A SURVEY OF SELECTED CORAL AND FISH ASSEMBLAGES NEAR THE WAIANAE OCEAN OUTFALL, O‘AHU, HAWAI‘I, 1995

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ABSTRACT

In 1995, 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 1995, 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 outfall diffuser. However, from 1986 to 1995 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 and speciose on the armor rock covering the pipeline. The fish species seen in 1994 were present in 1995, along with the 13 new species recorded at this station. These species were essentially the same as those seen in similar natural biotopes around Hawaiʻi. As for coral growth, no significant differences were seen in total mean coral cover at selected quadrats from 1994 to 1995 at Station W-2. However, there was a significant increase (5.2%) in total mean coral cover at selected quadrats from 1991 to 1995. 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 corals were numerous and thriving. The inshore transect (Alpha), off the armor rock, was heavily covered (60% to 70%) with the alga *Dictyopteris plagiogramma*. This alga was sparse when seen at this location in 1994. The water was clear (10- to 15-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 permit 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 have secondary treatment system by 1 February 1996. At present the plant discharges 3.0 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 26–27 April and 2 and 7 June 1995, researchers from the University of Hawai‘i 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 1995 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* at 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 terminal 30 m of 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. Two transects—one approximately 20 m west of the pipeline (Transect Alpha) and the other on the pipeline (Transect Beta)—were set up at this station. 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.

In late April 1995, the CCH Oceanographic Team found the 2-inch transect wire at Transect Alpha to be damaged and large sections moved or altogether gone from the area. It is not certain whether this was due to natural causes (wave action) or other causes (vandalism, anchor dragging). The transect wire was replaced on 8 and 9 May 1995 by the CCH team.

There is no spatial control station in this study; 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 upline looking 3 m to the right and then downline 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 past surveys using Cochran's nonparametric Q-test for species presence or absence (Green 1979). The Q value is tested against the chi-square critical value for years minus one degree of freedom and p = 0.05. 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 among survey 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 1995 fish community composition, abundance, and number of species were compared with survey results from earlier years. For Station W-3 comparisons of fish presence or absence (Cochran's Q-test) and dissimilarity were made for 1992 through 1995. 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, 1994, and 1995. 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 1994 and 1995 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 data for 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.

A two-way analysis of variance (ANOVA) without replication (quadrat vs. year) was used to test for differences in coral cover over all the survey years (Sokal and Rohlf 1981).

RESULTS

Station W-2

Fishes were very abundant at Station W-2 in 1995 (total = 171). Thirty species were represented. Fish abundance, by species, for 1991 through 1995 is shown in Table 2. Station W-2 was monitored in 1986, 1988, and 1990 through 1995, but not in 1987 and 1989. Total fish abundance for 1995 was slightly lower than in 1990 and 1994 but was higher than in other years subsequent to 1988 (Figure 5). Fish species richness decreased in 1991, increased from 1991 to 1993, decreased slightly in 1994, and increased again in 1995 (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% 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 but less abundant in 1995. 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*), several jacks or ulua (*Caranx* sp.), and a school of weke (*Mulloidichthys flavolineatus)*. The pair of eagle rays was seen in each survey since 1992.

There were no significant differences in presence or absence of fish species from 1991 to 1995 (Q = 7.2, 4 df, p = 0.05). Similarity among years in species composition was high (similarity index = 0.67 to 0.77). Any similarity index over 0.5 is considered to be significant (Green 1979).

No significant differences in mean coral cover at selected quadrats (see Table 1) were found between 1994 and 1995 (t-test, p = 0.05, Table 1). Coral cover at selected quadrats have been compared with data from subsequent years since 1991 (Russo 1994), and no significant changes in mean coral cover between the year of survey and the subsequent year have been found. When data for all years were tested by two-way ANOVA, a significant difference in coral cover ($p < 0.05$) was found among years. Coral cover at selected quadrats was significantly higher in 1995 than in 1991. At some quadrats coral cover increased and at others it decreased over the years of study, but total mean cover has steadily increased (Figure 7). Coral cover was high on the deck of the *Mahi*; the deck platform is an ideal place for the settlement and subsequent colonization of corals (Figures 8 and 9). In 1994 coral cover ranged from 13.2% to 62.2% for 10 selected quadrats, whereas in 1995 cover ranged from 18.4% to 57.8% for the same quadrat locations. For both years, dominant coral species recorded were *Pocillopora meandrina* (16% to 57%) and *Porites compressa* (1% to 6%). Other coral genera 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 52 fishes representing 16 species were counted in 1995; whereas 53 fishes representing 14 species were counted in 1994 (Table 3), and 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 10 and 11 show fish abundance and species richness for 1986, 1990, and 1992 through 1995. Fish species richness increased from 1986 to 1995.

