A SURVEY OF SELECTED CORAL AND FISH ASSEMBLAGES NEAR THE WAIANAE OCEAN OUTFALL, O‘AHU, HAWAI‘I, 1994

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Project Report PR-95-04

October 1994

PREPARED FOR

Department of Wastewater Management
City and County of Honolulu

Project Report
for
“The Assessment of the Impact of Ocean Sewer Outfalls
on the Marine Environment off Oahu, Hawaii”

Project No.: C59390

Project Period: 21 February 1990–31 December 1994

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ABSTRACT

In 1994, coral growth and fish abundance were monitored at stations located at and in the vicinity of the Waianae Ocean Outfall. This report summarizes the results of that survey and comparatively analyzes the data with data collected in previous sampling years. From 1986 to 1994, no significant differences were seen in the species composition or relative abundances of fish populations at Station W-2 (the sunken ship *Mahi*), which is located 1.2 km south of the diffuser. However, from 1986 to 1994 fish abundance and species richness increased at Station W-3, which is located at the diffuser. At Station WW, which is located 1 km from shore, fish were abundant near and on the armor rock covering the pipeline. Fish species at all stations were essentially the same as those seen in similar natural biotopes around Hawaii. As for coral growth, no significant differences were seen in total mean coral cover at selected quadrats from 1993 to 1994 or for previous years at Station W-2. At Station W-3, corals were seen growing on the diffuser pipe and on the riser discharge ports. In 1986, when the diffuser began operation at a discharge rate of 1.5 mgd, no corals were seen at this location. At inshore station WW corals seen off the pipeline were sparsely distributed, but on the armor rock over the pipeline both corals and fishes were numerous and thriving. Station WW, a new station set up in 1994, replaces Station W-4, which was located near the diffuser in the artificial fish haven. Station W-4 was not surveyed because in 1992 Hurricane Iniki covered the bottom with coarse sand. The water was clear (10- to 16-m horizontal visibility) at all stations surveyed, and the surrounding 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 (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 annually after the first year of discharge and benthic organisms be monitored photographically annually.

The Waianae Wastewater Treatment Plant (WWTP) is a primary treatment system that is scheduled to be upgraded to a secondary treatment system in 1996. At present the plant discharges 2.9 million gallons per day (0.13 m^3/s) of mainly domestic wastewater through an outfall 6,000 feet (1.8 km) offshore at a diffuser depth of approximately 110 feet (33 m). The diffuser is 531 feet (161.8 m) long and discharges at approximately 1.5 feet (0.5 m) above the seafloor through vertical risers.

On May 18, 1994, researchers from the University of Hawai‘i Water Resources Research Center and oceanographic personnel from the City and County of Honolulu Department of Wastewater Management collaborated in a scuba survey of the marine community near the Waianae Ocean Outfall. This reports summarizes the results of that survey and comparatively analyzes the 1994 data with data collected in previous years.

MATERIALS AND METHODS

Specific locations of the three sampling stations are provided in Figure 1. General information about the stations and their locations are given below.

Station W-2 is located 1.2 km south of the zone of initial dilution (ZID) on the deck of the sunken ship *Mahi* a depth of approximately 30 m. The area is one of the prime sites to which local 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 at a depth of approximately 30 m. The 1.5-m-diameter diffuser pipe 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 WW is located 1 km offshore on the effluent pipeline at a depth of approximately 8 m. At this new permanent station two transects—one approximately 20 m west of the pipeline (Transect Alpha) and the other on the pipeline (Transect Beta)—were set up. The outfall pipe is covered with tremie concrete and surrounded by large armor rock boulders. Transect Alpha lies on flat limestone substratum and Transect Beta on the armor rock covering the pipeline. Both transects are approximately 20 m long and run perpendicular to shore. With authorization from the Hawaii Department of Land and Natural Resources (DLNR), Station WW became a permanent station in 1994; it was established to monitor, temporally, any inshore movement of effluent discharged from the outfall. Transect Alpha was monitored in 1990 and 1991, although its monitoring was not then a requirement of DLNR. It was not monitored in 1992 or 1993 because of destruction of transects by Hurricane Iniki in September 1992. A new Transect Alpha was established in 1994.

