APPENDIX G

Biological Conditions

Appendix G

Biological Conditions

INTRODUCTION

This appendix provides detailed background information on the biological conditions found near the Sand Island (SI) outfall and area that is being monitored by the City and County of Honolulu (CCH). Where there is information to supplement that collected by the monitoring program, it is provided to put perspective on the resources that may be potentially influenced by the presence of the outfall and discharge of treated effluent. This appendix and various supplemental attachments contains more detailed information to support the Questionnaire and the biological conditions summary contained in Parts IIC and IIID of this application

OFFSHORE ENVIRONMENT

Description of Ocean Floor off Sand Island

Mamala Bay consists of a narrow insular shelf bounded by a steep escarpment that drops from 50 to 250 m water depth on the seaward edge of the shelf. This escarpment borders a broad southwest-trending trough that gently deepens from 250 to 650 m depth in the study area (Figure G-1).

The ocean bottom in the vicinity outfall is composed of a wide, predominately flat calcium carbonate (limestone) platform which is an erosional remnant of the extensive, geologically ancient emergent reef that forms the floor of Mamala Bay. The distance from the shoreline at Sand Island to the 20 meter depth contour is approximately 2 kilometers (4000 feet), indicating that the bottom topography has a very gentle slope. Sloping gradually increases from the shoreline out to well beyond the 100 meter depth contour (Figure G-1). The surface of this reef platform is relatively barren, characterized by short algal turf cover and a layer of sediment composed of sand. In some areas shallow sand-filled channels intersect the reef platform resulting in a limited groove and ridge system. In some of the deeper areas there are extensive sand deposits.

The nearshore area has a rather solid limestone bottom covered for the most part with sand and rubble cover. Offshore, the entire ocean floor consists of sand and rubble. Detailed characterization of the sediment characteristics in terms of grain size, chemical characteristics and the concentrations of trace metals and priority pollutants as determined through the present monitoring program are presented in Attachment G-1. The sea floor is an important habitat for benthic biota and is discussed in more detail in the context of benthic sampling later in this Appendix.

Phytoplankton

Phytoplankton populations are not required to be monitored as part of the CCH Sand Island Outfall NPDES Permit monitoring program. No studies have been done in the past on phytoplankton directly, but the surrogate for measuring phytoplankton population abundance (chlorophyll a) is routinely measured.

Overall, plankton studies have not been a normal requirement of the 301(h) monitoring protocols due to their difficulty to design, implement and interpret. Water quality parameters such as chlorophyll *a* have been used to assess phytoplankton presence and potential influences of wastewater discharge on populations of phytoplankton.

Zooplankton

Zooplankton populations are not required to be monitored as part of the CCH Sand Island Outfall monitoring program. A study to characterization and assess zooplankton populations near the Sand Island Outfall were completed in 1979 by AECOS (AECOS, 1979). These studies were used to support the original 301(h) applications filed in 1979 for the Sand Island waiver permit The results of the study were included in the 1979 and 1983 Applications for the Sand Island WWTP and reviewed and summarized by EPA's contractor Tetra Tech (Tetra Tech, 1987) as follows:

> "Zooplankton - the major deficiencies in the data are poor study design, inadequate taxonomic identification of some groups of organisms, and inappropriate statistical tests. The presence or absence of adverse effects of the Sand Island discharge on zooplankton and larval fishes cannot be established, given the limitations on the available data."

Overall characterization of the zooplankton community was inadequate because taxonomic identification was limited to gross categorization of species other than larval fishes as either herbivores or carnivores. Taxonomic identification of larval fishes was adequate for predischarge/post discharge comparisons of numerical abundance, numbers of species, diversity, and total biomass. However, the study lacked analyses of the effects of the discharge on: 1) species composition of the larval fishes, and 2) larvae of the individual fish species.