Fish species composition in 1995 was significantly different ($p < 0.05$; Q-test) from that in 1992. The Bray–Curtis dissimilarity index was 0.19. Species composition in 1995 was fairly similar to that in 1993 (SI = 0.61) and to that in 1994 (SI = 0.58). More than twice as many species were seen in 1995 than in 1992. Butterfly fishes were not seen in 1992 but were common in 1994 and 1995, especially the species *Chaetodon kleinii*. The fantail filefish or ‘O(o,¯)‘ili ‘uwO(i,¯)‘uwO(i,¯) (*Pervagor spilosoma*) was seen in 1992 but was absent in 1994 and 1995. Also, large numbers of the juvenile manybar goatfish or moano (*Parupeneus multifasciatus*) were seen in 1994 and 1995, 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 and 1994, 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 1995 survey (Figures 12 and 13). Cover, as in 1993 and 1994, 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 and to 3.0 mgd in 1995.

Other macroinvertebrates recorded in 1995 were six 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 over selected years (1990, 1991, 1994, and 1995) at Transect Alpha of Station WW (Figure 14). The number of fish species increased over the years but dropped slightly in 1995 (Figure 15). Fishes were relatively abundant at this station in 1995, especially at Transect Beta on the pipeline (Table 4). On Transect Beta, abundance of fish was lower in 1995 (297) than in 1994 (523). The decrease in numbers of individuals from 1994 to 1995 was due to a large drop in counts of the bluelined snapper *Lutjanus kasmira* and the convict tang *Acanthurus triostegus*. Species richness, however, was higher in 1995 than in 1994 (33 vs. 20 species). The species composition similarity based on presence/absence data was significantly different ($p < 0.001$) in 1995 because of the presence of 14 more species not seen in 1994. In 1995, for the two transects combined, 327 fishes representing 35 species were counted. Nearly ten times more fish individuals and over four times more species were recorded at Transect Beta (on the pipeline) than at Transect Alpha. Fishes appear to aggregate over artificial substrata (Figures 16 and 17).

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. Few corals were seen in the area (less than 1% coverage) in 1995. The marine seaweed *Dictyopteris plagiogramma* was very abundant, representing approximately 60% to 70% of the bottom cover at Transect Alpha. In 1994 this seaweed was much less abundant (less than 10% cover) and was present with other seaweeds (e.g., genera *Turbaria* and *Dictyota*). At Transect Beta the long-spined black sea urchin *Echinothrix diadema* (seven individuals) and the black sea urchin *Tripneustes gratilla* (four individuals) were abundant.

DISCUSSION

Off the Waianae coast, coral cover is normally 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 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, 1994, and 1995 coral heads (approximately 10 to 15 cm in diameter) of *Pocillopora meandrina* and *Porites lobata* were becoming established (Russo 1993, 1994).

At Station WW, many fishes were counted over the pipeline and armor rock (Transect Beta), whereas fewer were seen over the flat, algal-dominated limestone bottom (Transect Alpha). Over the survey years fish abundance and species richness increased at Transect Alpha. That bottom relief is of great importance in structuring fish communities and in determining the number of fishes living in the area is evidenced by the much greater abundance and diversity of fishes seen at Transect Beta, which has an appreciable structure of armor rock. Large schools of the bluelined snapper or ta‘ape (*Lutjanus kasmira*), the goldring surgeonfish or kole (*Ctenochaetus strigosus*), 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, 30 individual fishes representing 7 species were recorded in 1995. 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 and 1995 surveys. 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 16 and 17).

In 1995 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 1995 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 1995. When compared with extensive surveys done by Hobson

(1984), fish species richness, species composition, and abundance at the 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. At Station WW (the inshore station), fish populations were abundant and diverse, as well as representative of similar biotopes (Hobson 1984) found in Hawai‘i. 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.

