# A SURVEY OF SELECTED CORAL AND FISH ASSEMBLAGES NEAR THE WAIANAE OCEAN OUTFALL, OCTOBER 1991

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## ABSTRACT

Coral growth and fish abundance were monitored at two stations in the vicinity of the Waianae Wastewater Treatment Plant (WWWTP). One station, the sunken ship *Mahi*, was located 1.2 km (22–24 m deep) south of the outfall diffuser. The second station, located 0.5 km directly offshore of the WWWTP (depth, 8 m), was chosen to monitor possible effects of shoreward movement of sewage from the outfall diffuser on inshore coral and fish communities. Permanent quadrats were chosen at each station for photographic surveys of coral cover. Coral cover was comparable to that found in studies done in 1975. Fish counts made in 1990 and 1991 along set transects at each station were compared for temporal differences. No significant differences in fish species composition between these periods was found. At both stations, water-quality parameters showed no indication of reducing conditions and the sand sediments were clean and white. Corals, macroinvertebrates, algae, and fish populations will be monitored over five years and the results compared annually.

## INTRODUCTION

This report is part of the ongoing effort by the City and County of Honolulu (CCH) to monitor the marine environment in the vicinity of ocean sewer outfalls off O‘ahu, Hawai‘i.

On 20 October 1991, the author and the CCH oceanographic team completed a survey of selected stations near the Waianae ocean outfall. The Waianae Wastewater Treatment Plant (WWWTP) discharges approximately 2 mgd of primary effluent 1.8 km offshore at a depth of approximately 34 m. This survey was the second of five annual studies designed to monitor any possible effects of sewage effluent on corals and fishes inshore and down the coast from the outfall diffuser discharge.

## SURVEY STATIONS

The two coral and fish survey stations are shown in Figure 1. A description of each follows.

### Station W2

This station, located 1.2 km south of the zone of initial dilution (ZID) of the Waianae outfall diffuser, is the sunken ship *Mahi*, whose aft deck lies at a depth of 22 m. This deck was chosen as a control monitoring station because of the abundance of corals growing on the horizontal deck platform and the aggregations of fishes attracted to the artificial platform. The ship lies in an area normally devoid of bottom relief and hard substrata. Because of the many tourists taken there for scuba sightseeing, the wreck is also an important site for O‘ahu commercial dive shops.

### Station WW

This station is located 0.8 km directly offshore from the WWWTP and extends 8 to 10 m east and west of the outfall pipe (and surrounding armor rock) at a depth of 8 m. This site was chosen to monitor any possible effects of direct shoreward movement (east and west of the outfall pipe) of sewage effluent on coral cover and fish assemblage, abundance, and diversity in the area. The substratum at this station is hard carbonate limestone, to which corals attach and grow.

## METHODS AND MATERIALS

The sampling methodology used in this study generally followed the recommendations of Swartz (1978), Reed (1980), and U.S. Environmental Protection Agency (U.S. EPA 1987)

guidelines. This study is not a comparison of stations because Stations WW and W2 are unique and have no spatial controls.

## Corals, Other Invertebrates, and Water Quality

At Station W2, twelve permanent locations were chosen on the deck platform (Fig. 2). A 0.75-$m^2$ quadrat was placed at each location (with the quadrat number marked on the upper side), and photographs were taken of the corals growing on the deck platform with a camera mounted at a fixed focal length.

At Station WW, three permanent transects 25 m long were marked with stakes (Fig. 3). Transect I—approximately 8 to 10 m west of the outfall pipe, transect II—8 to 10 m east of the outfall, and transect III approximately 16 m east of the outfall. At designated positions, photographs were made of the quadrats, with the permanent marker numbers showing on the upper side of the quadrats. This is essentially the belt quadrat technique used by Dodge, Logan, and Antonius (1982), Ott (1975), and Ott and Sinclair (1977).