Plankton Characterization and Impact Assessment Plankton Characterization and Impact Assessment

Overall, plankton studies have not been a normal requirement of the 301(h) monitoring protocols due to their difficulty to design, implement and interpret. Zooplankton studies have not been required of 301(h) modified NPDES permittees. Water quality parameters such as chlorophyll *a* have been used to assess phytoplankton presence and potential influences of wastewater discharge on populations of phytoplankton. From such assessments, inferences can be drawn about the zooplankters which might feed on phytoplankton. Otherwise, studies of zooplankton may be more difficult to undertake than assessing phytoplankton populations due to their motility and diurnal migrations through the water column.

EPA made the following statements and conclusions regarding plankton in the 1998 Tentative Decision Document:

> "In bottom water, the geometric mean concentration at the ZOM (0.13 ug/l) was slightly higher than the geometric mean for reference stations (0.10 ug/l), but all concentrations were below the standard limit.
>
> Although information on phytoplankton species composition and community structure at the discharge site was not available, the small observed differences in bottom chlorophyll *a* concentrations were below the standards and eutrophication or other adverse ecological effects have not been observed."

Fish

Mamala Bay serves as habitat to a relatively large number of fish species. Hawaiian waters contain over 900 species of fish according to listings kept by the Bishop Museum. Of these, 59 species representing 16 families have been observed near the outfall diffuser over the years by video footage taken with a remotely operated vehicle (ROV). A summary listing of these fish is presented in Table G-1 at the back of this appendix. An even higher number of species (85 species from 23 families) has been observed in the nearshore areas where there is more structure and habitat in the form of coral reefs. These are listed in Table G-2. Over half of the species found at the outfall are also found in the nearshore waters. Those fish species common to both areas are listed in Table G-3. Table G-4 contains the listing of all the species observed over the years along with their Hawaiian names.

The following sections discuss what is known about fish populations near the outfall and at reference sites which have been studied for comparative purposes. Also, the studies done in the past to assess the potential impact of the Sand Island outfall on nearshore coral reef areas are described and summarized. This element of the monitoring program was discontinued in 1999 because the results did not show any quantifiable differences between the areas studies and no discernible outfall-related impacts.

Outfall Fish Observations

Biomonitoring of the Sand Island outfall was initiated the early 1980's to assess fish and benthic communities both before (December 1981) and after discharge (March 1983) via observations from the submersible *Makalii* to make visual and photographic transects (Russo, 1982). Transects were made on each side of the pipe and a species list and count was made. The submersible observations continued through 1990. After ~~this date, and through 1998, the City relied on observations derived through the use of~~ Remotely Operated Vehicle (ROV) which took video footage of the outfall along three designated transects. This work was done by Dr. Richard Brock of the University of Hawaii under contract to the City. These qualitative summaries provide some information on which species are present, but are inadequate for making any meaningful type of assessment of changes over time. These observations were discontinued with the issuance of the renewal permit in late 1998. An excellent summary of the survey work completed over the years (1991-98) is presented in the last report (Brock 1998) which is included as Attachment G-2. The key summary of the findings over the nine year period surveyed is presented below:

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

The survey work showed that the number of fish species near the outfall diffuser has ranged from 7-17 along the various transects with an average density of about one fish per square meter of area surveyed. The mean number of species per transect ranged from 10-17 while the number of individuals varied from 56-622 per transect observed (Brock, 1998). Estimates of biomass ranged from 21-92 g/sq.m. Among the abundant fishes surveyed in most years are the juvenile snappers seen close to the sea floor. It had been assumed that these juveniles were newly recruited *Lutjanus kasmira*, but they represent juveniles of a number of other snapper species including the pink snapper or ‘opakapaka (*Pristipomoides filamentosus*), which is an important species in the Hawaiian bottomfish fishery. If the latter is true, the diffuser may be providing significant local habitat to a commercially important species (Brock, R. E.,1998).

