measure of the mean number of square meters examined to find an individual fish should show a similar significant change, which it does. However, the application of another statistical test (Student–Newman–Keuls test) showed neither a clear statistical separation among the mean number of individual fish per transect nor a statistical separation for the area searched per fish over the thirteen sampling years. This lack of clear statistical separation among the means for the different years, as well as the fact that the decrease in numbers of fishes seen per transect does not follow any temporal trend, suggests that the changes are due to factors such as water clarity or camera angle and resolution and not to any real change occurring in the diffuser fish communities. The application of statistical procedures to the data derived using a video camera to census fish and invertebrates is probably not appropriate because of a number of drawbacks inherent with the use of a remotely operated video camera, including variability due to water clarity, camera angle relative to the substratum, and camera resolution. Thus little significance should be attached to any change noted in this study of 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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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. Commencing in 1992, video samplings of the diffuser fish communities have been carried annually except in 2000 when the equipment malfunctioned. The results of the thirteen annual surveys to date 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, the mean number of individual fish per transect showed statistically significant changes over the fourteen-year period. Not unexpectedly, a related parameter, the mean number of square meters examined to find an individual fish, also showed statistically significant changes.

The size of the area searched to find an individual fish is directly related only to the number of fishes counted because the area searched on a given transect does not vary among the different survey years. Thus, if the mean number of fishes censused per transect shows a statistically significant change, the measure of the mean number of square meters examined to find an individual fish should show a similar significant change, which it does. However, the application of another statistical test (Student–Newman–Keuls test) showed neither a clear statistical separation among the mean number of individual fish per transect nor a statistical separation for the area searched per fish over the thirteen sampling years. This lack of clear statistical separation among the means for the different years, as well as the fact that the decrease in numbers of fishes seen per transect does not follow any temporal trend, suggests that the changes are due to factors such as water clarity or camera angle and resolution and not to any real change occurring in the diffuser fish communities. The application of statistical procedures to the data derived using a video camera to census fish and invertebrates is probably not appropriate because of a number of drawbacks inherent with the use of a remotely operated video camera, including variability due to water clarity, camera angle relative to the substratum, and camera resolution. Thus little significance should be attached to any change noted in this

study of 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, originally discharged only primary treated effluent. Secondary treatment for reuse purposes for part of the flows was initiated in September 1996. Tertiary treatment was initiated in August 2000. Since then, a mixture of primary, secondary, and tertiary effluent has been discharged through the outfall. The amount discharged through the outfall used to be 24 mgd (1.05 m^3/s), but it has been reduced by the 5 to 8 mgd (0.22 to 0.35 m^3/s) taken offsite for reuse. The wastewater is released 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 thirteenth annual sampling effort carried out on 25 February 2005.

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 ‘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 Environmental Services (formerly Department of Wastewater Management), 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 m in width. For data analysis purposes in all surveys, 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). 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 traveled 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, 2001, 2002, 2003, and 2004, 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. In the 2005 survey the camera traveled along the seaward side of the discharge pipe, commencing at the shoreward end and moving in a seaward direction. This year, visibility along Transect 3 was usually less than 1 m due to the presence of a sewage plume, but on Transects 1 and 2, visibility ranged from about 1 to 10 m.

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 Hawaiʻi, the Naval Undersea Center (see Evans 1974), and the Hawaiʻi

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 (SNK) 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 2005 surveys (Brock 1994a, 1994b, 1995, 1996, 1997, 1998, 1999, 2001, 2002, 2003, 2005).

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 sample 31% of the entire diffuser length. Collectively, approximately 336 m^2 of substratum are sampled annually.