There are no control stations in this study because the stations selected are all located at different depths and differ in bottom type and relief. At the chosen stations, relief is provided by artificial structures (i.e., the diffuser, sunken ship, and armor rock). Because of the uniqueness of each station, comparisons cannot be made among stations for coral and fish abundance and species richness. Only year-to-year comparisons of survey data obtained at the same station can be made.

Normally at the diffuser isobath (33 m) and near the hull of the sunken ship *Mahi* (depth of 33 m) off the Waianae coast, the bottom is mostly sand with some rubble. Usually no coral are present, and few fishes reside at this depth. However, artificial reefs in the area can attract fishes and provide substrata for coral growth. At Stations W-2 and W-3, artificial structures (a sunken ship and the outfall structure) provide habitats for fish as well as surfaces and relief for coral settlement, colonization, and growth. At Station WW (depth of 8 m) armor rock covering the pipeline provides relief in areas where normally flat limestone with 1% to 2% coral cover exists.

At all stations fish counts were made along permanent transects by divers equipped with scuba (Brock 1982). Fishes were counted along the transect as the diver swam up line looking 3 m to the right and then down line looking 3 m to the right. At Station W-2 divers counted fishes along a permanent transect, 30 m long ∞ 6 m wide (Figure 2), down the centerline of the ship's deck. At Station W-3 fish counts were made along a transect located at the terminal 30 m of the diffuser (Figure 3). At Station WW fishes were counted along the two transects (20 m long ∞ 9 m wide each) (Figure 4).

Fish species composition at all stations was compared with recent 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.

A Bray–Curtis index was also used to measure dissimilarity of fish species composition. For Station W-2 the 1994 fish community composition, abundance, and number of species were compared with survey results from 1991, 1992, and 1993. For Station W-3 comparisons of fish presence or absence (Cochran's Q-test) and dissimilarity were made for 1992 through 1994. In 1991 there was some fish activity at Station W-3, but no fish were seen swimming on the transect. For Station WW comparisons of fish species composition were made for 1990, 1991, and 1994. Since errors can occur because of differences in technique and capability among observers, the same diver–observer (the author) performs the fish counts annually.

Estimates of coral cover on selected permanent quadrats (Table 1) were made using bottom photography and the subsequent projection of photos on a grid. Coral cover was estimated by total grid cover relative to the total area of the quadrat. For all stations the presence of all macroinvertebrates seen were recorded. Coral cover between 1993 and 1994 was compared (Station W-2) using a paired t-test to determine if significant differences in total coral cover exist. The use of inferential statistical analysis may not be valid when comparing the same location over time because the assumption of 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. This 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 1994 (total = 196). Twenty-five species were represented. Fish abundance, by species, for 1991 through 1994 is shown in Table 2. Station W-2 was monitored in 1986, 1988, and 1990 through 1994, but not in 1987 and 1989. Abundance in 1994 was the highest since 1986, when the discharge rate was only 1.5 mgd (Figure 5); and species richness decreased in 1991, increased from 1991 to 1993, and decreased slightly in 1994 (Figure 6). The bluelined snapper or ta‘ape (*Lutjanus kasmira*) was moderately abundant in all years surveyed. Prior to 1988 large numbers of both *L. kasmira* and the fantail filefish or ‘O(o,¯)‘ili ‘uwO(i,ˉ)‘uwO(i,ˉ) (*Pervagor spilosoma*) were present (e.g., in 1986, together they represented more than 50% of the total fish abundance). In 1993 no filefish were seen and *L. kasmira* represented only 13.4% of the total abundance. In 1994 *L. kasmira* represented 31% of the total abundance and filefishes were still absent. Surgeonfishes (pualu), probably *Acanthurus blochii* (or *A. nigoris*), were abundant in 1994. The identification of this fish, listed as *Acanthurus* sp. in Table 2, is questionable since most specimens were juveniles and, although they had a white ring around their tail, several surgeonfishes can have this pattern (Hoover 1993).

Other fishes seen near the *Mahi* but not on the transects were two eagle rays (genus *Aetobatus*), a moray eel (*Gymnothorax meleagris)*, several jacks or ulua (*Caranx* sp.), and a school of weke (*Mulloidichthys flavolineatus)*.