A listing of the species observed by remote sensing near the outfall are summarized in Table G-1. A total of 27 families representing 59 species have been observed in the offshore waters near the outfall. The most numerous species were from the families Labridae (wrasses, 11 species), Acanthuridae (Surgeonfishes, 8 species), Pomacentridae (Damselfishes, 8 species), and Chaetodontidae (Butterflyfishes, 6 species).

The most common species observed included:

Pseudanthias sp. various bass species of the family Serranidae
Chromis sp. various species of damselfish
Lutjanus sp. snappers, particularly the Blue-strip snapper

Other surveys of fish are made as part of shallow water coral reef surveys. The shallow areas where there is more relief and habitat for fish have a higher species richness and abundance. The observations of fish populations from these surveys are summarized under the Nearshore Section of this appendix. Of note is the large number of fish species in common between both locations. These include 8 species of wrasses (Labridae), 5 species of surgeonfish (Acanthuridae) and 4 species of damselfish (Pomacentridae) and 4 species of pufferfish (Tetraodontidae)(See Table G-3).

Macrobenthic Invertebrates

Only a few exposed macro invertebrates were evident on the videotapes of the diffuser and the numbers were insufficient for any meaningful analysis. Commonly identifiable macro invertebrates included the black sea cucumber (*Holothuria atra*) and the brown sea cucumber (*Bohadschia vitiensis*). Other identifiable invertebrates observed along the transects included the cushion starfish (*Culcita novaeguineae*), black sea urchin (*Tripneustes gratilla*), the serrate sea urchin (*Chonrocidaris gigantea*) and the spiny lobster (*Panulirus marginatus*).

Benthic Infauna

The monitoring of the sand bottom animal communities near the Sand Island ocean outfall has been underway for a number of years starting in 1986. Monitoring was consistently performed at seven stations annually beginning in 1990 for the time period (data was collected at seven stations for each survey at sampling stations in the zone of initial dilution (ZID or in this case, the zone of mixing or ZOM), on the boundary of the ZOM, and at distances from 0.5 - 2 km from the diffuser) through 1998. The outfall sampling was initiated in 1986, with subsequent surveys completed in 1987,1990, 1991, February 1992, June 1993, January-February 1994 and January 1995 (Nelson, et al, 1987, 1990, 1991, 1992, 1994a, 1994b, 1995, 1996, 1997, and 1998). With issuance of a new permit in 1998, the EPA designated a new series of monitoring stations that were set at a wider variety of depths and at further distances from the outfall. These new stations were intended to provide for a more regional focus to monitoring to identify impacts not only from the Sand Island outfall, but from other sources. To date, four surveys have been conducted in Mamala Bay, three of which have been published (Swartz, et. al, 1999,2000 and 2001).

The benthic monitoring program has been designed to evaluate whether any changes in the benthic community may be occurring as a result of wastewater discharge practices from the outfall diffuser. Both physical-chemical and biological measurements using standardized methods on sediments and infaunal organisms are conducted during each annual sampling period to evaluate benthic conditions. A summary description of the sampling methods used is contained in the City's Annual Assessment Reports (AARs) (CCH, 1998, 1999,2000,2001,2002, and 2003). It should be noted that the sampling strategy employed in the vicinity of the Sand Island outfall and other Hawaiian outfalls differs from that generally recommended and used on mainland sites because of the benthic fauna are known to be both small and abundant with large numbers of "micromolluscs" (Nelson, et al. 1987). Also of note is the change in stations and the number of replicates that was initiated with the 1998 permit monitoring requirements. The number of stations was increased to 15 and the number of replicate samples reduced from 6 to 3.

Historical Benthic Monitoring

The benthic monitoring program to monitor potential changes in sediments surrounding the Sand Island ocean outfall of the Sand Island Wastewater Treatment Plant (SIWWTP) was initiated in 1986 in response to a request from EPA Region IX for a benthic survey (letter to CCH, May 27, 1986). The design of the monitoring program was determined by members of the research team retained by the City and County of Honolulu (Walter .G. Nelson, Ph.D. and Anthony .R. Russo) through consultation with EPA Region IX. The objectives of the monitoring program was to establish stations at varying distances from the diffuser pipe within a similar depth range which could be monitored on an annual basis to evaluate whether or not changes in the benthic community and determine if these could be attributed to the discharge of treated effluent from the outfall.

