

**A SURVEY OF SELECTED CORAL AND FISH ASSEMBLAGES
NEAR THE WAIANAE OCEAN OUTFALL, O‘AHU, HAWAI‘I, 1993**

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ABSTRACT

In 1993, coral growth and fish abundance were monitored at stations located at and in the vicinity of the Waianae Ocean Outfall. Comparison of the 1993 results with fish surveys done in previous years showed no significant differences in the species composition or relative abundances of fish populations at the outfall diffuser and at a station 1.2 km south of the diffuser (the sunken ship *Mahi*). Fish species were essentially the same as those seen in similar natural biotopes around Hawaii. There were no significant differences in total coral cover from 1992 to 1993 at the station 1.2 km south of the diffuser. In 1986, when the diffuser began operation, no corals were seen at the diffuser; however, in 1993 corals were seen growing on the diffuser pipe and on the riser discharge ports. The water was clear at all stations surveyed (10 to 15 m horizontal visibility), and the sediments were clean and white. No significant deleterious effects resulting from outfall operation and discharge were seen on the biological community at the stations surveyed.

INTRODUCTION

The City and County of Honolulu's conservation district use application for installation of a wastewater outfall pipe at Wai'anae, O'ahu, Hawai'i, was approved subject to several conditions (see Board of Land and Natural Resources letter to the City, 11/15/83, ref. no. CPO-844, file no. OA- 4/11/83-1541). Among the conditions was the requirement that, in the vicinity of the outfall diffuser, fishery stocks be censused visually annually after the first year of discharge and benthic organisms be monitored photographically annually.

For 1993, the survey of the marine community near the Waianae Ocean Outfall was conducted in May. Researchers of the Water Resources Research Center (WRRC) at the University of Hawaii and oceanographic personnel of the City and County of Honolulu's Department of Wastewater Management (DWM) collaborated in the scuba survey. This report summarizes the results of that survey and comparatively analyzes the 1993 data with data collected in previous years.

MATERIALS AND METHODS

Three survey stations to monitor coral and fish abundance were originally requested by the Hawaii Department of Land and Natural Resources (DLNR) as follows: two stations in the zone of initial dilution (ZID) and one station (in the fish haven) at a distance from the outfall. Specific locations of the three stations are shown in Figure 1, and a description of each station is provided below. There is no spatial control station in this study.

The survey stations are all located at the same depth (approximately 100 ft [30.5 m]), but they differ in bottom type and relief. Comparisons cannot be made among stations for coral and fish abundance and species richness because of these differences. Comparisons can only be made from year to year at each station. Normally, the bottom at the diffuser isobath (100 ft) off the Waianae coast is mostly sand with some rubble. Usually no coral is present, and few fishes reside at this depth. However, artificial reefs in the area can attract fishes and provide substrate for coral growth. Stations were chosen at the diffuser (Station W-3) and at the sunken ship *Mahi* (Station W-2). At these stations artificial structures (the outfall pipe and a sunken ship) provide habitats for fish and surfaces and relief for coral settlement, colonization, and growth. In 1988, after reconnaissance of the area, Station W-4 was chosen because the bottom had some relief and a few scattered small coral heads. After Hurricane Iniki (September 1992) the area was completely covered with coarse sand.

Station W-2 is located 1.2 km south of the ZID in coarse sand at a depth of approximately 30 m. An artificial reef, the sunken ship *Mahi*, is located at the station. This area is important for tourist divers and is one of the prime sites to which dive shops take their tourist customers. It is known for its clear water and abundance of marine life.

Station W-3 is located at the diffuser (depth of approximately 34 m). The diffuser pipe (1.5 m diameter) is buried in the sediment and covered with tremie concrete. Discharge is through risers projecting vertically from the pipe. Surrounding sediments consist of coarse carbonate sands.

Station W-4 is located 100 m southeast of the diffuser at a depth of approximately 30 m on the ZID boundary. It is located in the extreme northern part of the fish haven (Figure 2). This station was severely affected by Hurricane Iniki in September 1992. The bottom, which was originally coarse sand and coral rubble, is now mostly covered with medium to fine sands, with pockets of coral rubble.

At all stations fish counts were made by a diver equipped with scuba. Since errors can exist because of differences in technique and capability among observers, the same diver-observer (the author) performs the fish counts annually. At Station W-2, fish counts were made along a permanent transect (30 m long, 6 m wide) established down the centerline of the ship's deck (Brock 1982). At Station W-3, fish counts were made along the terminal 30 m of the diffuser. No counts were made at Station W-4 because of the severe effects of Hurricane Iniki.