There were no significant differences in presence or absence of species from 1991 to 1994 (Q-test, $p > 0.05$). Similarity among years in species composition was high (similarity index = 0.66 to 0.73). Any similarity index over 0.5 is considered to be significant (Green 1979). Fish species composition among years earlier than 1991 also did not differ (Russo 1992, 1993).

No significant differences in mean coral cover at selected coral quadrats (see Table 1) were found between 1993 and 1994 ($p > 0.05$, Table 1). Coral cover at selected quadrats have been compared with data from subsequent years since 1991 (Russo 1993), and no significant changes in mean coral cover between the year of survey and the subsequent year have been found. When 1991 and 1994 data are compared, a slight increase in total mean coral cover is shown, but it is not significant statistically ($p = 0.065$). At some quadrats coral cover increased and at others it decreased over the years of study. Coral cover is high on the deck of the *Mahi*; the deck platform is an ideal place for the settlement and subsequent colonization of corals (Figures 7 and 8). In 1994 coral cover ranged from 13.2% to 62.2% for 10 selected quadrats. In 1993 cover ranged from 19.8% to 59.3% for the same quadrat locations. Dominant coral species recorded were *Pocillopora meandrina* (16% to 57%) and *Porites compressa* (1% to 6%). Other genera of corals seen were *Monitpora* and *Pavona,* but these were rare and small (<5 to 8 cm in diameter).

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

Station W-3

On the diffuser transect at Station W-3, a total of 53 fishes representing 14 species were counted in 1994, an increase over the 34 fishes representing 11 species in 1993 (Table 3), and the 24 fishes representing 6 species in 1986 (Russo 1992). In 1988 and 1991 no fishes were seen on the transect, but they were seen swimming in the area. In 1987 and 1989 this station was not monitored. Figures 9 and 10 show fish abundance and species richness for 1986, 1990, and 1992 through 1994. Both fish abundance and species richness increased from 1986 to 1994.

Fish species composition in 1994 was significantly different ($p < 0.05$; Q-test) from that in 1992. The Bray–Curtis dissimilarity index was 0.26. Species composition in 1993 was fairly similar (similarity index = 0.50) to that of 1994. There were twice as many species in 1994 as in 1992. Butterfly fishes were not seen in 1992 but were common in 1994. The fantail filefish or ‘O(o,¯)‘ili ‘uwO(i,ˉ)‘uwO(i,ˉ) (*Pervagor spilosoma*) was seen in 1992 but was absent in 1994. Also, large numbers of the juvenile manybar goatfish or moano (*Parupeneus multifasciatus*) were seen in 1994, whereas in 1992 they were fairly rare. In 1993 some butterfly fishes, along with relatively large numbers of balistids (triggerfishes), were seen.

As in 1993, corals of the genus *Pocillopora* (10 to 15 cm in diameter) were seen growing on the concrete cover of the outfall and on the riser ports (8 to 10 cm in diameter) during the 1994 survey (Figures 11 and 12). Cover, as in 1993, still 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 was completed and in service below full discharge capacity (1.5 mgd), no corals were seen growing on the diffuser or in its vicinity. Only after 1991 were corals seen colonizing the diffuser substratum. In 1991 the sewage discharge rate was approximately 2 mgd; it increased to 2.9 mgd in 1994.

Other macroinvertebrates recorded in 1994 were five long-spined black sea urchins (*Echinothrix diadema*), two black sea urchins (*Tripneustes gratilla*), one seastar (*Culcita* sp.), and one sea cucumber (*Holothuria atra*).

Station WW

There was a steady increase in fish abundance and species richness over selected years (1990, 1991, and 1994) at Transect Alpha of Station WW (Figures 13 and 14). Fishes were relatively abundant at this station in 1994, especially at Transect Beta on the pipeline (Table 4). For the two transects combined, 541 fishes representing 23 species were counted. Twenty-six times more fish individuals and almost 2.5 times more species were recorded at Transect Beta (on the pipeline) than at Transect Alpha (Figures 13 and 14). The location of

Transect Alpha is the same as that of the transect set up in 1990 to monitor inshore movement of effluent. Station WW was monitored for scientific interest and was not authorized by DLNR as a permanent sampling station until 1994. The station was not monitored in 1992 or 1993 because of the effects of Hurricane Iniki which changed the substratum characteristics and destroyed the permanent transects placed in 1990. New transects were set up at Station WW in 1994.