Specific locations of the seven historical stations along the 73 meter isobath (approximate depth of the diffuser). Survey station designations (lettering) were changed in 1990 from those used in the 1986 survey (Nelson et al., 1987) to avoid confusing with other outfall designations in use. Survey stations and their locations as specified in the 1990 NPDES permit for Sand Island were designated "B" stations (Shown in Table G-5).

In 1994, Walter G. Nelson, Ph.D. summarized the findings of the benthic monitoring that had been conducted since 1986 near the Sand Island Wastewater Treatment Facility ocean outfall (herein after referred to as the Sand Island outfall) as part of the 1994 waiver renewal application (Nelson, 1994 in Barrett Consulting Group, 1994). Since that time, eight additional benthic surveys have been completed. The results since the last application in 1994 are submitted in annual reports. The results for these surveys are summarized herein. The complete reports are part of the on-going monitoring program compliance submittals provided to EPA and the HDOH.

What is clear from all the work done to date is that the benthic environment near the Sand Island outfall has remained relatively stable over the years as evidenced by the data collected to date. There are few, if any, signals of significant responses of the benthic community or changes in sediment chemistry that can be associated with the discharge of treated wastewater.

Physical-chemical measurements include sediment grain size (reported as phi grain size), sediment organic content (total organic carbon or TOC), oxidation-reduction potential (ORP) of the sediments (an indicator or oxygen availability), and sediment oil and grease (O&G) content (an indicator of effluent particulates). To date, there has been no indication of changes in any of these parameters over the study period that is indicative of an accumulation of organic matter resulting from sewage effluent at the stations near the diffuser. These findings support earlier studies of Dr. Steven Dollar which indicated that only about one percent of the particulates settle out near the outfall (Dollar, 1986).

Analysis of biological parameters of the sediment-dwelling benthic communities has shown that the abundance, the number of species, diversity, evenness of individuals distributed among species in the community, and the species composition of the benthic community have no patterns of change which could be attributed to the influence of wastewater discharges from the Sand Island outfall. This is detailed in the Annual Benthic Infaunal Sampling Reports and Annual Assessment Reports.

The benthic community in the area of the Sand Island ocean outfall has shown no indications of changes attributable to the diffuser effluent. The Sand Island benthic studies provides support to the conclusions that wastewater discharge of primary effluents into the deeper waters of Mamala Bay are not having significant impacts on the benthic communities and that "balanced indigenous population" or BIP is found at the edge and beyond the Zone of Initial Dilution ZID) of the outfall diffuser and that this BIP is being maintained even at stations immediately adjacent to the Sand Island ocean outfall diffuser.

The presences of a BIP is critical to the granting of a waiver of secondary treatment of sewage effluent under the Clean Water Act (CWA) under the provisions of Section 301(h). To obtain a waiver, an applicant must meet certain requirements set by the U. S. Environmental Protection Agency (EPA) regarding the biological impact of the discharge. The regulations (40 CFR Section 125.61 (c)) state that the discharge "must allow for the attainment or maintenance of water quality which assures protection and propagation of a balanced indigenous population of shellfish, fish and wildlife." The balanced indigenous population (BIP) criterion must be met "immediately beyond the zone of initial dilution of the applicant's modified discharge" and "(i)n all other areas beyond the zone of initial dilution where marine life is actually or potentially affected by the applicant's modified discharge" [40 CFR Section 25.61(c)(2). Furthermore, "(c)onditions ~~within the zone of initial dilution must not contribute to extreme adverse~~ biological impacts, including, but not limited to, the destruction of distinctive habitats of limited distribution, the presence of disease epicenters, or the stimulation of phytoplankton blooms which have adverse effects beyond the zone of initial dilution." [40 CFR Section 125.61(c)(3)].