The results of all fish censuses for the 25 February 2005 survey are presented in Table 1, and the data for each transect are presented 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

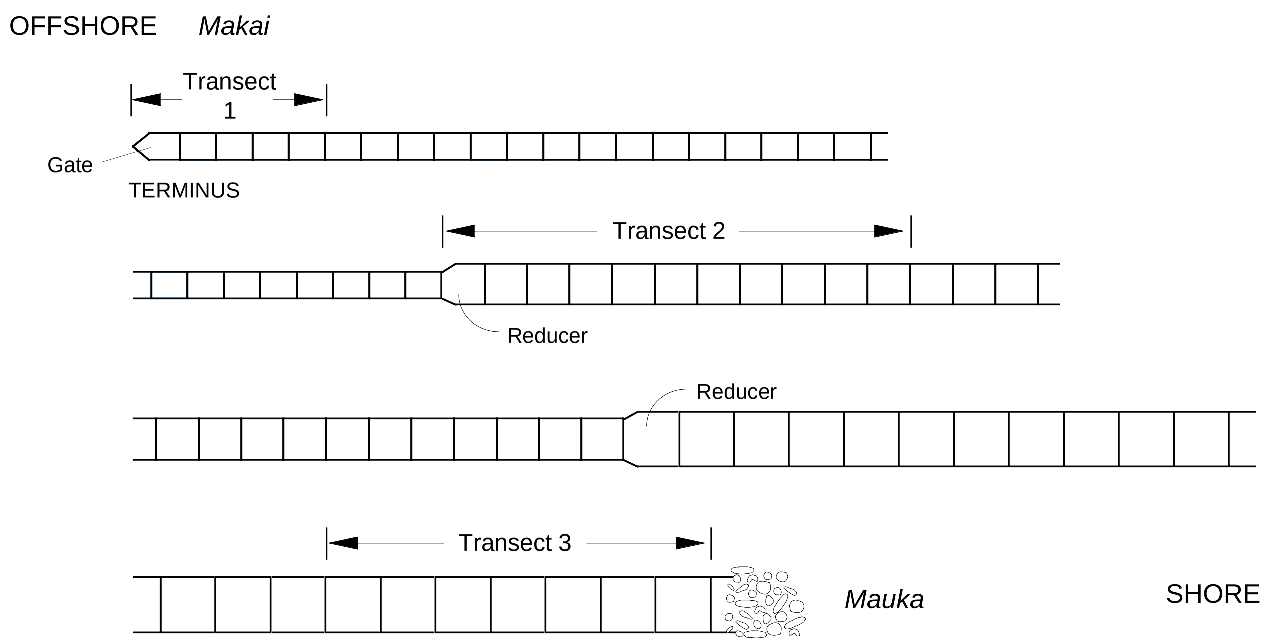

FIGURE 1. Rough schematic of the 534-m-long Barbers Point deep-ocean outfall diffuser pipe showing the approximate locations of three fish census transects (Transects 1 through 3) surveyed by a remotely controlled video recording system on 12 January 1992, 20 January 1993, 27 January 1994, 4 January 1995, 5 March 1996, 15 April 1997, 23 January 1998, 19 April 1999, 22 February 2001, 24 January 2002, 7 February 2003, 15 December 2004, and 25 February 2005. 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 25 February 2005. (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
SERRANIDAE			
Pseudanthias sp.	8		
CARANGIDAE			
Selar crumenophthalmus	8		
CHAETODONTIDAE			
Chaetodon kleinii			4
Chaetodon miliaris			1
POMACANTHIDAE			
Holocanthus arcatus	1		
POMACENTRIDAE			
Chromis hanui		2	
Chromis sp.	13	33	27
Damselfish unidentified		1	
LABRIDAE			
Labrid unidentified	1	7	4
ACANTHURIDAE			
Acanthurus olivaceus	1		
Acanthurus xanthopterus	1		
Acanthurus sp.	1		3
Acanthurus dussumieri		1	
BALISTIDAE			
Sufflamen fraenatus	3	1	
TETRAODONTIDAE			
Canthigaster sp.	1		
Total No. of Species	10	6	5
Total No. of Individuals	38	45	39
Estimated Biomass (g/m^2)	87	5	1

counted as being comprised of a single species, even though more than one species may have been present.

