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AN ANALYSIS OF THE FISH AND MACROBENTHOS ALONG THE SAND ISLAND OCEAN OUTFALL USING REMOTE VIDEO: IX. 1998 DATA

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[12] ABSTRACT (PURPOSE, METHOD, RESULTS, CONCLUSIONS)

Because the diffuser of the Sand Island Ocean Outfall lies below safe diving depths, a remotely controlled video camera system was used to determine the status of the fish and diurnally exposed macrobenthos resident to the diffuser. The use of a remotely operated vehicle is stipulated in the National Pollutant Discharge Elimination System 301(h) waiver permit for the Sand Island Wastewater Treatment Plant. Video reconnaissance was completed over the entire 1,036 m length of the outfall diffuser. Five visual "transects," which "sampled" approximately 41% of the total diffuser length, were established on the diffuser pipe. Video sampling of the diffuser marine communities was carried out annually from 1990 through 1998. Only a few species of diurnally exposed macroinvertebrates are evident on the videotapes of the diffuser; the numbers are insufficient for any meaningful analysis. In 1998, 30 fish species (1,046 individuals) having an estimated biomass ranging from 13 to 220 g/m^2 (mean 59 g/m^2) were censused. In the years from 1991 through 1997, the number of fish species encountered during a survey ranged from 22 species (in 1993) to 31 species (in 1992); the total number of individuals from 279 (in 1993) to 2,936 (in 1992); and the mean biomass from 21 g/m^2 (in 1993) to 92 g/m^2 (in 1996). Because the 1990 video census covered only the terminal 183 m of the diffuser, whereas the later surveys were spread out along the entire diffuser length, a direct comparison cannot be made between the 1990 data and the data for subsequent years. The 1998 census noted one "new" fish species for every 28.3 m^2 of substratum sampled and one fish for every 0.8 m^2. In the 1991 through 1997 period, measures of the fish community (number of species, number of individuals, and biomass)—after an initial increase from 1991 to 1992 and a decrease in 1993—have oscillated annually. From a statistical perspective, changes in the mean number of species per transect and the mean number of individual fishes per transect are significant (Kruskal–Wallis ANOVA); changes in the biomass of fishes over the same period are not significant. These changes in the fish community are attributed to changes in the general viewplane of the videotapes recorded in 1994 and later years from that recorded in earlier years, as well as to a change in the resolution of the videotape from which the data are derived. Poorer camera resolution results in lower counts; camera resolution is affected by local wind and currents interacting with the camera, tether, and support vessel as well as by water visibility. Controlling these sources of variation inherent with the use of the remotely operated video system is difficult if not impossible. 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 operated video camera should be viewed as qualitative, with little statistical rigor.

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Because the diffuser of the Sand Island Ocean Outfall lies below safe diving depths, a remotely controlled video camera system was used to determine the status of the fish and diurnally exposed macrobenthos resident to the diffuser. The use of a remotely operated vehicle is stipulated in the National Pollutant Discharge Elimination System 301(h) waiver permit for the Sand Island Wastewater Treatment Plant. Video reconnaissance was completed over the entire 1,036 m length of the outfall diffuser. Five visual "transects," which "sampled" approximately 41% of the total diffuser length, were established on the diffuser pipe. Video sampling of the diffuser marine communities was carried out annually from 1990 through 1998. Only a few species of diurnally exposed macroinvertebrates are evident on the videotapes of the diffuser; the numbers are insufficient for any meaningful analysis. In 1998, 30 fish species (1,046 individuals) having an estimated biomass ranging from 13 to 220 g/m^2 (mean 59 g/m^2) were censused. In the years from 1991 through 1997, the number of fish species encountered during a survey ranged from 22 species (in 1993) to 31 species (in 1992); the total number of individuals from 279 (in 1993) to 2,936 (in 1992); and the mean biomass from 21 g/m^2 (in 1993) to 92 g/m^2 (in 1996). Because the 1990 video census covered only the terminal 183 m of the diffuser, whereas the later surveys were spread out along the entire diffuser length, a direct comparison cannot be made between the 1990 data and the data for subsequent years. The 1998 census noted one "new" fish species for every 28.3 m^2 of substratum sampled and one fish for every 0.8 m^2. In the 1991 through 1997 period, measures of the fish community (number of species, number of individuals, and biomass)—after an initial increase from 1991 to 1992 and a decrease in 1993—have oscillated annually. From a statistical perspective, changes in the mean number of species per transect and the mean number of individual fishes per transect are significant (Kruskal–Wallis ANOVA); changes in the biomass of fishes over the same period are not significant. These changes in the fish community are attributed to changes in the general viewplane of the videotapes recorded in 1994 and later years from that recorded in earlier years, as well as to a change in the resolution of the videotape from which the data are derived. Poorer camera resolution results in lower counts; camera resolution is affected by local wind and currents interacting with the camera, tether, and support vessel as well as by water visibility. Controlling these sources of variation inherent with the use of the remotely operated video system is difficult if not impossible. 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 operated video camera should be viewed as qualitative, with little statistical rigor.