The results of the latest annual benthic monitoring program conducted in August of 2002 are summarized in Attachment G-3 of this Appendix. Previous benthic surveys completed since the last application was submitted are also summarized below followed by a discussion of the findings during the last permit period.

1986, 1987, and 1990-94 Annual Benthic Survey Results

The results section for the 1986 benthic community survey (Nelson et al., 1987) (the first undertaken for the Sand Island outfall) was reproduced in its entirety in the 1994 Sand Island waiver reapplication (Barrett Consulting Group, 1994 and included a detailed assessment of all the benthic surveys done to date for the Sand Island outfall prepared by Dr. Walter Nelson (Nelson, 1994 included as Appendix B to the 1994 application). The raw data and all statistical analysis tables referred to were contained in the appendices to the original reports (Nelson et al., 1994) previously submitted to EPA Region IX and reviewed are part of the Technical Review conducted by Tetra Tech in 1987 and EPA in the period 1994 to 1998 when the Tentative Decision Document was issued..

1995 and1996 Annual Benthic Survey Results

The results section for the 1995 and 1996 benthic community surveys (Nelson et al., 1996, and 1997) were completed after the 1994 renewal application was submitted and are being included here in summary form to provide a complete summary review of available findings. Copies of all the original documents which have referenced have been provided to EPA Region IX and the Hawaii Department of Health in the past and the data has also been submitted to EPA for archiving into the ODES data base where it can be stored and accessed.

1994 Benthic Sampling Report Conclusions1994 Benthic Sampling Report Conclusions

The following are the conclusions of the August 1994 Benthic faunal sampling near the Sand Island Ocean Outall conducted under contract to the University of Hawaii at Manoa (Nelson, et. al. 1995a)

> “Benthic infauna in the vicinity of the Sand Island Ocean Outfall were sampled at seven stations along the diffuser isobath in August 1994. Stations were located both within and on the boundary of the zone of initial dilution (ZID) and at distances of 1.2 to 2.0 km from the ZID boundary. Values for total organic carbon, total Kjeldahl nitrogen, and oxidation-reduction potential showed no indication of significant organic buildup in sediments at any station. Sediment oil and grease values were highest at reference station B2. Station B2 had significantly more nonmollusk individuals than all the other stations, and Station Z had significantly more individuals than Stations B6 and B1. No other differences among stations were significant. Station B2 had significantly more

> nonmollusk species than Station B1, B3, and B6; Station Z and B5 had significantly more species than Station B1 and B3: and Station B4 had significantly more species than Station B1. No other differences among stations were significant. Therefore, there was no relationship between nearness to the diffuser and mean nonmollusk species richness. Most stations differed significantly from each other in mollusk abundance. Mollusk species richness was significantly greater at near-ZID station B5 and ZID station Z than at all other stations. This pattern is the reverse of that expected as a result of an impact related to the discharge of effluent from an outfall diffuser. Cluster analysis of nonmollusk species composition and abundance in 1994 produced a substantially different pattern from the analysis in 1993. In 1993, stations in closest geographic proximity to each other tended to be clustered together, as was the case in previous sampling years. In 1994, reference stations B1 and B6, which are most distant from each other, were grouped together; and reference station B2 was grouped with the ZID and near-ZID stations. There was no pattern of lower diversity or evenness of either nonmollusk or mollusk groups at ZID or near-ZID stations relative to the other stations. The long-term pattern of lower species richness at Station B3, as compared to the other stations, was observed only for species richness of the crustacean component and not for other faunal components as in past years. The response patterns of benthic infauna near the Sand Island Ocean Outfall showed little indication of a strong influence by the diffuser effluent."