The 2005 census results of Transect 1 are given in Table 1. Thirty-eight individual fishes representing 10 species were censused. This amounts to one new fish species encountered for every 7.3 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 bigeye scad or ʻōpelu (*Selar crumenophthalmus*), the damselfish *Chromis* sp., and the anthias *Pseudanthias* sp. The standing crop was estimated at 87 g/m^2, with the largest contributors being *S. crumenophthalmus* (comprising 55% of the total) and a single yellowfin surgeonfish or pualu (*Acanthurus xanthopterus*—making up 12%).

Three macroinvertebrate species (eight individuals) were seen on Transect 1 during the February 2005 survey. These species were the black sea cucumber *Holothuria atra*, the black sea urchin or wana (*Echinothrix diadema*), and the cushion starfish *Culcita novaeguineae*.

The 2004 fish survey at Transect 1 noted 16 species representing 207 individuals (Brock 2005). This amounts to one new species seen for every 4.9 m^2 of substratum censused and one new individual fish seen for every 0.4 m^2 of bottom surveyed. The most abundant fishes were *Decapterus macarellus*, *Chromis hanui*, and *Pseudanthias* sp. The estimated standing crop was 237 g/m^2, with the largest contributors being *Decapterus macarellus*, *Gymnothorax flavimarginatus*, and *Acanthurus xanthopterus*.

The 2003 fish census at Transect 1 noted 19 species representing 115 individuals (Brock 2003). One new fish species was seen for every 3.8 m^2 of bottom examined or one new individual fish was seen for every 0.6 m^2 of substratum sampled on this transect. The most abundant fishes were unidentified damselfishes of the genus *Chromis* and *Acanthurus xanthopterus*. The standing crop was estimated at 302 g/m^2, with *A. xanthopterus* and *Bodianus bilunulatus* being the largest contributors.

The 2002 census conducted at Transect 1 noted 10 fish species representing 27 individuals (Brock 2002). This amounts to one new fish species encountered for every 7.3 m^2 of substratum examined or one new individual fish seen for every 2.7 m^2 of bottom sampled on this transect. The most abundant species were *Cantherhines dumerilii* and unidentified wrasses or labrid sp. The standing crop was estimated at 41 g/m^2, with the largest contributors being *C. dumerilii* and *Acanthurus olivaceus*.

In the 2001 survey, 9 species of fishes representing 20 individuals were censused at Transect 1 (Brock 2001). One new fish species was seen for every 8.1 m 2 of substratum surveyed or one new fish seen for every 3.6 m 2 of bottom sampled on this transect. The most common fish species were *Sufflamen fraenatus* and *Chromis hanui*. The standing crop was estimated at 33 g/m^2 (Brock 2001).

The 1999 survey of Transect 1 noted 11 species representing 39 individuals (Brock 1999). This amounts to one new fish species seen for every 6.6 m^2 of substratum surveyed or one new fish encountered for every 1.9 m^2 of bottom surveyed. The most abundant species were *Pseudanthias* sp., *Chromis* sp., and unidentified labrids or wrasses. The standing crop was estimated at 65 g/m^2, with *Acanthurus xanthopterus* and *Sufflamen fraenatus* being the greatest contributors.

The results of the 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 *Lutjanus kasmira* and *Acanthurus olivaceus*. The standing crop of fishes on Transect 1 was estimated at 70 g/m^2, with *L. kasmira* and *A. olivaceus* being the largest contributors.

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

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 *Chromis* sp. The standing crop of fishes on Transect 1 was estimated at 8 g/m^2, with *Acanthurus dussumieri* and *Bodianus bilunulatus* being large contributors.

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* and *A. olivaceus* contributing greatly.

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*), *Chromis hanui*, and *Chromis* sp. The standing crop was estimated at 67 g/m^2, with the most important contributors being *Acanthurus olivaceus* and *Parupeneus multifasciatus*.