Corals were seen colonizing on the armor rock and a 4-inch cable that was discarded or moved close to Transect Alpha during Hurricane Iniki in 1992. Corals were sparsely represented in the area (less than 2% coverage) in 1994. Marine seaweeds (genera *Dictyota*, *Turbinaria,* and *Dictyopteris*) were abundant, growing in clumps on the flat limestone bottom at Transect Alpha. At Transect Beta the long-spined black sea urchin *Echinothrix diadema* (nine per transect) and the black sea urchin *Tripneustes gratilla* (six per transect) were abundant.

DISCUSSION

Off the Waianae coast, coral cover is normally low (1% to 2% of bottom area) and is dominated by the two coral species, *Pocillopora meandrina* and *Porites lobata* (Reed et al. 1977). This dominance existed long before the modified Waianae outfall pipeline began discharge in January 1986. The old outfall pipe, which discharged effluent into water less than 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 W-2, abundance and diversity of fishes remained high over all the survey years. No significant decrease in fish stocks or coral cover has occurred at this station, which has been monitored since 1986; nor has there been any significant difference in fish community structure or diversity over the years.

At Station W-3, fishes were moderately abundant and corals were beginning to colonize the areas near the diffuser and 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 1993 and 1994 coral heads (approximately 10 to 15 cm in diameter) of *Pocillopora meandrina* and *Porites lobata* were becoming established (Russo 1993).

Bottom relief is of great importance in structuring fish communities and in determining the number of fishes living in an area. This is evidenced by the much greater abundance and diversity of fishes at Station WW (Transect Beta), which has an appreciable structure of armor rock and pipeline and is only 20 m away from Transect Alpha, which lies on flat bottom. Large schools of the bluelined snapper or ta‘ape (*Lutjanus kasmira*), the convict tang or manini (*Acanthurus triostegus*), the black damselfish or ‘O(a,¯)lo‘ilo‘i (*Dascyllus albisella*), and other common fish species were seen swimming over the rocks at Transect Beta. *L. kasmira* was introduced to Hawaii from the Marquesas Islands in 1958 (Randall 1987). Since then it has dramatically increased in abundance and has spread throughout the entire Hawaiian archipelago. Local fishermen suspect that *L. kasmira* may eat the juveniles of locally important fish species since 40% of its diet is fish (Tabata 1981). However, there is little conclusive evidence to support this. Oda and Parrish (1981) found some evidence of holocentrid fish (genus *Myripristis* [menpachi]) remains in the guts of *L. kasmira* but not in sufficient quantity to justify its classification as a major fish predator of locally important fishes. *L. kasmira* is an active, generalized carnivore that feeds mainly on crabs and juvenile fishes (Oda and Parrish 1981). However, there seems to be no significant overlap in diet to warrant a conclusion of intense competition for food with locally important fish species such as *Parupeneus porphyreus* (kumu), or *Mulloidichthys flavolineatus* (weke). The ecological niche of *L. kasmira* is still not completely understood, and more information is needed to conclusively determine why it has increased greatly in abundance since 1958 while, coincidentally, other fish species important to the local fishermen have declined. One other important factor, the possibility of overfishing, must still be addressed before cause-and-effect relationships can be made about the impact of *L. kasmira* on Hawaiian fish community dynamics (Grigg 1994).

The armor rock surrounding the outfall pipe provides ample habitat space for hiding and mating, ample surface for the colonization of food sources, and a reference point above the substratum for aggregation and maintenance of schools. Artificial structures placed in an area normally devoid of bottom relief can attract large numbers of fish and provide surfaces for coral and other sessile organism attachment.