CONTENTS

INTRODUCTION 1

MATERIALS AND METHODS 1

RESULTS 3

DISCUSSION 22

REFERENCES CITED 24

Figures

1. Schematic of the 1,036-m-long Sand Island Ocean Outfall diffuser pipe showing the approximate locations of the five transects established in August 1991 and monitored annually using a remotely controlled video recording system 5
2. Number of fish species censused annually on five transects along the Sand Island Ocean Outfall diffuser, O'ahu, Hawai'i, 1991 through 1998 20
3. Number of individual fish censused annually on five transects along the Sand Island Ocean Outfall diffuser, O'ahu, Hawai'i, 1991 through 1998 20
4. Estimated biomass of fishes censused annually on five transects along the Sand Island Ocean Outfall diffuser, O'ahu, Hawai'i, 1991 through 1998 21

Tables

1. Family and species of fishes censused on five transects along the 1,036-m-long diffuser pipe of the Sand Island Ocean Outfall as delineated using a remotely controlled video camera system on 1 September 1998 7
2. Summary of the diurnally exposed macroinvertebrates censused on five video transects carried out along the 1,036-m-long diffuser pipe of the Sand Island Ocean Outfall on 1 September 1998 8
3. Summary of diurnally exposed macroinvertebrates censused on five transects along the 1,036-m-long diffuser pipe of the Sand Island Ocean Outfall as delineated using a remotely controlled video camera system in the annual surveys from 1991 through 1997 9
4. Summary of the characteristics of five transects carried out at various points along the 1,036-m-long Sand Island Ocean Outfall diffuser, with data from the fish censuses carried out at each transect in September 1998 11
5. Family and species of fishes censused on five transects along the 1,036-m-long diffuser pipe of the Sand Island Ocean Outfall as delineated using a remotely controlled video camera system on 22 August 1991 12
6. Family and species of fishes censused on five transects along the 1,036-m-long diffuser pipe of the Sand Island Ocean Outfall as delineated using a remotely controlled video camera system on 28 August 1992 13
7. Family and species of fishes censused on five transects along the 1,036-m-long diffuser pipe of the Sand Island Ocean Outfall as delineated using a remotely controlled video camera system on 5 August 1993 14

INTRODUCTION

In recent years controversy has arisen regarding the impact that sewage effluent from the Sand Island Wastewater Treatment Plant may have on marine communities resident to the receiving waters. The outfall was constructed in 1975, and screened sewage has been discharged since 1976. The ocean portion of the outfall is comprised of 2,780 m of 2.1-m-diameter reinforced concrete pipe that terminates in a 1,036-m-long diffuser. The diffuser is made up of reinforced concrete pipe of three diameters: 490 m of 2.1-m-diameter pipe, 271 m of 1.7-m-diameter pipe, and 275 m of 1.2-m-diameter pipe at the terminus. Along its length, the diffuser, which lies in water from 68 to 73 m in depth, has 282 ports that range from 7.6 to 9 cm in diameter. The diffuser rests on a gravel pad and has some ballast rock placed at the junctures between sections. Fishes and macroinvertebrates 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 resident to the discharge port areas of the outfall. This report presents a synopsis of the data from the eighth annual sampling effort carried out on 1 September 1998 and comparatively analyzes this data with information collected annually since 1991.

MATERIALS AND METHODS

A remotely controlled video camera was used to conduct the census because the fish and diurnally exposed macroinvertebrate communities of interest to this study reside in waters below safe diving depths. In addition, the system was used because the waiver permit issued by the U.S. Environmental Protection Agency/Hawaii Department of Health requires the use of a remotely operated vehicle. There are a number of drawbacks as well as positive aspects to using a video camera system to visually census fishes and diurnally exposed macroinvertebrates. The drawbacks include problems with camera resolution, making species and size identifications difficult, and the problem of adequately controlling the camera to focus-in on rapidly fleeing fishes, adding further difficulty to identification problems. On the positive side, a permanent record of the organisms in the path of the camera is obtained. An additional benefit to 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

wider field of view was attained, but with the small average size of fish present this meant a decrease in resolution with greater height above the pipe, resulting in a decrease in apparent abundance of fishes.

The path of the camera in the 1994, 1995, 1997, and 1998 surveys was quite different. The camera remained along one (inshore) side of the pipe while traveling toward the outfall terminus, and on reaching the terminus, the camera was moved to the opposite (offshore) side, for its travel back to the beginning of the diffuser. The censuses for the 1994, 1995, 1997, and 1998 surveys were carried out at each of the five transect sites on the offshore side of the diffuser only, to make data between surveys comparable. In general, the camera traveled within 1 to 2 m of the substratum during these surveys. For the 1996 survey, the camera traveled down the offshore side of the pipe; this is the segment of the videotape used for the assessment.