Photographic prints (3" by 5") of all permanent quadrats at both stations were analyzed by estimating the percentage of live coral cover and actual coral surface area, using a grid overlay (250 squares = 0.75 $m^2$; 1 square = 30 $cm^2$). Results were checked with a planimeter. These photographs will be compared annually over a five-year period for coral cover, composition, and color.

Permanent transects, with predetermined quadrats, were used instead of randomly laid transects, to estimate temporal changes in coral cover. Because of the extremely patchy distribution and coral abundance per unit area on this coast, a prohibitively large number of random replicate transects would be necessary to validly test for statistical differences in mean coral cover over time. In some cases, the use of inferential statistical analysis may not be valid at the same location over different periods because the assumption of independent sampling may be violated. In the future, paired comparison t-tests will be used to test the null hypothesis that the mean difference in the amount of coral cover per quadrat from time $t_1$ to time $t_2$ is zero or positive (Daniel 1987). This test is not sensitive to moderate deviations from normality, is not affected by the assumption of independence because only differences are tested, does not consider equality of 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 normal distribution, the nonparametric paired sign test will be used for analysis.

The presence or absence of macroinvertebrates and algae were recorded for all transects. Water-quality parameters were monitored using standard temperate-density-salinity (TDS) and oxygen probes.

## Fish Counts

On the deck of the sunken ship, Station W2 (Fig. 2), permanent transect markings (or lines) were not laid because many tourist divers visit the wreck. A diver swimming the length of the deck centerline (approx. 25 m) counted fishes from the centerline to the port railing (approx.
7 m). The starboard railing (length = 25 m) was used as the second transect. Fishes were counted and identified from the starboard railing to the centerline of the deck (approx. 7 m). At Station WW, fishes were counted along three transects 25 m long, 3 m to either side of the line marked with stakes (Fig. 3). Diurnally active fishes are reasonably well censused by transecting, but the most common species are usually underestimated and cryptic fishes will be poorly represented (Brock 1982).

Comparisons of 1990 and 1991 fish counts were made for both stations. Fish assemblages for all transects pooled at both stations were compared using the techniques described below.

Similarity in the relative species abundance recorded during the two periods was analyzed using the Bray-Curtis similarity index. Differences in species composition were based on data on fish species presence or absence and were tested using Cochran's nonparametric Q-test (Siegel 1956; Green 1979).

Dominance was calculated as the number of species accounting for 75% of the total abundance. To quantify variations in species composition between the two periods, a turnover rate (percentage) was calculated according to the methods of Ogden and Ebersole (1981). Turnover rate was thus calculated as

$$0.5\ \mathrm{blc}^{(}\mathrm{rc}^{)}(f(d,nj) + f(g,nk)) \infty 100\ ,$$

where d = number of species lost from $t_1$ to $t_2$, g = number gained, nj = number of species at time $t_1$, and nk = number of species at time $t_2$.

## RESULTS

Coral cover (percentage and actual area) at permanent quadrats for both Stations WW and W2 are shown in Table 1. Estimates of coral cover by grid overlay and planimeter differed by less than 1.2%. Grid overlay estimates were used in this report.

Due to the loss of the 1990 transect marking floats during heavy swell, no direct comparison of the 1990 coral cover measurements can be made with the 1991 measurements. The mean total coral cover per quadrat for Station WW transects (Table 1) is as follows: transect I, 8.5% (n = 5); transect II, 35.0% (n = 4); and transect III, 6.3% (n = 5). The coral species *Porites lobata* dominated the coral cover at Station WW (Table 1). On the deck of the ship *Mahi* (Sta. W2), the mean coral cover per quadrat (all quadrats pooled, n = 12) was

31.7% (Table 1). The coral species *Pocillopora meandrina* dominated at this station. Figures 4 through 7 are representative photographs of permanent quadrats.

At transect I (Sta. WW), one pen shell *(Pinna semicostata)*, three spaghetti worms (*Loimia medusa*), and eight sea urchins *(Tripneustes gratilla)* were recorded along the 25-m transect. Also present, but rare, were the long-spined sea urchin *Echinothrix diadema*, small patches of the alga *Dictyota crenulata*, and coralline algae. At transect II, the urchin *T. gratilla*, the alga *D. crenulata*, and coralline algae were present but rare.