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. The most important contributors to the estimated standing crop of 18 g/m^2 were a single *Acanthurus olivaceus*, two *Naso unicornis*, and a single *Cantherhines dumerilii*.

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., *Chromis hanui*, and *Chromis* sp. In terms of standing crop, which was estimated at 13 g/m^2, juvenile snappers (*Lutjanus* sp.) and *Acanthurus olivaceus* contributed greatly.

Transect 2 sampled 161 m^2 of substratum over 11 sections of pipe (Figure 1). The February 2005 survey noted 6 species of fishes representing 45 individuals (Table 1). The most abundant fish species was the damselfish *Chromis* sp., which made up 73% of the numbers present. This amounts to encountering one new fish species for every 26.8 m^2 of substratum sampled or one new individual seen for every 3.6 m^2 of bottom examined. The standing crop of fishes was estimated at 5 g/m^2, with a single yellowfin surgeonfish or palani (*Acanthurus dussumieri*) making 73% of the total.

In 2005, two macroinvertebrate species were censused on Transect 2. These were the black sea cucumber *Holothuria atra* and the brown sea cucumber *Holothuria* sp.

The December 2004 census noted 10 species of fishes representing 238 individuals (Brock 2005). This amounts to one new fish species seen for every 16.1 m^2 of substratum sampled or one new individual seen for every 0.7 m^2 of bottom surveyed (Brock 2005). The most abundant fishes were the damselfish *Chromis hanui* and the anthias *Pseudanthias* sp. The standing crop was estimated at 27 g/m^2, with species contributing heavily including *Acanthurus xanthopterus*, *Acanthurus olivaceus*, and *Cantherhines dumerilii*.

The February 2003 survey of Transect 2 noted 12 species of fishes representing 49 individuals (Brock 2003). This amounts to one new fish species seen every 13.4 m^2 of substratum sampled or one new fish seen every 3.3 m^2 of substratum surveyed. The most common species encountered were unidentified damselfish (*Chromis* sp.) and surgeonfish (*Acanthurus* sp.). The standing crop was estimated at 36 g/m^2, with species contributing heavily including *Bodianus bilunulatus*, *Acanthurus xanthopterus,* and unidentified surgeonfishes (*Acanthurus* sp.).

The January 2002 census noted 14 species of fishes representing 63 individuals (Brock 2002). This is equivalent to one new species encountered for every 14.6 m^2 of bottom sampled or one new fish seen for every 2.6 m^2 of substratum sampled. The most abundant fishes were the unidentified damselfishes, and the unidentified wrasses or labrids. The standing crop was estimated at 34 g/m^2, with significant contributors including a single *Caranx melampygus*, a single unidentified surgeonfish (*Acanthurus* sp.), and a single unidentified spiny puffer (*Diodon* sp.).

In the February 2001 census, 11 species representing 59 individual fishes were counted (Brock 2001). One new species was encountered for every 14.6 m^2 of substratum examined, and one new individual was seen for every 2.7 m^2 of bottom surveyed. The anthias *Pseudanthias* sp. and the damselfishes *Chromis* sp. and *Chromis hanui* were the most abundant species seen. The standing crop of fishes was estimated at 39 g/m^2, with the species contributing the most including *Acanthurus xanthopterus* and a single *Aluterus scriptus*.

In the April 1999 survey of Transect 2, 11 species representing 84 individual fishes were counted (Brock 1999). In this census 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 the most abundant species. The standing crop of fishes was estimated at 31 g/m^2, with the species contributing the most including *Acanthurus xanthopterus* and *A. olivaceus*.

In the January 1998 survey 15 species of fishes representing 489 individuals were encountered at Transect 2 (Brock 1998). 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 was estimated at 30 g/m^2, with *Acanthurus xanthopterus* and juvenile *Lutjanus kasmira* contributing greatly.

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 a group of unidentified pomacentrids and *Abudefduf abdominalis*. The standing crop was estimated at 8 g/m^2, with *A. abdominalis* and a single unidentified unicornfish (*Naso* sp.) contributing significantly.