In 1975, total fish abundance at a transect located approximately 1 km offshore from the Waianae WWTP near the pipeline was 18 individuals representing 6 species (number adjusted to a 30 m ∞ 6 m transect area) (Reed et al. 1977). At Transect Alpha of Station WW, which is close (<50 m) to the above-mentioned transect, 20 individual fishes representing 8 species were recorded in 1994. Aggregations of fish species comparable to those found in similar biotopes around the Hawaiian islands were seen over the armor rock (Transect Beta) at Station WW during the 1994 survey. For example, Hobson’s (1984) record of aggregations over “boulder” regions includes schools of yellowstripe goatfish or weke (*Mulloidichthys flavolineatus*), surgeonfish or na‘ena‘e (*Acanthurus olivaceus)*, and menpachi or ‘o(¯,u)‘o(¯,u) (*Myripristis berndti*). These same species and many others were photographed over the armor rock at Station WW in 1994 (Figures 15 and 16).

In 1994 there was no observable indication that the Wai‘anae sewer outfall effluent was adversely affecting the fish, coral, or macroinvertebrates at selected stations in the vicinity of the discharge. Since studies before 1986 were not conducted at the same deeper stations but in an area closer to shore (depth of 8 m), a before-and-after-discharge comparison at Stations W-2 and W-3 cannot be made. However, generally, the dominant fishes and coral species seen from 1986 through 1994 were essentially the same as those seen in earlier discharge years and before the outfall was modified (Reed et al. 1977). Sediments at all stations were clean, and horizontal visibility was good (15 to 18 m). The three parameters of fish abundance, diversity, and species composition at the sunken ship *Mahi* 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 1994. When compared with extensive surveys done by Hobson (1984), fish species richness, species composition, and abundance at the Wai‘anae stations surveyed were similar to those found in other typical Hawaiian subtidal biotopes. Fishes normally intolerant of moderate sewage pollution (e.g., *Dascyllus albisella* [‘O(a,¯)lo‘ilo‘i] and *Chaetodon multicinctus* [kO(i,ˉ)kO(a,¯)kapu]), along with many coral heads, were seen at Station W-2. The growth of coral and the ship structure itself may be attracting large numbers of fish. At Station W-3, corals were growing on the diffuser ports and seemed to be thriving where none were seen prior to 1991. Fishes associated with corals became more abundant after 1991. Coral coverage was low, a condition typical of shallow, flat, low-relief bottoms in this area (Reed et al. 1977). However, corals were thriving on the armor rock at the inshore pipeline probably because of artificial topographical relief. This study showed that, since the beginning of biomonitoring in 1986, no significant deleterious effects have occurred on the fish and coral communities at the stations surveyed.

REFERENCES CITED

Brock, R.E. 1982. A critique of visual census methods for assessing coral reef populations. *Bull. Mar. Sci.* 32:24–35.

Daniel, W.W. 1987. *Biostatistics: A foundation for analysis in the health sciences.* New York: Wiley and Sons.

Grigg, R.W. 1994. Effects of sewage discharge, fishing pressure and habitat complexity on coral reef ecosystems and reef fishes in Hawaii. *Mar. Ecol. Prog. Ser.* 103:25–34.

Green, R.H. 1979. *Sampling design and statistical methods for environmental biologists*. New York: Wiley-Interscience. 314 pp.

Hoover, J.P. 1993. *Hawaii's fishes: A guide for snorkelers, divers, and aquarists.* Honolulu: Mutual Publ. 178 pp.

Hobson, E.S. 1984. The structure of reef fish communities in the Hawaiian Archipelago. In *Proc. N.W. Hawaiian Island Symp.,* MR-84-01, 57–70; University of Hawaii Sea Grant College Program, Honolulu.

Oda, D.K., and J.D. Parrish. 1981. Ecology of commercial snappers and groupers introduced to Hawaiian waters. *Proc. 4th Int. Coral Reef Symp.,* vol. I, Manila, Philippines.

Randall, J. 1987. Introductions of marine fishes to the Hawaiian islands. *Bull. Mar. Sci.* 4(2):490–502.

Reed, S.A., E.A. Kay, and A.R. Russo. 1977. Survey of benthic coral reef ecosystems, fish populations, and micromollusks in the vicinity of the Waianae sewage ocean outfall, O‘ahu, Hawai‘i—summer 1975. Tech. Rep. 104, Water Resources Research Center, University of Hawaii at Manoa, Honolulu. 36 pp.