1995 Benthic Sampling Report Summary

The following are the conclusions of the August 1995 Benthic faunal sampling near the Sand Island Ocean Outfall conducted under contract to the University of Hawaii at Manoa (Nelson, et. al. 1996a)

> "Benthic fauna in the vicinity of the Sand Island Ocean Outfall was sampled at seven stations along the, diffuser isobath in August 1995. Stations were located both within and on the boundary of the zone of initial dilution (ZID) and at distances of 1.2 to 2 km from the ZID boundary. Values for total organic carbon, total Kjeldahl nitrogen, and oxidation-reduction potential showed no indication of significant organic buildup in sediments at any station. Correlations between sediment oil and grease from Sand Island samples and both crustacean abundance and species richness were not significant. Mean nonmollusk abundance and crustacean abundance did not differ significantly among stations. Mean nonmollusk species richness was not significantly different among stations. Mean crustacean species richness was significantly lower at Station B3 as compared only to reference station B1.
>
> Therefore, there was no general relationship between nearness to the diffuser and mean nonmollusk or crustacean species richness.
>
> Mean mollusk abundance was significantly greater at Station B4, located on the ZID boundary, than at reference station B1 or Station B5, located near the ZID. Mean mollusk species richness was highest at Stations B5 and Z, located either

> on the ZID boundary or within the ZID, as compared to most other stations. These patterns are the reverse of those expected as a result of an impact related to the diffuser effluent.
>
> Cluster analysis of nonmollusk species composition and abundance showed two groupings of stations; the three reference stations formed one group and the four stations near the diffuser formed a second group. In 1994, reference station B2 was grouped with the ZID and near-ZID stations. There was no pattern of lower diversity or evenness for either nonmollusk or mollusk groups at ZID or near-ZID stations relative to the other stations. The long-term pattern of lower species richness at Station B3, as compared to the other stations, was observed only for crustacean species richness and not for other faunal components.
>
> The response patterns of benthic fauna near the Sand Island Ocean Outfall showed little indication of a strong influence by the diffuser effluent."

1996 Benthic Sampling Report Summary1996 Benthic Sampling Report Summary

The following are the conclusions of the September 1996 Benthic faunal sampling near the Sand Island Ocean Outfall conducted under contract to the University of Hawaii at Manoa (Nelson, et. al. 1997a)

> "Benthic fauna in the vicinity of the Sand Island Ocean Outfall was sampled at seven stations along the diffuser isobath in September 1996. Stations were located both within and on the boundary of the zone of initial dilution (ZID) and at distances of 1.2 to 2 km from the ZID boundary. Values for total organic carbon, total Kjeldahl nitrogen, and oxidation-reduction potential showed no indication of significant organic buildup in sediments at any station. Correlations between sediment oil and grease from Sand Island samples and both crustacean abundance and species richness showed no evidence of a negative relationship. Mean nonmollusk abundance was significantly greater at Station B2 than at Stations B1 and B6, and mean nonmollusk taxa richness was significantly greater at Station B5 than at Station B1. Station B2 had significantly greater mean crustacean abundance than Stations B3, B1, and Z and greater mean number of crustacean taxa than all other stations. No other pairwise differences in stations for the nonmollusk or crustacean component of the benthic fauna were significant.
>
> Therefore, there was no general relationship between nearness to the diffuser and mean nonmollusk or crustacean species richness.
>
> Mean mollusk abundance was significantly greater at Station B4, located on the ZID boundary, than at all other stations, and at reference station B2 than at reference station B1 and ZID station Z.
>
> Mean mollusk species richness was significantly greater at Stations B5 and Z, respectively located on the ZID boundary and within the ZID, as compared to all other stations, and significantly greater at ZID-boundary station B4 as compared

> to reference station B1. These patterns show no evidence of a negative effect of the diffuser effluent on mollusks.
>
> Cluster analysis of nonmollusk species composition and abundance showed two groupings of stations; one group consisted of two reference stations (B2 and B6), and the second group consisted of the four stations located near the diffuser outfall (B3, B4, B5, and Z). Station B1 was most different from all other stations in 1996.
>
> There was no pattern of lower diversity or evenness for either nonmollusk or mollusk groups at ZID or near-ZID stations relative to the other stations. The long-term pattern of lower species richness at Station B3, as compared to the other stations, was observed only for the crustacean component and not for other faunal components. The response patterns of benthic fauna near the Sand Island Ocean Outfall showed little indication of a strong influence by the diffuser effluent."