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*, *Chromis* sp., and *Lutjanus* sp. In terms of the standing crop, which was estimated at 56 g/m^2, contributors were *Acanthurus dussumieri* and *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*, *Chromis* sp., and unidentified labrids. The standing crop was estimated at 29 g/m^2, with *Acanthurus xanthopterus*, *A. dussumieri*, and *A. olivaceus* contributing 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., the damselfishes *Chromis hanui* and *Chromis* sp., and a group of unidentified labrids. 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 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, ten *Acanthurus olivaceus*, fifteen *A. dussumieri*, and eight *A. mata*.

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* and *Chromis hanui*. 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 was estimated at 13 g/m^2, with the species contributing most heavily including two *Acanthurus xanthopterus*, one *Sufflamen fraenatus*, and one *Cantherhines dumerilii*.

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 standing crop was estimated at 41 g/m^2. Important species by weight included one *Caranx melampygus*, three *Sufflamen fraenatus*, 341 juvenile *Lutjanus* sp., and one *Arothron hispidus*.

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 February 2005 survey of this transect site noted 5 species representing 39 individual fishes (Table 1). This amounts to one new fish species encountered for every 20.4 m^2 of substratum surveyed and one new individual fish seen for every 2.6 m^2 of bottom sampled. The most abundant fish species was the damselfish *Chromis* sp. The standing crop of fishes was estimated at 1 g/m^2, with three species (*Chromis* sp., labrid unidentified, and *Acanthurus* sp.) contributing about 75% to the total.

Two macroinvertebrate species were seen on Transect 3 in the February 2005 survey. The cushion starfish *Culcita novaeguineae* and the black sea cucumber *Holothuria atra* were represented by four individuals.

The December 2004 survey at Transect 3 noted 7 species representing 90 individual fishes (Brock 2005). This amounts to one new fish species encountered for every 14.6 m^2 of substratum surveyed or one new individual fish seen for every 1.1 m^2 of bottom censused. The most common fish species present was *Chromis hanui*. The standing crop was estimated at 3 g/m^2, and the most important contributors were a single *Cantherhines dumerilii* and unidentified surgeonfish.

In the 2003 survey at Transect 3, 4 species representing 92 individual fishes were counted (Brock 2003). This amounts to one new fish species seen for every 25.5 m^2 of substratum surveyed or 1.1 m^2 of bottom sampled for each individual fish seen. The most common species seen were unidentified wrasses and damselfishes (*Chromis* sp.). The standing crop was estimated at 2 g/m^2, with unidentified labrids and three *Parupeneus multifasciatus* being the greatest contributors.

In the January 2002 survey, 9 species representing 35 fishes were censused at Transect 3 (Brock 2002). In this case, 10.2 m^2 of substratum was examined for each new fish species encountered or 2.8 m^2 of substratum was inspected for each individual fish seen. The most abundant species included unidentified damselfishes and unidentified labrids or wrasses. The standing crop of fishes was estimated at 19 g/m^2, with the species making the greatest contribution including a single *Acanthurus olivaceus*, a single *Cantherhines dumerilii*, and a single *Gymnothorax* sp.

The February 2001 fish census at Transect 3 noted 11 species representing 94 individuals (Brock 2001). This amounts to one new species of fish seen for every 9.3 m^2 of substratum or one new individual fish encountered for every 1.1 m^2 of bottom examined. The most abundant fishes seen include *Chromis* sp., unidentified wrasses or labrids, and *Chromis hanui*. The standing crop of fishes at this site was estimated at 7 g/m^2, with the species contributing most heavily including a single *Sufflamen bursa* and three *S. fraenatus*.

The April 1999 survey noted 13 fish species representing 120 individuals (Brock 1999). 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 *Chromis* sp., unidentified wrasses or labrids, and *Chromis hanui*. The standing crop was estimated at 17 g/m^2, with *Gymnothorax* sp., *Sufflamen fraenatus*, and *Acanthurus olivaceus* contributing the greatest percentages.