The camera grossly underestimates the number of fish and invertebrates, thus everything seen in an arbitrary 2-m-wide path was counted, regardless of whether it was encountered directly below the camera (as when viewing from above) or several meters ahead (as when the camera is in a horizontal position). The fish census involved not only the counting of populations but also the estimating of 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; Brock and Norris 1989). Species-specific regression coefficients have been developed over the last 30 years by the author and others at the University of Hawai'i, the Naval Undersea Center (see Evans 1974), and the Hawai'i Division of Aquatic Resources from weight and body length measurements of captured fishes; for many species, sample sizes were in excess of a hundred individuals.

RESULTS

Video "transects" of the fish communities resident to the Sand Island diffuser pipe have been carried out on nine occasions: 7 November 1990, 22 August 1991, 28 August 1992, 5 August 1993, 10 August 1994, 16 November 1995, 26 September 1996, 26 August 1997, and 1 September 1998. The November 1990 survey only covered the final 183 m of the 1,036-m-long diffuser pipe. In the more recent surveys, the camera commenced just shoreward of the first discharge port on the diffuser and "sampled" the fish and macrobenthos for the entire diffuser length. The 1991 survey tape was viewed several times to determine where representative transects could best be established. Five transect sites selected as being representative sections of the diffuser pipe were sampled using the visual census technique.