Russo, A.R. 1992 . A survey of selected coral and fish assemblages near the Waianae Ocean Outfall, 1992. Spec. Rep. 10.19:92, Water Resources Research Center, University of Hawaii, Manoa, Honolulu. 8 pp.

Russo, A.R. 1993. A survey of selected coral and fish assemblages near the Waianae Ocean Outfall, O‘ahu, Hawai‘i, 1993. Proj. Rep. PR-94-10, Water Resources Research Center, University of Hawai‘i, Mo(¯,a)noa, Honolulu. 14 pp.

Russo, A., and L.S. Lau. 1986. Benthic and fish survey in the vicinity of the Waianae sewer outfall. Unpubl. rep. to City and County of Honolulu. Water Resources Research Center, University of Hawaii at Manoa, Honolulu.

Tabata, R. 1981. Ta‘ape: What needs to be done? Workshop Proc. Paper 46, University of Hawaii Sea Grant College Program, Honolulu. 31 pp.

TABLE 1. Total Coral Cover (%) for Selected Quadrats at Station W-2, Waianae Ocean Outfall, Oʻahu, Hawaiʻi, for 1991 Through 1994

	Coral Cover (%)			
Quadrat	1991	1992	1993	1994
AAA1	17.2	19.6	19.8	26.0
AAA3	39.8	38.4	46.6	46.7
AAB1	30.5	41.2	34.5	28.0
AAB2	29.8	34.0	28.0	13.2
AAB3	33.4	30.8	33.0	39.5
AAB4	63.6	53.2	59.3	57.7
AAC1	40.8	51.9	51.2	35.5
AAC2	29.4	28.4	29.5	49.8
AAC3	49.5	48.4	48.7	62.2
AAC4	36.4	42.7	42.8	54.9

TABLE 2. Fish Abundance (no./transect) at Station W-2, Waianae Ocean Outfall, O‘ahu, Hawai‘i, for 1991 Through 1994

Taxon	1991	1992	1993	1994
FAMILY CHAETODONTIDAE				
Chaetodon miliaris	18	13	20	20
Chaetodon multicinctus	0	1	2	1
Chaetodon kleinii	2	2	2	9
Chaetodon ornatissimus	0	3	0	0
Chaetodon lunula	0	0	1	0
Forcipiger flavissimus	1	0	1	1
FAMILY POMACANTHIDAE				
Holacanthus arcuatus	0	0	1	0
Centropyge potteri	0	0	2	0
FAMILY ACANTHURIDAE				
Acanthurus olivaceus	0	2	11	7
Naso lituratus	1	0	1	0
Naso hexacanthus	2	1	3	12
Zanclus cornutus	0	1	1	1
Ctenochaetus strigosus	4	6	3	8
Zebrasoma flavescens	0	1	12	4
Acanthurus thompsoni	0	1	0	0
Acanthurus nigroris	3	4	4	5
Acanthurus sp.	0	0	0	25
Acanthurus nigrofuscus	0	0	0	3
FAMILY POMACENTRIDAE				
Dascyllus albisella	25	21	13	11
Chromis agilis	0	0	1	4
Chromis hanui	0	1	6	8
FAMILY LABRIDAE				
Thalassoma duperrey	6	12	4	5
Labroides phthirophagus	1	1	0	0
Thalassoma ballieui	0	0	1	0
FAMILY BALISTIDAE				
Sufflamen bursa	1	2	3	4
Rhinecanthus rectangulus	1	0	1	0
Melichthys vidua	0	2	2	1
Melichthys sp.	0	0	1	0
FAMILY MULLIDAE				
Mulloidichthys flavolineatus	0	0	11	0
Parupeneus multifasciatus	2	2	1	2
Parupeneus porphyreus	1	3	8	1
FAMILY LUTJANIDAE				
Lutjanus kasmira	50	33	18	60
FAMILY MONACANTHIDAE				
Pervagor spilosoma	1	4	0	0