The January 1998 survey noted 11 species representing 90 individual fishes (Brock 1998). 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* and four *Sufflamen fraenatus* contributing greatly.

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 new individual fish seen for every 0.8 m^2 of bottom surveyed. The most common species on this transect were unidentified pomacentrids, unidentified labrids, and *Chromis* sp. The standing crop was estimated at 12 g/m^2. The most important contributors to the standing crop were *Parupeneus multifasciatus*, unidentified pomacentrids, and *Sufflamen fraenatus*.

The March 1996 survey at Transect 3 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* and *Chromis* sp. The standing crop of fishes was estimated at 13 g/m^2, with *Parupeneus multifasciatus* and *Bodianus bilunulatus* being important contributors.

In the January 1995 survey at Transect 3, 10 species representing 207 individual fishes were noted (Brock 1995). This amounts to one new fish species seen for every 10.2 m^2 of substratum sampled or one new individual fish seen for every 0.5 m^2 of bottom sampled. The most common species were *Chromis hanui*, *Chromis* sp., and unidentified labrids. The group of unidentified labrids was probably comprised of *Thalassoma duperrey*, *Oxycheilinus bimaculatus*, and *Pseudojuloides cerasinus*. The standing crop of fishes was estimated at 16 g/m^2, with the unidentified labrids and *Acanthurus xanthopterus* contributing greatly.

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 new individual fish seen for every 1.2 m^2 of bottom surveyed. The most abundant species were *Chromis* sp. and unidentified wrasses (categorized as labrid unidentified). The estimated standing crop of fishes was 46 g/m^2, with the species contributing the greatest percentages including *Acanthurus xanthopterus*, *A. mata*, and *A. dussumieri*.

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 surveyed. The most abundant identifiable fish species was *Chromis* sp. The standing crop of fishes was estimated at 12 g/m^2, with a single sleek *Naso hexacanthus* contributing significantly.

In the January 1992 survey at Transect 3, 13 species of fishes representing 221 individuals were seen (Brock 1993b). This represents one new fish species encountered for every 7.8 m^2 of substratum sampled or one new individual fish for every 0.5 m^2 of bottom surveyed. The most abundant fish species appeared to be juvenile snappers (*Lutjanus* sp.), *Chromis* sp., and *Parupeneus multifasciatus*. The standing crop of fishes, estimated at 51 g/m^2, was comprised of three *Acanthurus xanthopterus*, one *Acanthurus olivaceus*, and ten *Parupeneus multifasciatus*.

The physical characteristics and survey results for the three transects annually censused in 1992 through 1999 and again in 2001 through 2005 are summarized in Table 2. In general, the number of species of fish has been similar for all survey years except 1997 and 2005, when it was less. The number of individual fishes has fluctuated among survey years, with 1998 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 survey years except 1994 (when higher numbers were recorded for all three transects) and 2003 and 2004 (when higher numbers of larger fishes were recorded for Transect 1). The estimated biomass was low in 2005. Other than the 1994, 2003, 2004, and 2005 biomass estimates, 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 thirteen years using the Kruskal–Wallis ANOVA suggests that despite the changes among the survey periods (as shown in Table 2), only two parameters have changed significantly. Specifically, the number of individual fishes censused per transect has changed significantly among the thirteen survey years ($p > 0.03$). Not unexpectedly, and related to this significant change, is the fact that the mean amount of substratum censused to find an individual fish has changed significantly among the thirteen survey years ($p > 0.01$). There were no significant changes on the three transects for any of the other measured parameters (i.e., the mean number of fish species encountered, the mean estimated biomass of fishes, the mean amount of substratum covered to encounter a new fish species, and the mean number of invertebrate species or individuals). Further analysis using the nonparametric SNK test provided little support to the significant Kruskal–Wallis ANOVA findings. In the case of the mean number of individual fish censused per year, there is considerable overlap in the SNK test results, suggesting that the statistical separation has little biological meaning. As for the mean number of square meters sampled for each individual fish censused, there is no statistical separation in the SNK test results.