Fish abundances in 1993 at Stations W-2 and W-3 were compared with those determined in past surveys using a nonparametric test of presence or absence (Cochran's Q-test; Green 1979). Green recommends this test because it precludes meeting the assumptions of homogeneous variances of abundances and normal distribution of the data. The test addresses the null hypothesis "no differences in species composition between years." Species composition is a better estimator of temporal stability in fish communities than relative abundance since there may be large natural fluctuations in fish abundances from year to year and season to season. Also, a Bray-Curtis index was used to measure similarity in species composition. The 1993 survey results of fish community composition, abundance, and number of species at Station W-2 were compared with the results for 1988, 1991, and 1992. No survey was made at this station in 1989 or 1990. Also compared were the 1986, 1992, and 1993 results of fish abundance and diversity surveys at Station W-3. During the years between 1986 and 1992, reconnaissance dives (<5 minutes) showed little fish activity at the diffuser, and no fish were seen swimming on the transect.

Coral cover on selected permanent transects was estimated by bottom photography and the subsequent projection of photos on a grid. The percentage of coral cover was estimated

by determining total grid cover relative to the total area of the quadrat. For all stations, the presence of all macroinvertebrates seen was recorded. Coral cover for 1992 and 1993 was compared using a paired comparison t-test to determine if there were significant differences in total coral cover. The use of inferential statistical analysis may not be valid when comparing abundance at the same location over time because the assumption of the independent sampling may be violated. The abundance of an organism at time t1 may influence the abundance at time t2. This problem of independence is not a factor when using the paired t-test. The paired comparison test is not sensitive to moderate deviations from normality, is not affected by assumptions of homogeneous variances because only one variable is involved, and eliminates a maximum number of sources of extraneous variation by making pairs similar with respect to as many variables as possible (Daniel 1987). If the data are seriously skewed from normality, a nonparametric paired sign test may be used instead.

RESULTS

Station W-2

Fishes were very abundant at Station W-2 in 1993 (total = 138). Thirty species were represented. Fish abundance, by species, for 1988, 1991, 1992, and 1993 is shown in Table 1. The snapper *Lutjanus kasmira* (ta‘ape) was moderately abundant in all years surveyed. Prior to 1988, large numbers of both *L. kasmira* and the filefish *Pervagor spilosoma* (‘o(¯,o)‘ili ‘uwo(¯,i)‘uwo(¯,i)) were seen (e.g., *L. kasmira* and *P. spilosoma* together represented >50% of the total fish abundance in 1986). In 1993 no filefish were seen and *L. kasmira* represented only 13.4% of the total abundance. *L. kasmira* was introduced into Hawaii from the Society Islands in the early 1950s and since then has shown a rapid rate of increase in stocks around the islands. There was no significant difference in presence or absence of species between years (Q-test, $p < .01$). Similarity in species composition among years was high (SI = 0.60 to 0.77). Any similarity index over 0.5 is considered significant (Green 1979).

Between 1992 and 1993 there were no significant differences in coral cover at selected coral quadrats ($p < .04$; Table 2). The deck platform of the *Mahi* (Figure 3), where coral cover is generally high, is an ideal place for the settlement and subsequent colonization of corals (Figures 4 and 5). In 1992, coral cover ranged from 19.6 to 51.9% for ten 0.75-m² selected quadrats. In 1993, coral cover ranged from 19.8 to 59.3% for the same quadrat locations. Dominant coral species recorded were *Pocillopora meandrina* (17 to 56%) and

Porites compressa (1 to 6%). Other corals seen were *Montipora* sp. and *Pavona* sp., but these were rare and small (<6 to 8 cm diameter).

Other organisms seen at this station were the seastar *Acanthaster planci* (crown-of-thorns), the bryozoan *Triphyllozoan* sp., red and yellow sponges, the coralline alga *Lithothamnion* sp., the seastar *Culcita* sp., and the black spiny sea urchin *Echinothrix diadema* (wana).

Station W-3

In 1992, 28 fishes representing 7 species were counted on the diffuser transect; in 1993, 34 fishes representing 11 species were counted. Fish abundance and diversity for both these years were comparable to 1986 values (Table 3). In 1987 and 1988, few fishes were seen in the area and none on the transect (Russo 1992).

As in 1992, corals were seen growing on the concrete cover of the outfall diffuser (10 to 15 cm diameter) and on the riser ports (8 to 10 cm diameter) during the 1993 survey (Figures 6 and 7). Cover ranged from 1 to 2% of the substratum along a 6-m-wide strip on the diffuser. The most dominant species of corals were *Pocillopora meandrina*, *Porites lobata*, and *Montipora verrucosa*. In 1986, the year the outfall extension was completed and put into service, no corals were seen growing on the diffuser or in its vicinity. Other macroinvertebrates recorded in 1993 were four *E. diadema*, one *Culcita* sp., and one sea cucumber (*Holothuria atra*).