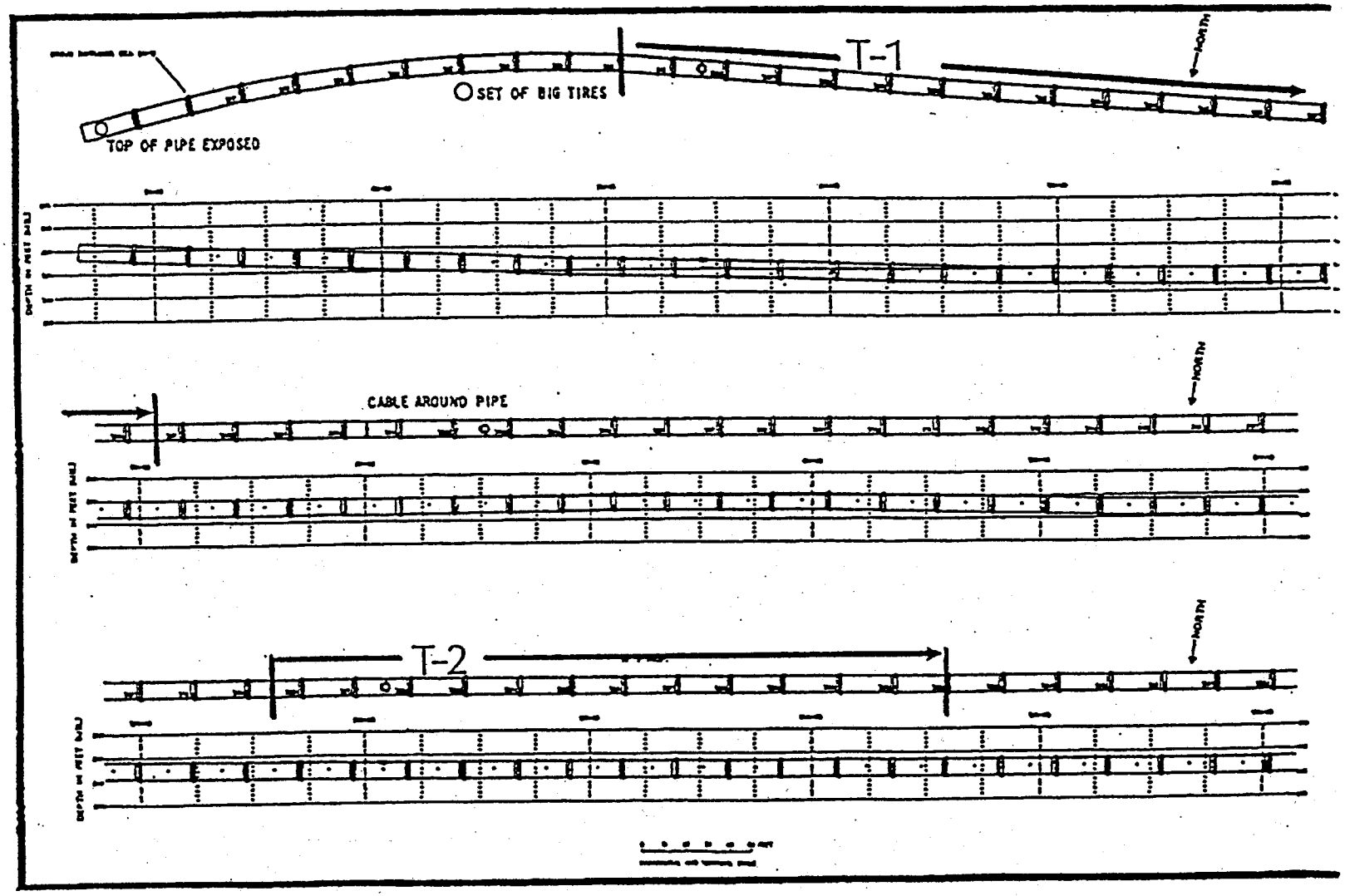

Figure courtesy of the Oceanographic Team, Department of Wastewater Management, City and County of Honolulu

OCEANOGRAPHIC AUG 1991

FIGURE 1. Schematic of the 1036-m-long Sand Island Ocean Outfall diffuser pipe showing the approximate locations of the five transects established in August 1991 and monitored annually using a remotely controlled video recording system. Transects are numbered, and the length of diffuser pipe covered by each is shown with an arrow.

TABLE 1. Family and Species of Fishes Censused on Five Transects Along the 1,036-m-Long Diffuser Pipe of the Sand Island Ocean Outfall as Delineated Using a Remotely Controlled Video Camera System on 1 September 1998

FAMILY and Species	Transect				
	1	2	3	4	5
MURAENIDAE					
Gymnothorax flavimarginatus			1		1
SERRANIDAE					
Pseudanthias sp.	8	7	28	67	72
CARANGIDAE					
Caranx melampygus			1		
Caranx lugubris					1
LUTJANIDAE					
Lutjanus kasmira				21	
Lutjanus sp.		1			23
MULLIDAE					
Parupeneus multifasciatus	5	1	2		1
CHAETODONTIDAE					
Chaetodon miliaris					2
Chaetodon kleinii		1		1	
Chaetodon sp.	1				
POMACANTHIDAE					
Holocanthus arcatus		3			
Centropyge sp.		1			
POMACENTRIDAE					
Chromis sp.	125	51	136	115	42
Pomacentrid unidentified			32	67	40
LABRIDAE					
Bodianus bilunulatus	1				1
Pseudojuloides cerasinus	1			3	3
Macropharyngodon geoffroy	1				
Thalassoma sp.		1			
Anampses chrysocephalus					1
Labrid unidentified	15	16	19	50	
ACANTHURIDAE					
Acanthurus sp.		2			
Acanthurus xanthopterus			1	1	6
Naso hexacanthus					10
Zanclus cornutus		5		7	4
BALISTIDAE					
Sufflamen fraenatus	3	2	1	7	5
MONACANTHIDAE					
Cantherhines dumerili					1
TETRAODONTIDAE					
Arothron hispidus	3	6	4	2	1
Canthigaster coronata		1	1	2	
Canthigaster sp.					1
DIODONTIDAE					
Diodon holocanthus	1				
Total No. of Species	11	14	11	12	18
Total No. of Individuals	164	98	226	343	215
Biomass (g/m^2)	13	15	25	23	220

NOTE: Areas sampled on the five transects varied: 190 m^2 for Transect 1, 182 m^2 for Transect 2, 220 m^2 for Transect 3, 168 m^2 for Transect 4, and 88 m^2 for Transect 5. The numbers of individuals of each species censused are given in the body of the table. Totals for numbers of species and individuals and an estimate of biomass for each transect are given at the foot of the table.

TABLE 3. Summary of Diurnally Exposed Macroinvertebrates Censused on Five Transects Along the 1,036-m-Long Diffuser Pipe of the Sand Island Ocean Outfall as Delineated Using a Remotely Controlled Video Camera System in the Annual Surveys from 1991 Through 1997

PHYLUM and Species	1991 Transect					1992 Transect				
	1	2	3	4	5	1	2	3	4	5
ARTHROPODA										
Panulirus marginatus							2			
ECHINODERMATA										
Bohadschia vitiensis			1			2		7		
Culcita novaeguineae							1			
Diadema setosum	7	1								
Holothuria atra	2	2	32	12	1			14	11	4
Tripneustes gratilla					3					
Total No. of Species	2	2	2	1	2	1	2	2	1	1
Total No. of Individuals	9	3	33	12	4	2	3	21	11	4

	1993 Transect					1994 Transect				
	1	2	3	4	5	1	2	3	4	5
ARTHROPODA										
Panulirus marginatus	1					1		1		
ECHINODERMATA										
Bohadschia vitiensis (?)	1	1	2	3				1		
Chondrocidaris gigantea		1				1	1			
Culcita novaeguineae	1		1							
Holothuria atra	2	2	21	23	7			4	16	10
Tripneustes gratilla			1	1						
Total No. of Species	4	3	4	3	1	2	1	3	1	1
Total No. of Individuals	5	4	25	27	7	2	1	6	16	10