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 and for 2001 Through 2005

Parameter	1992 Transect			1993 Transect			1994 Transect		
	1	2	3	1	2	3	1	2	3
Transect Length (m)	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
No. of Fish Species	11	13	13	10	16	7	14	17	11
No. of Fish Individuals	294	413	221	52	97	48	127	303	86
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
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
Fish Biomass (g/m^2)	13	41	51	18	13	12	67	206	46
No. of Macroinvertebrate Species	5	4	5	5	5	4	4	2	3
No. of Macroinvertebrate Individuals	8	13	22	14	28	16	7	9	12

Parameter	1995 Transect			1996 Transect			1997 Transect		
	1	2	3	1	2	3	1	2	3
Transect Length (m)	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
No. of Fish Species	16	12	10	14	15	13	11	8	9
No. of Fish Individuals	106	191	207	43	127	212	25	32	132
No. of m^2 Sampled/ New Fish Species	4.6	13.4	10.2	5.2	10.7	7.8	6.6	20.1	11.3
No. of m^2 Sampled/ Individual Fish	0.7	0.8	0.5	1.7	1.3	0.5	2.9	5.0	0.8
Fish Biomass (g/m^2)	27	29	16	8	56	13	60	8	12
No. of Macroinvertebrate Species	4	4	3	3	4	14	1	5	1
No. of Macroinvertebrate Individuals	11	9	14	5	17	14	2	10	1

TABLE 2—*Continued*

Parameter	1998 Transect			1999 Transect			2001 Transect		
	1	2	3	1	2	3	1	2	3
Transect Length (m)	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
No. of Fish Species	11	15	11	11	11	13	9	11	11
No. of Fish Individuals	402	489	90	39	84	120	20	59	94
No. of m^2 Sampled/ New Fish Species	6.6	10.7	9.3	6.6	14.6	7.8	8.1	14.6	9.3
No. of m^2 Sampled/ Individual Fish	0.2	0.3	1.1	1.9	1.9	0.9	3.6	2.7	1.1
Fish Biomass (g/m^2)	70	30	34	65	31	17	33	39	7
No. of Macroinvertebrate Species	4	3	3	1	4	1	1	4	3
No. of Macroinvertebrate Individuals	7	12	11	6	12	7	1	20	10

Parameter	2002 Transect			2003 Transect			2004 Transect		
	1	2	3	1	2	3	1	2	3
Transect Length (m)	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
No. of Fish Species	10	14	9	19	12	4	16	10	7
No. of Fish Individuals	27	63	35	115	49	92	207	238	90
No. of m^2 Sampled/ New Fish Species	7.3	14.6	10.2	3.8	13.4	25.5	4.9	16.1	14.6
No. of m^2 Sampled/ Individual Fish	2.7	2.6	2.8	0.6	3.3	1.1	0.4	0.7	1.1
Fish Biomass (g/m^2)	41	34	19	302	36	2	237	27	3
No. of Macroinvertebrate Species	2	3	1	3	2	2	2	4	1
No. of Macroinvertebrate Individuals	7	3	2	3	7	2	5	9	1

TABLE 2—*Continued*

Parameter	2005 Transect		
	1	2	3
Transect Length (m)	36.5	80	51
Area Sampled (m^2)	73	161	102
No. of Fish Species	10	6	5
No. of Fish Individuals	38	45	39
No. of m^2 Sampled/ New Fish Species	7.3	26.8	20.4
No. of m^2 Sampled/ Individual Fish	1.9	3.6	2.6
Fish Biomass (g/m^2)	87	5	1
No. of Macroinvertebrate Species	3	2	2
No. of Macroinvertebrate Individuals	8	2	4

NOTE: Included are summary data from the fish and invertebrate censuses carried out at each transect location. Data for previous survey years are from Brock (1993b, 1994a, 1994b, 1995, 1996, 1997, 1998, 1999, 2001, 2002, 2003, 2005).