At Station W2, macroinvertebrates present were the sea urchin *E. diadema*, the bryozoan *Triphyllozoan hirsutsum* (lace coral), the crown of thorns starfish *Acanthaster planci*, and hydrozoa (unidentified). The alga *D. crenulata* was also present in small patches.

At Station WW, a total of 88 fishes were counted (23 species) in 1990, and 62 (27 species) in 1991 (all transects pooled, Table 2). The species turnover rate was 3.7%. Zero species were lost, and 2 gained from 1990 to 1991 (all transects pooled). The similarity index for the comparison of the two periods was 0.81. Based on the presence or absence of species, it can be concluded that there was no significant difference in species composition between the two periods ($Q = 0.55$, $df = 1$, n.s.). Five species dominated (represented >75% of the abundance) in 1990, and 7 in 1991. At Station WW, the most common fish species during both periods were the wrasse *Thalassoma duperrey*, the goatfish *Parupeneus porphyreus*, and the damselfishes *Chromis* sp. and *Dascyllus albisella*.

Horizontal visibility was good at both stations (>15 m), and sand sediments were clean and white at Station WW and at the base of the ship *Mahi* (Sta. W2). Water-quality parameters for both stations are recorded in Table 4. None of the water-quality data, when analyzed in terms of depth, showed any indication of reducing conditions at either station. Secchi depth was 15 m at both stations.

Comparison of fish-count data recorded at Station W2 in 1990 with that recorded in 1991 showed a species turnover rate of 11.6% (the centerline and starboard transects were pooled). From 1990 to 1991, 1 species was lost and 7 species gained. At Station W2, 6 fish species dominated in 1990, and 4 in 1991. The butterfly fish *Chaetodon miliaris* and the snapper *Lutjanus kasmira* were present in large numbers in both years. In 1991, the damselfish *D. albisella* was present in moderate numbers but absent in 1990. In 1990, a total of 236 fish were counted (34 species), and in 1991 fish abundance was 222 (43 species) (Table 3).

Based on the presence or absence of species (transects pooled), the similarity index for the comparison of 1990 fish counts at Station W2 with 1991 ones was 0.62. There was no significant difference in the presence or absence of fish species between the two periods ($Q = 1.99$, $df = 1$, n.s.).

## DISCUSSION

Coral cover off the Waianae coast is dominated by the two species *P. meandrina* and *P. lobata* (Reed, Kay, and Russo 1977). This dominance of the two species existed before, and continued after, the commencement of discharge at the modified Waianae outfall. The outfall pipe, which discharged wastes at a depth less than 20 m prior to 1977, was modified and extended to discharge into the 33-m isobath approximately 1.8 km offshore. In the summer of 1975, Reed, Kay, and Russo (1977) reported coral cover range to be 8% to 12% between the 6- and 12-m isobath offshore from the WWWTP (transect C in their study) and within 50 m of the present Station WW. In 1991, coral cover in this area ranged from approximately 6% to 35%. There were no apparent shifts in either coral species dominance or range of cover from 1975 to 1991. The clean sand sediments and good horizontal water visibility may indicate no large influx of sewage effluent to inshore survey Station WW.

In 1975, total fish abundance offshore from the WWWTP (6- to12-m depths) varied between 18 and 95 (nos. adjusted to 175-$m^2$ area) (Reed, Kay, and Russo 1977). In 1990 at the 8-m isobath in the same area (Sta. WW), total fish abundance varied between 6 (transect I) and 46 (transect II) per transect area. In 1991, fish abundance ranged from 6 to 29 per transect area. No significant differences were seen in species composition between the two periods, and turnover rate in species lost, relative to species gained, was low (3.7%).

On the ship *Mahi*, there were no significant differences between 1990 and 1991 in fish species presence or absence, and species turnover rate was low (<12%). Also, the Bray-Curtis similarity index was relatively high (0.81) for the two periods.