Station W-4

Station W-4 was not surveyed in 1993. The permanent transects that were part of the 1992 study were covered or moved by Hurricane Iniki, and the area was found to be very different in sediment composition and type when compared with a year earlier. The substratum is now covered with medium to fine sands and some coral rubble (Figures 8 and 9). No invertebrates or fishes were seen during reconnaissance dives.

A request from the City and County of Honolulu's Department of Public Works (letter WPW 93-823, 06/30/93, p. 3) to DLNR was made to monitor another station (WW), which is inshore of the diffuser, 0.8 km offshore adjacent to the outfall pipe, at a depth of 8 m. Beginning in 1994 this station will be monitored instead of Station W-4 because it is an area of abundant coral and fishes. At this station any inshore movement of sewage effluent may be indicated by changes in coral cover and fish diversity and abundance from year to year.

DISCUSSION

Off the Waianae coast, coral cover is low (1 to 2% of bottom area) and is dominated by two coral species, *Pocillopora meandrina* and *Porites lobata* (Reed et al. 1977). This dominance existed long before the Waianae outfall pipeline was extended. In 1986, the old outfall pipe, which discharged wastes into water <20 m deep, was modified and extended to discharge into the 33-m isobath approximately 1.8 km offshore.

On the ship *Mahi* at Station W2, abundance and diversity of fishes remained high. This station has been monitored since 1986 for both fishes and corals, and no decline in fish stocks or coral cover has been seen over the years. There were no significant differences over the years for either community indicator.

At Station W-3 fishes were moderately abundant and corals were beginning to colonize the area not only near the diffuser but also on the diffuser riser ports themselves. The surrounding sediments were clean and white. In 1986, 1987, and 1988, corals were not seen at this station. In 1992 and 1993, coral heads (approximately 10 to 15 cm diameter) of *Pocillopora meandrina* and *Porites lobata* were becoming established.

Station W-4 was not monitored because of major shifts in sediment by Hurricane Iniki, which removed the permanent transects originally placed there. A request for a change in station location from W-4 to WW, an inshore location, was made to dlnr. An inshore station can be monitored for outfall effects on fish and coral resulting from inshore movement of effluent. Very little information has been (or will be) gleaned from Station W-4 because of the paucity of coral and fishes at this station. It is more important to monitor any inshore movement of outfall discharge.

Large shifts in surrounding sediment also occurred at Stations W-2 and W-3; however, the fish, coral, and macroinvertebrates on the artificial structures at these stations were not seriously affected. Most coral heads were left intact after the storm.

In 1993, there was no observable indication that the Waianae Ocean Outfall effluent was adversely affecting the fish, coral, or other macroinvertebrates at selected stations in the vicinity of the discharge. Since studies before 1986 were not conducted at the same stations but in an area closer to shore (depth of 8 m), no comparison can be made. However, the dominant fishes and coral species seen in 1992 and 1993 were essentially the same as those seen in earlier discharge years and before the outfall pipeline was modified (Reed et al. 1977). Sediments were clean; horizontal visibility was good (15 to 22 m); and fish abundance, diversity, and species composition in the outfall area did not vary greatly from year to year. Numbers and species of fishes seen in the late 1970s were similar to those seen from 1986 through 1993. When compared to extensive surveys done by Hobson (1984), fish species richness, species composition, and abundance were found to be similar to those in typical Hawaiian subtidal biotopes. Along with many coral heads, fishes normally intolerant

of moderate sewage pollution (e.g., *Dascyllus albisella* [‘o(̄,a)lo‘ilo‘i] and *Chaetodon multicinctus* [ko(̄,i)ko(̄,a)kapu]) were seen at Station W-2. Coral growth and the ship structure itself may be attracting large numbers of fish. At the diffuser, corals were growing on the diffuser ports and seemed to be thriving where none were seen from 1986 to 1988. This study showed that there were no significant deleterious effects on the fish and coral communities at the stations surveyed over the years of study.