	1995 Transect					1996 Transect				
	1	2	3	4	5	1	2	3	4	5
ARTHROPODA										
Panulirus marginatus			1				1			
ECHINODERMATA										
Bohadschia vitiensis (?)			3	4		1			2	5
Chondrocidaris gigantea	2	1					2			
Culcita novaeguineae							1			
Holothuria atra			6	16	2			12	11	
Tripneustes gratilla				1						
Total No. of Species	1	1	3	3	1	1	3	1	2	1
Total No. of Individuals	2	1	10	21	2	1	4	12	13	5

	1997 Transect				
	1	2	3	4	5
ARTHROPODA					
Panulirus marginatus		1			
ECHINODERMATA					
Bohadschia vitiensis (?)				2	1
Chondrocidaris gigantea			2		
Culcita novaeguineae		1			
Holothuria atra				4	4
Total No. of Species	0	2	1	2	2
Total No. of Individuals	0	2	2	6	5

NOTE: Areas sampled on the five transects varied: 190 m^2 for Transect 1, 182 m^2 for Transect 2, 220 m^2 for Transect 3, 168 m^2 for Transect 4, and 88 m^2 for Transect 5. The numbers of individuals of each species are given in the body of the table. Totals for numbers of species and individuals for each transect are given at the foot of each section of the table.

TABLE 4. Summary of the Characteristics of Five Transects Carried Out at Various Points Along the 1,036-m-Long Sand Island Ocean Outfall Diffuser, with Data from the Fish Censuses Carried Out at Each Transect in September 1998

Parameter	Transect					Mean
	1	2	3	4	5	
Transect Length (m)	95	91	110	84	44	85
Area Sampled (m^2)	190	182	220	168	88	170
No. of Species	11	14	11	12	18	13
No. of Individuals	164	98	226	343	215	209
No. of m^2 Sampled Per New Species	17.3	13.0	20.0	14.0	4.9	13.8
No. of m^2 Sampled Per Individual	1.2	1.9	1.0	0.5	0.4	1.0
Biomass (g/m^2)	13	15	25	23	220	59

NOTE: Means are presented in the right column.

videotape was considerably less. Average visibility in 1993 was about 3 m, less than in previous survey years. The net result is an apparent decrease in counts of fish species and individuals for 1993. A summary of the standing crops estimated for each transect over the eight-year period of this study is presented in Figure 4. In general, the biomass estimates are similar among the different transects and years, except for Transect 5 (located at the diffuser terminus) in 1996 and 1998. In both years the estimated biomass was considerably elevated over the other years. This was due to the presence of a school of ʻōmilu (*Caranx melampygus*) in 1996 and a mixed school of kala holo (*Naso hexacanthus*) and pualu (*Acanthurus xanthopterus*) in 1998.

As noted above, Table 12 presents a summary of the parameters measured in the fish community along the Sand Island diffuser for the eight sampling dates. Statistically significant differences were found for the mean number of fish species encountered on a transect among the eight years (Kruskal–Wallis ANOVA, df = 7, $p > 0.008$; see Siegel 1956). The nonparametric Student–Newman–Keuls multiple range test on ranked values of each variable (SAS Institute Inc. 1985) was used to delineate statistically significant differences for the mean number of fish species per transect among the eight years. These results are presented in Table 13; only the mean number of fish species for 1993 differed significantly from the other seven years. The same analyses were performed for the mean number of individual fishes censused on a transect. Again, the Kruskal–Wallis ANOVA pointed out that a statistically significant difference exists in the mean number of individual fishes per transect among the eight years

TABLE 6. Family and Species of Fishes Censused on Five Transects Along the 1,036-m-Long Diffuser Pipe of the Sand Island Ocean Outfall as Delineated Using a Remotely Controlled Video Camera System on 28 August 1992