The two survey stations will be monitored annually over a five-year period for changes in the coral cover and fish diversity and abundance. Changes in the biological indicators near an impact area may be the result of (1) natural environmental fluctuations or (2) impact of other than natural phenomena. Presently, there are no observable indications that movement of sewage effluent onshore or along shore is taking place near the WWWTP, and circumstantial evidence suggests little or no effect from the outfall on fish and coral communities. Coral species dominance has not changed since 1975, sediments are clean, and water clarity is good. Also, fish community structure in 1990 is essentially similar to that in 1991, and similar to other community structures around the Hawaiian Islands with similar substrata. When compared to the results of extensive surveys done by Hobson (1984), values for fish species richness, composition, and abundance are very similar to those found in typical Hawaiian subtidal biotopes. Numbers and species of fish seen in the WWWTP area in 1975 were similar to those recorded in 1990 and 1991. Fishes normally intolerant of moderate to heavy sewage pollution (e.g., *D. albisella* and *Chaetodon multicinctus*) were seen at both

stations. Aggregations of fish species were comparable to those found in similar biotopes around the Hawaiian Islands and seen during swimming reconnaissance over the outfall pipe and surrounding armor rocks. For example, Hobson (1984) recorded species in "boulder" regions to include schools of goatfishes (*Mulloides auriflamma*), surgeonfishes (*Acanthurus oliveceus*), and menpachi (*Myripristis* sp.), species that were photographed at the outfall pipe (Figs. 8, 9, and 11). Corals (*Porites* sp.) were also photographed growing on armor rocks at the outfall pipe (Fig. 10). EPA studies of sewage impact on coral reefs can be found in Tetra Tech (1983) and U.S. EPA (1987). As this study is but one in a five-year series, only after analysis of a series of annual surveys can direct and significant evidence for or against outfall effects be apparent.

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TABLE 1. CORAL COVER IN SELECTED QUADRATS, WAIANAE OCEAN OUTFALL, O'AHU, HAWAI'I, OCTOBER 1991

| Quadrat | Amt. of Cover (%) | Area ($cm^2$) | | Quadrat | Amt. of Cover (%) | Area ($cm^2$) |
|---|---|---|---|---|---|---|
| | | | | | | |
| **STATION WW** | | | | **STATION W2** | | |
| **Transect I** | | | | AAA1 | | |
| AAA4 | | | | *P. meandrina* | 17.2 | 1290 |
| *Pocillopora meandrina* | 5.3 | 400 | | *P. lobata* | 1.6 | 120 |
| | | | | Total | 18.8 | 1410 |
| ABB1 | | | | | | |
| *P. meandrina* | 4.5 | 337.5 | | AAA2 | | |
| | | | | *P. meandrina* | 21.6 | 1620 |
| AAB1 | | | | | | |
| *P. meandrina* | 4.5 | 336.9 | | AAA3 | | |
| *Porites lobata* | 3.6 | 275.6 | | *P. meandrina* | 34.2 | 2565 |
| Total | 8.1 | 612.5 | | *P. lobata* | 5.6 | 420 |
| | | | | Total | 39.8 | 2985 |
| ACC3 | | | | | | |
| *P. meandrina* | 8.6 | 650 | | AAA4 | | |
| | | | | *P. meandrina* | 28.0 | 2160 |
| ABA1 | | | | *P. lobata* | 1.6 | 120 |
| *P. meandrina* | 6.3 | 475 | | Total | 29.6 | 2280 |
| | | | | | | |
| **Transect II** | | | | AAB1 | | |
| BAB3 | | | | *P. meandrina* | 36.2 | 2715 |
| *P. lobata* | 50.5 | 3788 | | *P. lobata* | 1.0 | 75 |
| | | | | Total | 37.2 | 2790 |
| BAB2 | | | | | | |
| *P. lobata* | 20.0 | 1500 | | AAB2 | | |
| | | | | *P. meandrina* | 25.2 | 1890 |
| BAC1 | | | | *P. lobata* | 4.6 | 345 |
| *P. lobata* | 29.0 | 2175 | | Total | 29.8 | 2235 |
| | | | | | | |
| BBB2 | | | | AAB3 | | |
| *P. lobata* | 40.5 | 3037.5 | | *P. meandrina* | 30.6 | 2295 |
| | | | | *P. lobata* | 2.8 | 210 |
| **Transect III** | | | | Total | 33.4 | 2505 |
| BCC2 | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| *P. meandrina* | 2.4 | 181.5 | | AAB4 | | |
| *P. lobata* | 7.2 | 543.7 | | *P. meandrina* | 57.0 | 4275 |
| Total | 9.6 | 725.0 | | *P. lobata* | 6.6 | 495 |
| | | | | Total | 63.6 | 4770 |
| BCC1 | | | | | | |
| *P. meandrina* | 1.7 | 125 | | AAC1 | | |
| | | | | *P. meandrina* | 39.4 | 2955 |
| BBC3 | | | | *P. lobata* | 1.4 | 105 |
| *P. meandrina* | 5.3 | 400 | | Total | 40.8 | 3060 |
| | | | | | | |
| CCC3 | | | | AAC2 | | |
| *P. lobata* | 14.8 | 1112.5 | | *P. meandrina* | 27.2 | 2040 |
| | | | | *P. lobata* | 2.2 | 165 |
| CCC1 | | | | Total | 29.4 | 2205 |
| *P. meandrina* | 2.6 | 200 | | | | |
| *P. lobata* | 2.6 | 200 | | AAC4 | | |
| Total | 5.2 | 400 | | *P. meandrina* | 28.8 | 2160 |
| | | | | *P. lobata* | 7.6 | 570 |
| | | | | Total | 36.4 | 2730 |
| | | | | | | |
| | | | | | | |