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TABLE 1. Total Coral Cover for Selected Quadrats at Station W-2, Waianae Ocean Outfall, O‘ahu, Hawai‘i, for 1991 Through 1995

	Coral Cover (%)				
Quadrat	1991	1992	1993	1994	1995
AAA1	17.2	19.6	19.8	26.0	25.0
AAA3	39.8	38.4	46.6	46.7	48.8
AAB1	30.5	41.2	34.5	28.0	32.9
AAB2	29.8	34.0	28.0	13.2	18.4
AAB3	33.4	30.8	33.0	39.5	36.6
AAB4	63.6	53.2	59.3	57.7	55.1
AAC1	40.8	51.9	51.2	35.5	49.4
AAC2	29.4	28.4	29.5	49.8	42.7
AAC3	49.5	48.4	48.7	62.2	57.8
AAC4	36.4	42.7	42.8	54.9	55.3
Mean	37.0	38.9	39.3	41.4	42.2

TABLE 2. Fish Abundance (no./transect) at Station W-2, Waianae Ocean Outfall, O‘ahu, Hawai‘i, for 1991 Through 1995

Taxon	1991	1992	1993	1994	1995
FAMILY CHAETODONTIDAE					
Chaetodon miliaris	18	13	20	20	11
Chaetodon multicinctus	0	1	2	1	3
Chaetodon kleinii	2	2	2	9	7
Chaetodon ornatissimus	0	3	0	0	0
Chaetodon lunula	0	0	1	0	0
Forcipiger flavissimus	1	0	1	1	4
FAMILY POMACANTHIDAE					
Holacanthus arcuatus	0	0	1	0	0
Centropyge potteri	0	0	2	0	1
FAMILY ACANTHURIDAE					
Acanthurus olivaceus	0	2	11	7	2
Naso lituratus	1	0	1	0	4
Naso hexacanthus	2	1	3	12	0
Zanclus cornutus	0	1	1	1	2
Ctenochaetus strigosus	4	6	3	8	9
Zebrasoma flavescens	0	1	12	4	6
Acanthurus thompsoni	0	1	0	0	0
Acanthurus nigroris	3	4	4	5	4
Acanthurus sp.	0	0	0	25	5
Acanthurus nigrofuscus	0	0	0	3	0
FAMILY POMACENTRIDAE					
Dascyllus albisella	25	21	13	11	40
Chromis agilis	0	0	1	4	4
Chromis hanui	0	1	6	8	8
FAMILY LABRIDAE					
Thalassoma duperrey	6	12	4	5	11
Labroides phthirophagus	1	1	0	0	1
Thalassoma ballieui	0	0	1	0	1
Gomphosus varius	0	0	0	0	2
FAMILY BALISTIDAE					
Sufflamen bursa	1	2	3	4	4
Rhinecanthus rectangulus	1	0	1	0	1
Melichthys vidua	0	2	2	1	1
Melichthys sp.	0	0	1	0	1
FAMILY MULLIDAE					
Mulloidichthys flavolineatus	0	0	11	0	0
Parupeneus multifasciatus	2	2	1	2	1
Parupeneus porphyreus	1	3	8	1	0
FAMILY LUTJANIDAE					
Lutjanus kasmira	50	33	18	60	32
FAMILY MONACANTHIDAE					

Pervagor spilosoma	1	4	0	0	0
FAMILY DIODONTIDAE					
Diodon hystrix	0	0	0	1	1

TABLE 2—*Continued*

Taxon	1991	1992	1993	1994	1995
FAMILY TETRADONTIDAE					
Canthigastor jactator	0	1	0	0	2
Arothron hispidus	1	0	1	1	1
FAMILY SCARIDAE					
Scarus dubius	0	1	0	0	0
FAMILY CIRRHITIDAE					
Paracirrhites forsteri	0	2	1	1	1
FAMILY LETHRINIDAE					
Monotaxis grandoculis	0	0	2	0	0
FAMILY AULOSTOMIDAE					
Aulostomus chinensis	0	0	0	1	0
FAMILY MURAENIDAE					
Gymnothorax meleagris	1	0	0	0	1
Total No. of Individuals	121	120	138	196	171
Total No. of Species	18	24	30	25	30

TABLE 3. Fish Abundance (no./transect) at Station W-3, Waianae Ocean Outfall, O‘ahu, Hawai‘i, for 1992 Through 1995