FAMILY and Species	Transect 1	2	3	4	5
MURAENIDAE					
Gymnothorax flavimarginatus		1	1		
Gymnothorax sp.			1	1	
AULOSTOMIDAE					
Aulostomus chinensis			1		
PRIACANTHIDAE					
Priacanthus sp. (?)					1
SERRANIDAE					
Pseudanthias thompsoni		24	158	41	148
LUTJANIDAE					
Lutjanus kasmira		261			
Lutjanus fulvus	1	2	2		
Lutjanus sp. (?)			722	153	375
MULLIDAE					
Parupeneus multifasciatus	11	24	32	5	
CHAETODONTIDAE					
Chaetodon kleinii (?)		2			
Chaetodon multicinctus (?)	4	1			
Chaetodon sp.		3	1		
POMACANTHIDAE					
Holocanthus arcuatus		1	1		
Centropyge sp. (?)	1	2	16	2	3
POMACENTRIDAE					
Chromis hanui	52	31	28	19	8
Chromis sp.	76	126	91	55	11
Pomacentrid unidentified	11	3			
LABRIDAE					
Bodianus bilunulatus			1		1
Thalassoma duperrey (?)	23	17	8		
Pseudojuloides cerasinus		3	15	5	
Gomphosus varius	3			1	
Macropharyngodon geoffroy	1		3		
Halichoeres ornatissimus (?)	1	1	1		
Labrid unidentified	111	83	56	30	8
ACANTHURIDAE					
Acanthurus dussumieri	7	1	1		
Zanclus cornutus				1	7
BALISTIDAE					
Sufflamen bursa (?)			1		
Sufflamen fraenatus			1		1
MONACANTHIDAE					
Cantherhines dumerilii	3	5	2	11	2
TETRAODONTIDAE					
Arothron hispidus	3		1	1	1
Canthigaster jactator (?)		2			
Total No. of Species	15	20	23	13	12
Total No. of Individuals	308	593	1,144	325	566
Biomass (g/m^2)	39	45	58	44	77

NOTE: Areas sampled on the five transects varied: 190 m^2 for Transect 1, 182 m^2 for Transect 2, 220 m^2 for Transect 3, 168 m^2 for Transect 4, and 88 m^2 for Transect 5. The numbers of individuals of each species are given in the body of the table. Totals for numbers of species and individuals and an estimate of biomass for each transect are given at the foot of the table. (Data from Brock 1993a)

TABLE 8. Family and Species of Fishes Censused on Five Transects Along the 1,036-m-Long Diffuser Pipe of the Sand Island Ocean Outfall as Delineated Using a Remotely Controlled Video Camera System on 10 August 1994

FAMILY and Species	Transect 1	2	3	4	5
MURAENIDAE					
Gymnothorax sp.	2	1	4	2	1
AULOSTOMIDAE					
Aulostomus chinensis			2		
SERRANIDAE					
Pseudanthias sp.	6	18	91	35	103
APOGONIDAE					
Apogon kallopterus		4	17		
CARANGIDAE					
Caranx melampygus			3	1	
LUTJANIDAE					
Lutjanus kasmira	2		72		20
MULLIDAE					
Mulloidichthys vanicolensis			2		
Parupeneus multifasciatus	6	3	5	1	
CHAETODONTIDAE					
Chaetodon kleinii			1		
Chaetodon miliaris			2		2
POMACANTHIDAE					
Centropyge fisheri	3	3	5	2	2
POMACENTRIDAE					
Chromis agilis				9	7
Chromis hanui	18	16	64	14	4
Chromis sp.	141	90	339	77	22
Plectroglyphidodon johnstonianus (?)		1			
Pomacentrid unidentified	6	19	4	4	1
LABRIDAE					
Anampses chrysocephalus			1		
Bodianus bilunulatus					1
Halichoeres ornatissimus			3		
Pseudojuloides cerasinus (?)	18	5	15	12	2
Labrid unidentified	15	22	50	18	8
ACANTHURIDAE					
Acanthurus sp.			3		
Naso brevirostris	1				
Naso unicornis (?)			1		
Zanclus cornutus					1
BALISTIDAE					
Sufflamen fraenatus	1			1	
Sufflamen fuscus (?)			2		
MONACANTHIDAE					
Alutera scripta		3		1	
Cantherhines dumerilii		3	2	6	3
TETRAODONTIDAE					
Arothron hispidus	5	4	2	1	
Canthigaster coronata	1	1		2	
Canthigaster jactator		1	1		
Total No. of Species	14	16	24	16	14
Total No. of Individuals	225	194	691	186	177
Biomass (g/m^2)	16	46	42	43	28

NOTE: Areas sampled on the five transects varied: 190 m^2 for Transect 1, 182 m^2 for Transect 2, 220 m^2 for Transect 3, 168 m^2 for Transect 4, and 88 m^2 for Transect 5. The numbers of individuals of each species are given in the body of the table. Totals for numbers of species and individuals and an estimate of biomass for each transect are given at the foot of the table. (Data from Brock 1995)

TABLE 10. Family and Species of Fishes Censused on Five Transects Along the 1,036-m-Long Diffuser Pipe of the Sand Island Ocean Outfall as Delineated Using a Remotely Controlled Video Camera System on 26 September 1996