TABLE 2. FISH ABUNDANCE AT STATION WW TRANSECTS, WAIANAE OCEAN OUTFALL, O‘AHU, HAWAI‘I, 1990 AND 1991

| TAXON | | TRANSECT | | | | | |
|---|---|---|---|---|---|---|---|
| | | I | | II | | III | |
| | | 1990 | 1991 | 1990 | 1991 | 1990 | 1991 |
| | | | | | | | |
| **ACANTHURIDAE** | | | | | | | |
| **(Surgeonfishes)** | | | | | | | |
| ACANTHURUS NIGORIS | | 1 | 1 | 3 | 0 | 0 | 1 |
| A. TRIOSTEGUS | | 0 | 0 | 4 | 1 | 1 | 2 |
| | | | | | | | |
| **BALISTIDAE** | | | | | | | |
| **(Triggerfishes)** | | | | | | | |
| MELICTHYS VIDUA | | 0 | 0 | 1 | 0 | 1 | 1 |
| RHINECANTHUS RECTANGULUS | | 0 | 0 | 2 | 1 | 3 | 1 |
| SUFFLAMEN BURSA | | 0 | 1 | 0 | 1 | 0 | 2 |
| | | | | | | | |
| **CHAETODONTIDAE** | | | | | | | |
| **(Butterfly fishes)** | | | | | | | |
| CHAETODON MULTICINCTUS | | 0 | 0 | 0 | 0 | 2 | 1 |
| | | | | | | | |
| **LABRIDAE** | | | | | | | |
| **(Wrasses)** | | | | | | | |
| THALASSOMA DUPERREY | | 0 | 1 | 15 | 7 | 9 | 4 |
| | | | | | | | |
| **MULLIDAE** | | | | | | | |
| **(Goatfishes)** | | | | | | | |
| MULLOIDES AURIFLAMMA | | 0 | 0 | 1 | 3 | 4 | 3 |
| PARUPENEUS PORPHYREUS | | 0 | 0 | 11 | 4 | 3 | 1 |
| | | | | | | | |
| **MONACANTHIDAE** | | | | | | | |
| **(Filefishes)** | | | | | | | |
| PERVAGOR SPILOSOMA | | 3 | 1 | 5 | 6 | 0 | 3 |
| | | | | | | | |
| **POMACENTRIDAE** | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **(Damselfishes)** | | | | | | | |
| CHROMIS *SP.* | | 1 | 2 | 2 | 0 | 10 | 2 |
| DASCYLLUS ALBISELLA | | 1 | 0 | 3 | 3 | 3 | 7 |
| | | | | | | | |
| **TETRADONTIDAE** | | | | | | | |
| **(Puffers)** | | | | | | | |
| CANTHIGASTOR CINCTUS | | 0 | 0 | 0 | 1 | 0 | 1 |
| | | | | | | | |
| | | | | | | | |
| **Total Individuals (Nos./175** | | 6 | 6 | 46 | 27 | 36 | 29 |
| Total Number of Species | | 4 | 5 | 10 | 9 | 9 | 13 |
| | | | | | | | |
| | | | | | | | |