Taxon	1992	1993	1994	1995
FAMILY ACANTHURIDAE				
Acanthurus nigrofuscus	10	2	0	2
Acanthurus sp.	5	2	1	1
Acanthurus olivaceus	4	5	7	9
Acanthurus nigroris	0	0	5	0
Naso literatus	0	0	0	4
Zanclus cornutus	0	0	0	2
FAMILY BALISTIDAE				
Sufflamen bursa	3	4	2	3
Rhinecanthus rectangulus	1	1	0	0
Melichthys vidua	0	8	2	1
Melichthys niger	0	2	1	0
FAMILY CHAETODONTIDAE				
Heniochus diphreutes	0	2	0	4
Forcipiger flavissimus	0	1	1	0
Chaetodon miliaris	0	0	7	0
Chaetodon kleinii	0	0	3	10
Chaetodon multicinctus	0	0	0	3
Chaetodon lunula	0	0	0	1
FAMILY MULLIDAE				
Parupeneus multifasciatus	2	5	14	2
FAMILY MONACANTHIDAE				
Pervagor spilosoma	3	0	0	0
FAMILY LABRIDAE				
Bodianus bilunulatus	0	2	2	0
Coris gaimard	0	0	1	1
Thalassoma duperrey	0	0	2	2
FAMILY POMACENTRIDAE				
Chromis hanui	0	0	5	6
Chromis vanderbilti	0	0	0	1
Total No. of Individuals	28	34	53	52
Total No. of Species	7	11	14	16

TABLE 4. Fish Abundance (no./transect) at Station WW, Waianae Ocean Outfall, O‘ahu, Hawai‘i, for 1994 and 1995

Taxon	1994 Transect Alpha	1994 Transect Beta	1995 Transect Alpha	1995 Transect Beta
FAMILY ACANTHURIDAE				
Acanthurus olivaceus	3	16	0	8
Acanthurus blochii	0	121	0	3
Acanthurus nigroris	0	10	0	3
Acanthurus triostegus	0	0	0	3
Ctenochaetus strigosus	0	33	0	35
Zanclus cornutus	0	0	0	3
Zebrasoma flavescens	0	0	0	5
FAMILY BALISTIDAE				
Sufflamen bursa	5	0	5	0
Melichthys vidua	2	0	0	0
Rhinecanthus rectangulus	1	0	0	1
FAMILY CHAETODONTIDAE				
Chaetodon miliaris	0	5	0	8
Chaetodon multicinctus	0	0	0	6
Chaetodon fremblii	0	0	0	2
Forcipiger longirostris	0	2	0	2
FAMILY CIRRHITIDAE				
Paracirrhites forsteri	0	2	0	1
FAMILY LABRIDAE				
Thalassoma duperrey	3	35	6	8
Bodianus bilunulatus	2	1	0	2
Coris gaimard	0	0	0	1
Anampses chrysocephalus	0	0	0	2
FAMILY LETHRINIDAE				
Monotaxis grandoculis	0	2	0	0
FAMILY LUTJANIDAE				
Lutjanus kasmira	0	200	0	60
FAMILY MONACANTHIDAE				
Pervagor spilosoma	0	0	1	0
FAMILY MULLIDAE				
Parupeneus multifasciatus	2	6	10	6
Parupeneus porphyreus	0	2	0	8
Mulloidichthys flavolineatus	0	5	0	1
Mulloidichthys vanicolensis	0	0	0	6
FAMILY HOLOCENTRIDAE				
Myripristis berndti	0	12	0	9
Sargocentron sp.	0	0	0	12

TABLE 4—*Continued*

Taxon	1994 Transect Alpha	1994 Transect Beta	1995 Transect Alpha	1995 Transect Beta
FAMILY POMACENTRIDAE				
Dascyllus albisella	0	45	5	19
Chromis agilis	0	10	2	2
Chromis hanui	0	12	0	6
Chromis verator	0	2	0	2
Chromis vanderbilti	0	0	0	5
Abudefduf sordidus	0	2	0	1
Abudefduf abdominalis	0	0	0	65
FAMILY TETRAODONTIDAE				
Arothron hispidus	2	0	1	0
FAMILY SERRANIDAE				
Epinephelus quernus	0	0	0	1
FAMILY FISTULARIIDAE				
Fistularia commersonii	0	0	0	1
Total No. of Individuals	20	523	30	297
Total No. of Species	8	20	7	33