1997 Benthic Sampling Report Summary

August 1997 Benthic Sampling Results Abstract from Swartz, et. al., 1998 PR-98-08 WRRC, University of Hawai'i at Manoa.

> "Benthic fauna in the vicinity of the Sand Island Ocean Outfall was sampled at seven stations along the diffuser isobath in August 1997. Stations were located both within and on the boundary of the zone of initial dilution (ZID) and at distances of 1.2 to 2 km from the ZID boundary. Values for total organic carbon, total Kjeldahl nitrogen, and oxidation-reduction potential showed no indication of significant organic buildup in sediments all stations. Correlations between sediment oil and grease from Sand Island samples and both crustacean abundance and species richness showed no evidence of a negative relationship. There were no significant differences in mean nonmollusk abundance or number of nonmollusk taxa among the stations. There were no significant differences among stations in mean crustacean abundance, although the mean number of noncopepod crustaceans was significantly less at within-ZID station Z and ZID-boundary station B3 than at reference station B6. There were significantly more crustacean taxa at all three reference stations (B1, B2, and B6) than at Station B3 and significantly more crustacean taxa at Station B6 than at Station Z. No other pairwise differences in stations for the nonmollusk or crustacean component of the benthic fauna were significant. Therefore, there was no general relationship between nearness to the diffuser and the abundance and richness of nonmollusks and crustaceans. There were significant differences among stations in mean mollusk abundance and number of mollusk taxa, but the differences showed no evidence of a negative effect of the diffuser effluent on mollusks. For example, mean mollusk abundance was significantly greater at reference station B2 than at ZID station Z or reference stations B 1 and B5. Also. there were significantly more mollusk taxa at ZID station Z than at all three reference stations (B 1, B2, and B6). Cluster analysis of nonmollusk species composition and abundance showed high similarity (> 65%) among all stations.

> Two reference stations (B 1 and B2) were linked together in a weakly defined subcluster, but the third reference station (B6) was clustered with the ZID and ZID-boundary stations. There was no pattern of lower diversity or evenness for either nonmollusk or mollusk groups at ZID or near-ZID stations relative to the other stations. In fact, the highest diversity and evenness values for both mollusks and nonmollusks were observed at ZID-boundary station B5. The long-term pattern of lower species richness at Station B3, as compared to the other stations, was observed only for the crustacean component and not for other faunal components. The response patterns of benthic fauna near the Sand Island Ocean Outfall showed little indication of a strong influence by the diffuser effluent."

1998 Benthic Infaunal and Sediment Quality Survey Summary

August 1998 Benthic Sampling Results Abstract from Swartz, et. al., 1999 PR-99-10 WRRC, University of Hawai'i at Manoa.