TABLE 3. FISH ABUNDANCE AT STATION W2 TRANSECTS, WAIANAE OCEAN OUTFALL, O‘AHU, HAWAI‘I, 1990 AND 1991

| | | DECK STBD. RAILING | | | DECK CENTERLINE | |
|---|---|---|---|---|---|---|
| TAXON | | 1990 | 1991 | | 1990 | 1991 |
| | | | | | | |
| **ACANTHURIDAE** | | | | | | |
| **(Surgeonfishes)** | | | | | | |
| ACANTHURUS NIGORIS | | 0 | 5 | | 2 | 3 |
| A. OLIVECEUS | | 0 | 1 | | 1 | 0 |
| A. THOMPSONI | | 2 | 1 | | 1 | 0 |
| CTENOCHAETUS STRIGOSUS | | 0 | 6 | | 0 | 4 |
| NASO HEXACANTHUS | | 1 | 4 | | 3 | 2 |
| N. LITERATUS | | 0 | 1 | | 2 | 1 |
| ZANCLUS CORNUTUS | | 1 | 1 | | 1 | 0 |
| ZEBRASOMA FLAVESCENS | | 0 | 3 | | 0 | 2 |
| | | | | | | |
| **AULOSTOMIDAE** | | | | | | |
| (Trumpetfishes) | | | | | | |
| AULOSTOMUS CHINENSIS | | 0 | 0 | | 1 | 1 |
| | | | | | | |
| **BALISTIDAE** | | | | | | |
| (Triggerfishes) | | | | | | |
| MELICHTHYS VIDUA | | 0 | 4 | | 0 | 0 |
| RHINECANTHUS RECTANGULUS | | 0 | 1 | | 2 | 1 |
| SUFFLAMEN BURSA | | 1 | 3 | | 2 | 1 |
| | | | | | | |
| **CHAETODONTIDAE** | | | | | | |
| (Butterfly fishes) | | | | | | |
| CHAETODON KLEINI | | 2 | 4 | | 3 | 2 |
| C. MILIARIS | | 6 | 10 | | 50 | 18 |
| C. ORNATISSIMUS | | 0 | 0 | | 1 | 0 |
| FORCIPIGER FLAVISSIMUS | | 1 | 1 | | 4 | 1 |
| HEMITAURICHTHYS POLYLEPIS | | 0 | 4 | | 0 | 0 |
| | | | | | | |
| **CIRRHITIDAE** | | | | | | |
| (Hawkfishes) | | | | | | |
| PARACIRRHITES FORSTERI | | 1 | 3 | | 3 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **DIODONTIDAE** | | | | | | |
| (Spiny puffers) | | | | | | |
| DIODON HOLOCANTHUS | | 0 | 1 | | 1 | 1 |
| | | | | | | |
| **LABRIDAE** | | | | | | |
| (Wrasses) | | | | | | |
| LABROIDES PHTHIROPHAGUS | | 1 | 0 | | 1 | 1 |
| THALASSOMA DUPPEREY | | 8 | 7 | | 12 | 6 |
| | | | | | | |
| **LUTJANIDAE** | | | | | | |
| (Snappers) | | | | | | |
| LUTJANUS KASMIRA | | 20 | 20 | | 95 | 50 |
| | | | | | | |
| **MONACANTHIDAE** | | | | | | |
| **(Filefishes)** | | | | | | |
| PERVAGOR SPILOSOMA | | 0 | 0 | | 3 | 1 |
| | | | | | | |
| **MULLIDAE** | | | | | | |
| **(Goatfishes)** | | | | | | |
| PARUPENEUS MULTIFASCIATUS | | 0 | 0 | | 1 | 2 |
| P. PORPHYREUS | | 0 | 0 | | 1 | 1 |
| | | | | | | |