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TABLE 1. Fish Abundance (no./180 m²) at Station W-2, Waianae Ocean Outfall Survey, O‘ahu, Hawai‘i, for 1988, 1991, 1992, and 1993

Taxon	1988	1991	1992	1993
CHAETODONTIDAE				
<i>Chaetodon miliaris</i>	21	18	13	20
<i>C. multicinctus</i>	—	—	1	2
<i>C. kleini</i>	6	2	2	2
<i>C. ornatissimus</i>	2	—	3	—
<i>C. lunula</i>	—	—	—	1
<i>Forcipiger flavissimu</i>	2	1	—	1
POMACANTHIDAE				
<i>Holacanthus arcuatus</i>	—	—	—	1
<i>Centropyge potteri</i>	—	—	—	2
ACANTHURIDAE				
<i>Acanthurus olivaceus</i>	2	—	2	11
<i>Naso lituratus</i>	2	1	—	1
<i>Naso hexacanthus</i>	3	2	1	3
<i>Zanclus cornutus</i>	2	—	1	1
<i>Ctenochaetus strigosu</i>	11	4	6	3
<i>Zebrasoma flavescens</i>	9	—	1	12
<i>A. thompsoni</i>	9	—	1	—
<i>A. nigroris</i>	2	3	4	4
POMACENTRIDAE				
<i>Dascyllus albisella</i>	5	25	21	13
<i>Chromis agilis</i>	—	—	—	1
<i>C. hanui</i>	2	—	1	6
LABRIDAE				
<i>Thalassoma duperrey</i>	9	6	12	4
<i>Labroides phthirophagus</i>	1	1	1	—
<i>Thalassoma ballieui</i>	—	—	—	1
BALISTIDAE				
<i>Sufflamen bursa</i>	4	1	2	3
<i>Rhinecanthus rectangulus</i>	1	1	—	1
<i>Melichthys vidua</i>	3	—	2	2
<i>Melichthys</i> sp.	—	—	—	1
MULLIDAE				
<i>Mulloidichthys vanicolensis</i>	5	—	—	11
<i>Parupeneus multifasciatus</i>	1	2	2	1
<i>P. porphyreus</i>	1	1	3	8
LUTJANIDAE				
<i>Lutjanus kasmira</i>	30	50	33	18
MONACANTHIDAE				
<i>Pervagor spilosoma</i>	6	1	4	—
TETRADONTIDAE				
<i>Canthigaster jactator</i>	—	—	1	—
<i>Arothron hispidus</i>	—	1	—	1
SCARIDAE				
<i>Scarus dubius</i>	—	—	1	—
CIRRHITIDAE				
<i>Paracirrhites forsteri</i>	1	—	2	1
LETHRINIDAE				
<i>Monotaxis grandoculis</i>	—	—	—	2

Total No. of Individuals	140	120	120	138
Total No. of Species	25	17	24	30

TABLE 2. Total Coral Cover for Selected Quadrats at Station W-2, Waianae Ocean Outfall Survey, O‘ahu, Hawai‘i, for 1991, 1992, and 1993

		1991			1992			1993	
Quadrat		Area (cm ²)	%		Area (cm ²)	%		Area (cm ²)	%
AAA1		1 290	17.2		1 470	19.6		1 488	19.8
AAA3		2 985	39.8		2 880	38.4		3 500	46.6
AAB1		2 790	30.5		3 090	41.2		2 668	34.5
AAB2		2 235	29.8		2 550	34.0		2 100	28.0
AAB3		2 505	33.4		2 310	30.8		2 479	33.0
AAB4		4 770	63.6		3 990	53.2		4 450	59.3
AAC1		3 060	40.8		3 890	51.9		3 835	51.0
AAC2		2 205	29.4		2 130	28.4		2 215	29.5
AAC3		3 712	49.5		3 630	48.4		3 655	48.7
AAC4		2 730	36.4		3 200	42.7		3 210	42.8

NOTE: Total quadrat area = 7 500 cm²; see Figure 3 for quadrat locations.

TABLE 3. Fish Abundance (no./transect) at Station W-3, Waianae Ocean Outfall Survey, O‘ahu, Hawai‘i, for 1986, 1992, and 1993

Taxon	1986	1992	1993
ACANTHURIDAE			
<i>Acanthurus nigrofuscus</i>	6	10	2
<i>Acanthurus</i> sp.	—	5	2
<i>A. olivaceus</i>	3	4	5
BALISTIDAE			
<i>Sufflamen bursa</i>	5	3	4
<i>Rhinecanthus rectangulus</i>	2	1	1
<i>Melichthys vidua</i>	—	—	8
<i>M. niger</i>	—	—	2
CHAETODONTIDAE			
<i>Heniochus diphreutes</i>	—	—	2
<i>Forcipiger flavissimus</i>	—	—	1
MULLIDAE			
<i>Parupeneus porphyreus</i>	3	2	5
MONACANTHIDAE			
<i>Pervagor spilosoma</i>	5	3	—
LABRIDAE			
<i>Bodianus bilunulatus</i>	—	—	2
Total No. of Individuals	24	28	34
Total No. of Species	6	7	11