FAMILY DIODONTIDAE				
Diodon hystrix	0	0	0	1

TABLE 2—*Continued*

Taxon	1991	1992	1993	1994
FAMILY TETRADONTIDAE				
Canthigastor jactator	0	1	0	0
Arothron hispidus	1	0	1	1
FAMILY SCARIDAE				
Scarus dubius	0	1	0	0
FAMILY CIRRHITIDAE				
Paracirrhitus forsteri	0	2	1	1
FAMILY LETHRINIDAE				
Monotaxis grandoculis	0	0	2	0
FAMILY AULOSTOMIDAE				
Aulostomus chinensis	0	0	0	1
FAMILY MURAENIDAE				
Gymnothorax meleagris	1	0	0	0
Total No. of Individuals	121	120	138	196
Total No. of Species	18	24	30	25

NOTE: The single *Gymnothorax meleagris* reported for 1991 was not listed in previous reports.

TABLE 3. Fish Abundance (no./transect) at Station W-3, Waianae Ocean Outfall, O‘ahu, Hawai‘i, for 1992, 1993, and 1994

Taxon	1992	1993	1994
FAMILY ACANTHURIDAE			
Acanthurus nigrofuscus	10	2	0
Acanthurus sp.	5	2	1
Acanthurus olivaceous	4	5	7
Acanthurus nigroris	0	0	5
FAMILY BALISTIDAE			
Sufflamen bursa	3	4	2
Rhinecanthus rectangulus	1	1	0
Melichthys vidua	0	8	2
Melichthys niger	0	2	1
FAMILY CHAETODONTIDAE			
Heniochus diphreutes	0	2	0
Forcipiger flavissimus	0	1	1
Chaetodon miliaris	0	0	7
Chaetodon kleinii	0	0	3
FAMILY MULLIDAE			
Parupeneus multifasciatus	2	5	14
FAMILY MONACANTHIDAE			
Pervagor spilosoma	3	0	0
FAMILY LABRIDAE			
Bodianus bilunulatus	0	2	2
Coris gaimard	0	0	1
Thalassoma duperrey	0	0	2
FAMILY POMACENTRIDAE			
Chromis hanui	0	0	5
Total No. of Individuals	28	34	53
Total No. of Species	7	11	14

TABLE 4. Fish Abundance (no./transect) at Station WW, Waianae Ocean Outfall, Oʻahu, Hawaiʻi, for 1990, 1991, and 1994

Taxon	Alpha 1990	Alpha 1991	Alpha 1994	Beta 1994
FAMILY ACANTHURIDAE				
Acanthurus olivaceus	0	0	3	16
Acanthurus nigroris	1	1	0	10
Acanthurus triostegus	0	0	0	121
Ctenochaetus strigosus	0	0	0	33
FAMILY BALISTIDAE				
Sufflamen bursa	0	1	5	0
Melichthys vidua	0	0	2	0
Rhinecanthus rectangulus	0	0	1	0
FAMILY CHAETODONTIDAE				
Chaetodon miliaris	0	0	0	5
Forcipiger longirostris	0	0	0	2
FAMILY CIRRHITIDAE				
Paracirrhitus forsteri	0	0	0	2
FAMILY LABRIDAE				
Thalassoma duperrey	0	1	3	35
Bodianus bilunulatus	0	0	2	1
FAMILY LETHRINIDAE				
Monotaxis grandoculis	0	0	0	2
FAMILY LUTJANIDAE				
Lutjanus kasmira	0	0	0	200
FAMILY MONACANTHIDAE				
Pervagor spilosoma	3	1	0	0
FAMILY MULLIDAE				
Parupeneus multifasciatus	0	0	2	6
Parupeneus porphyreus	0	0	0	2
Mulloidichthys flavolineatus	0	0	0	5
FAMILY HOLOCENTRIDAE				
Myripristis berndti	0	0	0	12
FAMILY POMACENTRIDAE				
Dascyllus albisella	1	0	0	45
Chromis agilis	1	2	0	10
Chromis hanui	0	0	0	12
Chromis verator	0	0	0	2
Abudefduf sordidus	0	0	0	2
FAMILY TETRADONTIDAE				
Arothron hispidus	0	0	2	0

Total No. of Individuals		6	6		20	523
Total No. of Species		4	5		8	20