FAMILY and Species	Transect 1	2	3	4	5
MURAENIDAE					
Gymnothorax flavimarginatus		1			1
Gymnothorax sp.		1			
SERRANIDAE					
Pseudanthias sp.	6	26	216	22	71
APOGONIDAE					
Apogon kallopterus		1			
CARANGIDAE					
Caranx melampygus					21
LUTJANIDAE					
Lutjanus sp.		162	380	48	3
MULLIDAE					
Parupeneus multifasciatus		20	14	1	
CHAETODONTIDAE					
Chaetodon kleinii			3		
Chaetodon miliaris		4			
Chaetodon sp.	4		2		
POMACENTRIDAE					
Chromis agilis	1				
Chromis hanui	27	9	20	7	
Chromis sp.	192	61	416	52	13
Plectroglyphidodon johnstonianus	1				
Pomacentrid unidentified		2			
LABRIDAE					
Bodianus bilunulatus	1				1
Pseudojuloides cerasinus			1		
Thalassoma sp.	9	15	30		
Labrid unidentified			21		
GOBIIDAE					
Ptereleotris heteropterus					1
ACANTHURIDAE					
Acanthurus xanthopterus					2
Acanthurus sp.			3	1	
Naso hexacanthus		1			
Naso unicornis	2	1			1
Zanclus cornutus					12
BALISTIDAE					
Sufflamen fraenatus	2	2	3	3	4
TETRAODONTIDAE					
Arothron hispidus		2	1		
Arothron sp.		1			1
Canthigaster coronata		1	1		
Total No. of Species	10	17	14	7	12
Total No. of Individuals	245	310	1,111	134	131
Biomass (g/m^2)	21	79	55	12	293

NOTE: Areas sampled on the five transects varied: 190 m^2 for Transect 1, 182 m^2 for Transect 2, 220 m^2 for Transect 3, 168 m^2 for Transect 4, and 88 m^2 for Transect 5. The numbers of individuals of each species censused are given in the body of the table. Totals for numbers of species and individuals and an estimate of biomass for each transect are given at the foot of the table. (Data from Brock 1997)

TABLE 12. Comparative Summary of Fish Community Development Measured Over Eight Years at Five Locations Along the 1,036-m-Long Sand Island Ocean Outfall Diffuser

Transect	No. of Species							
	1991	1992	1993	1994	1995	1996	1997	1998
1	12	15	11	14	11	10	13	11
2	13	20	10	16	14	17	18	14
3	14	23	11	24	14	14	14	11
4	11	13	8	16	9	7	15	12
5	11	12	9	14	10	12	14	18
Mean	12	17	10	17	12	12	15	13
Transect	**No. of Individuals**							
	1991	1992	1993	1994	1995	1996	1997	1998
1	169	308	42	225	253	245	97	164
2	217	593	52	194	433	310	360	98
3	1,045	1,144	126	691	882	1,111	2,073	226
4	147	325	23	186	128	134	369	343
5	207	566	36	177	100	131	212	215
Mean	357	587	56	295	359	386	622	209
Transect	**Biomass (g/m^2)**							
	1991	1992	1993	1994	1995	1996	1997	1998
1	32	39	6	16	19	21	17	13
2	8	45	12	46	37	79	90	15
3	55	58	11	42	21	55	31	25
4	10	44	39	43	24	12	16	23
5	106	77	39	28	51	293	15	220
Mean	42	53	21	35	30	92	34	59

NOTE: Data are drawn from Tables 1 and 5 through 11, and means for the five transects are given at the foot of each section of the table (see also Figures 2, 3, and 4).