TABLE 3.—*Continued*

| TAXON | | DECK STBD. RAILING | | | DECK CENTERLINE | |
|---|---|---|---|---|---|---|
| | | 1990 | 1991 | | 1990 | 1991 |
| | | | | | | |
| **MURAENIDAE** | | | | | | |
| **(Eels)** | | | | | | |
| GYMNOTHORAX MELEGRIS | | 0 | 0 | | 1 | 1 |
| | | | | | | |
| **POMACENTRIDAE** | | | | | | |
| **(Damselfishes)** | | | | | | |
| CHROMIS HANUI | | 0 | 10 | | 0 | 0 |
| DASCYLLUS ALBISELLA | | 0 | 4 | | 0 | 25 |
| | | | | | | |
| **TETRADONTIDAE** | | | | | | |
| **(Puffers)** | | | | | | |
| CANTHIGASTOR CINCTUS | | 0 | 0 | | 1 | 2 |
| | | | | | | |
| | | | | | | |
| **Total (Nos./175 m²)** | | 44 | 94 | | 192 | 128 |
| **Total Number of Species** | | 11 | 21 | | 23 | 22 |
| | | | | | | |
| | | | | | | |

TABLE 4. WATER-QUALITY PARAMETERS, WAIANAE OCEAN OUTFALL, O‘AHU, HAWAI‘I, OCTOBER 1991

| Depth (m) | Temperature (°C) | Salinity (ppt) | Oxygen (mg/l) | pH |
|---|---|---|---|---|
| | | | | |
| **STATION W2** | | | | |
| 2 | 26.77 | 34.5 | 45.82 | 8.02 |
| 4 | 26.80 | 34.69 | 6.34 | 8.03 |
| 6 | 26.80 | 34.70 | 6.34 | 8.03 |
| 8 | 26.80 | 34.71 | 6.33 | 8.03 |
| 10 | 26.80 | 34.71 | 6.32 | 8.03 |
| 12 | 26.79 | 34.72 | 6.28 | 8.03 |
| 14 | 26.79 | 34.72 | 6.23 | 8.03 |
| 16 | 26.79 | 34.72 | 6.25 | 8.03 |
| 18 | 26.79 | 34.72 | 6.25 | 8.03 |
| 20 | 26.78 | 34.72 | 6.25 | 8.03 |
| 22 | 26.77 | 34.73 | 6.25 | 8.03 |

| | | | | |
|---|---|---|---|---|
| 24 | 26.77 | 34.73 | 6.20 | 8.03 |
| | | | | |
| **STATION WW*** | | | | |
| 1 | 26.75 | 34.83 | 5.84 | 8.11 |
| 2 | 26.75 | 34.85 | 6.14 | 8.11 |
| 3 | 26.74 | 34.85 | 6.14 | 8.11 |
| 4 | 26.74 | 34.85 | 6.15 | 8.11 |
| 5 | 26.74 | 34.85 | 6.16 | 8.11 |
| 6 | 26.74 | 34.85 | 6.17 | 8.11 |
| | | | | |

NOTE: ppt = parts per thousand.
*Water-quality measurements were made at CCH Station W-8, 250 m seaward of the present location of Station WW.