DISCUSSION

Despite the differences in the number of species and abundance of fishes on each transect among the thirteen annual surveys, the Kruskal–Wallis ANOVA found that only the mean number of fishes censused per transect and the mean number of square meters examined to find an individual fish showed statistically significant changes. The size of the area searched to find an individual fish is directly related only to the number of fishes counted because the area searched on a given transect does not vary among the survey years. Thus, if the mean number of fishes censused per transect shows a statistically significant change, the measure of the mean number of square meters examined to find an individual fish should also show a similar significant change, which it does. However, as stated above, the SNK test did not find a clear statistical separation among the means over the thirteen survey years. This lack of clear statistical separation among the means for the different survey years, as well as the fact that the decrease in numbers of fishes seen per transect does not follow any temporal trend, suggests that the changes are due to factors such as water clarity or camera angle and resolution and not due to any real change occurring in the diffuser fish communities. 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* in past years), 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 *Oxycheilinus bimaculatus*, *Pseudocheilinus* spp., *Thalassoma* spp., or *Pseudojuloides cerasinus*). In terms of abundance, these unidentified fishes are important but, in general, contribute 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 controlling 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. In 2005 the videotape of the transect areas was changed through the period of the survey, as did the local currents. The videotape of Transect 3 was done at a time when the current kept the discharge materials close to the pipe, resulting in hindered visibility and hence very low counts. During much of the taping, the camera was focused on the bottom and, because of poor visibility, was kept in close proximity to the seaward side of the discharge pipe. The situation was similar at Transect 2. At Transect 1 much of the armor stone was covered with sand, eliminating much of the shelter normally used by small fishes. This probably contributed to the decrease in numbers of the normally abundant small fish on this transect.

From 2001 through 2004, the camera was operated such that viewing was primarily near-horizontal, making many of the smaller fishes difficult to identify. In general, visibility was acceptable, ranging from about 1 to 10 m. In 2001 and 2003 two videotapes each were generated, and in 2002 and 2004 only one tape each was produced.

In 1999 only one videotape was generated. The camera traveled from the discharge terminus toward shore, first along one side of the diffuser pipe then along the other side. Census work was carried out along the seaward side of the diffuser; 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, from 30 to 70 g/m^2 in the January 1998 survey, from 17 to 65 g/m^2 in the April 1999 survey, from 7 to 39 g/m^2 in the February 2001 survey, from 19 to 41 g/m^2 in the 2002 survey, from 2 to 302 g/m^2 in the February 2003 survey, from 3 to 237 g/m^2 in the December 2004 survey, and from 1 to 87 g/m^2 in the February 2005 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, 1997, and 2002 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 and 2001 *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 standing crop estimates for Transects 1 and 2, and *A. olivaceus* and *S. fraenatus* were important contributors at all three transects. In 2001 *S. fraenatus* contributed the greatest estimated standing crop at Transects 1 and 3 and continued to be an important contributor at Transect 2. In 2002 the barred filefish or ‘ō‘ili (*Cantherhines dumerilii*) was an important contributor at both Transects 1 and 3. In 2003 *Acanthurus blochii* and *A. xanthopterus* were major contributors at Transect 1, where the estimated biomass was unusually high. These fishes were probably only seen because of the near-horizontal angle of the camera on this transect. In 2005 *Selar crumenophthalmus* comprised over half of the standing crop at Transect 1.

It should be noted that all of the species contributing heavily to the estimated standing crop of fish seen on a given transect are diurnally active species. Many species that could contribute significantly to the standing crop of fishes present, such as the moray eels or puhi (family Muraenidae), are nocturnal. Occasionally, an eel is encountered in the camera surveys, but it is suspected that eels are greatly underrepresented in the census data.

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 the 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.

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