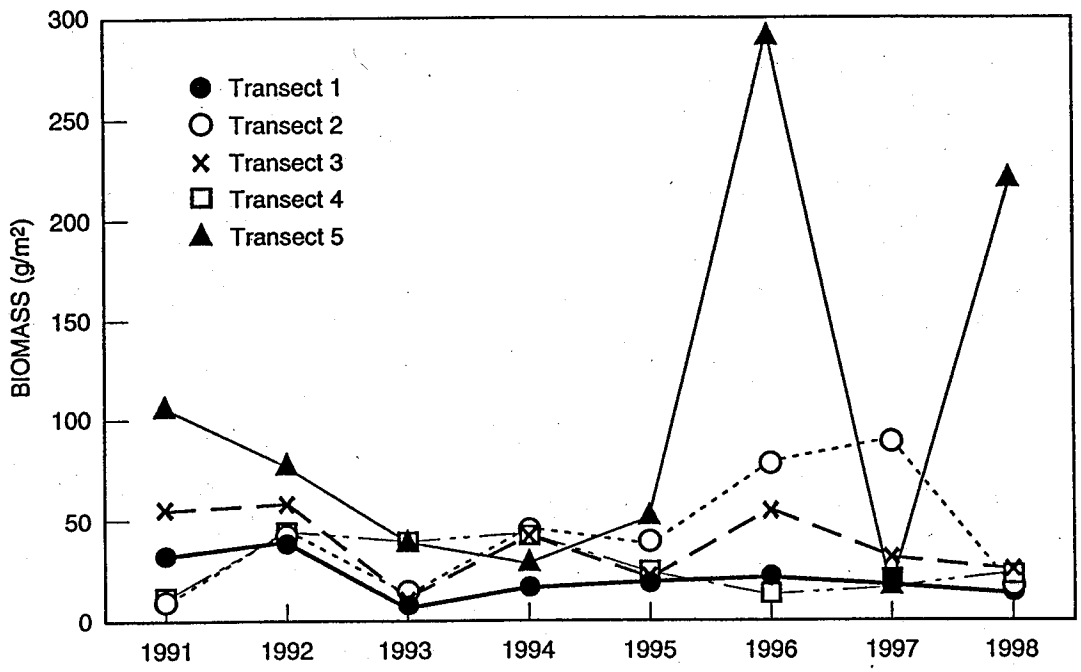

FIGURE 4. Estimated biomass of fishes censused annually on five transects along the Sand Island Ocean Outfall diffuser, O'ahu, Hawai'i, 1991 through 1998

(df = 7, $p > 0.02$). The Student–Newman–Keuls multiple range test found no statistically significant differences among the eight years. No statistically significant differences were found in the mean standing crop of fishes encountered on a transect among the eight sampling dates (Kruskal–Wallis ANOVA, df = 7, $p > 0.34$, not significant; see also Table 13).

TABLE 13. Summary of the Nonparametric Student–Newman–Keuls Multiple Range Test on Ranked Values of Parameters Measured in the Fish Community at Five Permanent Transects Along the 1,036-m-Long Sand Island Ocean Outfall Diffuser Censused Annually from 1991 Through 1998

Parameter	Year and Mean								
Mean No. of Species Per Transect	Year	1994	1992	1997	1998	1991	1996	1995	1993
	Mean	17	17	15	13	12	12	12	10
Mean No. of Individuals Per Transect	Year	1997	1992	1996	1995	1991	1994	1998	1993
	Mean	622	587	386	359	357	295	209	56
Biomass (g/m²)	Year	1996	1998	1992	1991	1994	1997	1995	1993
	Mean	92	59	53	42	35	34	30	21

NOTE: The means on a per-transect basis are given in the body of the table. Horizontal lines connect means that do not differ significantly; breaks in the line show significant differences ($p > 0.05$).

The substratum in the vicinity of the Sand Island 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 diffuser pipe situated on a gravel pad with some ballast stone placed at the ends of most pipe sections provides additional local topographical structure, which has probably influenced the development of the fish community. Because of the small graded sizes used, the ballast stone and gravel pad provide only small-scale shelter. Small-scale shelter favors species that are either small as adults or juveniles of larger species. The average size of the fishes censused in this survey supports this contention. Additionally, many of the larger fishes seen (especially *Acanthurus xanthopterus*) were in the vicinity of known areas of topographical relief, such as the set of large tires near the start of the diffuser pipe, the discarded 55-gallon drum, and the construction debris. The accuracy of censusing is less with smaller fishes.

The data from 1991 to present suggest that there is considerable variation in the fish and invertebrates counts over time. The identification of some species of fishes in this study was not difficult because of their size (such as adult *Acanthurus xanthopterus* and *Bodianus bilunulatus*) or color (such as *Zanclus cornutus*). In past years some species such as the bluelined snapper or ta'ape (*Lutjanus kasmira*) occurred in such high abundance that species identification was not difficult. Despite this, a number of fishes have consistently been difficult or impossible to identify because of (1) poor camera resolution, (2) their rapid movement to cover, (3) their small size, or (4) their being on the peripheral field of view. Some of these fishes were small damselfishes (probably *Chromis hanui* and/or *C. agilis*), small *Lutjanus* sp., and small wrasses (family Labridae, possibly *Cheilinus bimaculatus, Pseudocheilinus* spp., *Thalassoma* spp., or *Pseudojuloides cerasinus*). As for abundance, these unidentified fishes are important, but they generally contribute little to the biomass estimates because of their small size.

Among the abundant fishes surveyed in most years are the juvenile snappers seen close to the substratum. It has been assumed that these juveniles are newly recruited *Lutjanus kasmira*, but they may represent juveniles of a number of other snapper species including the pink snapper or 'ōpakapaka (*Pristipomoides filamentosus*), which is an important species in the Hawai'i bottomfish fishery. If the latter is true, the diffuser may be providing significant local habitat to a commercially important species.

The counts for the parameters measured in the 1994 fish census appear to be higher than those for 1993. The change in operation of the camera commencing in 1994 to view the fish community along each side of the diffuser rather than continually crossing over the pipe from side to side as done in previous years may account for some of the increase. The better camera resolution in 1994, compared with 1993, is probably another reason for the increase in the

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