> "Benthic fauna in the vicinity of the Sand Island Ocean Outfall was sampled at seven stations along the diffuser isobath in August 1998. Stations were located both within and on the boundary of the zone of initial dilution (ZID) and at distances of 1.2 to 2 km from the ZD boundary. Values for total organic carbon, total Kjeldahl nitrogen, and oxidation-reduction potential showed no indication of significant organic buildup in sediments at any station. Correlations between sediment oil and grease from Sand Island samples and both crustacean abundance and taxa richness showed no evidence of a negative relationship. There were no significant differences in mean nonmollusk abundance among the stations. The only significant difference in number of nonmollusk taxa was a reduction in richness at reference station B 1. There were no significant differences among stations in mean crustacean abundance. ZID-boundary stations B3 and B4, within-ZID station Z, and reference station B1 had fewer crustacean taxa and noncopepod crustacean individuals than reference stations B2 and B6. There were no significant differences in the number of crustacean taxa and noncopepod crustaceans at reference station B 1 and any of the four ZID-boundary and within-ZD stations. These comparisons indicate that the crustacean assemblage at the ZID and near-ZID stations was within the range of natural variability as defined by conditions at all three reference stations. There were significant differences among stations in mean mollusk abundance and number of mollusk taxa, but the differences showed no evidence of a negative effect of the diffuser effluent on mollusks. For example, mean mollusk abundance was significantly greater at reference station B2 and at ZID-boundary station B4 than at all other stations. Also, there were significantly more mollusk taxa at ZID station Z and ZID-boundary station B5 than at reference stations B1 and B6. Cluster analysis of nonmollusk species composition and abundance showed high similarity (>63%) among all stations. Reference and ZID stations were not segregated in the cluster pattern. There was no pattern of lower diversity or evenness for either nonmollusk or mollusk groups at ZID stations

> relative to reference stations. In fact, the highest diversity and evenness values for both mollusks and nonmollusks were observed at ZID-boundary station B5. The long-term pattern of lower species richness at Station B3, as compared to the other stations, was observed only for the crustacean component and not for other faunal components. The abundance and richness of amphipods and all crustaceans increased at all ZID and ZID-boundary stations in 1998. In summary, the response patterns of benthic fauna near the Sand Island Ocean Outfall showed little or no indication of a strong influence by the diffuser effluent."

NOTE: Monitoring Program was changed hereafter with issuance of the December 1998 NPDES permit for Sand Island.

Summary of August 1999 Benthic Sampling Report

These results were completed as part of a regional survey under the auspices of the national EMAP program. The results are not in a published report.

Summary of August 2000 Benthic Sampling Report

The University of Hawaii team of benthic experts provided a comprehensive report to the CCH dated March 2000 (Swartz, et. al, 2000). Their findings were as follows:

> "In August 2000, benthic fauna in the vicinity of the Sand Island Ocean Outfall was sampled at fifteen stations established in 1999. Five stations were located on each of three transects along isobaths of approximately 20 m (Transect C), 50 m (Transect D), and 100 m (Transect E). Each transect included two stations near the diffuser at or inshore of the boundary of the zone of mixing (ZOM) and three stations beyond the diffuser at distances of approximately 2.4 to 2.7 km east, 4.4 to 4.9 km west, and 5.9 to 6.5 km west of the center of the diffuser. The 2000 survey followed the design initiated in 1999. The eleven surveys at this site prior to 1999 were based on seven stations located on one transect (herein called Transect B) at 58 to 77 m, the approximate depth of the outfall diffuser. Measurements of total organic carbon, total Kjeldahl nitrogen, and oxidation-reduction potential showed no indication of significant organic buildup in sediments at any station. The biological data indicate that there are few, if any, negative effects of the Sand Island outfall on the macrobenthic community. Most statistically significant differences in nonmollusk abundance and taxa richness among the fifteen stations were associated with differences among the three transects and reflect the influence of depth-related factors. The abundance and number of taxa of polychaetes, crustaceans, and all nonmollusks were usually significantly greater at several Transect D stations than at many stations on Transects C and E. When stations were pooled by proximity to the outfall, there were no significant differences between the near-diffuser station group and the beyond-diffuser station group in the abundance or taxa richness of polychaetes, crustaceans, and all nonmollusks. Species composition, diversity, and evenness of nonmollusks were also more closely associated with water depth than proximity to the outfall. Cluster analysis of nonmollusk taxa composition and abundance resulted in

three station groups that were associated primarily with the three transects. Most of the relatively few statistically significant differences in mollusk abundance and taxa richness among the fifteen stations were associated with high values at two near-diffuser stations (E2 and E3) and one beyond-diffuser station (E5), as well as low values at three beyond-diffuser stations (El, E6, and D1) and one near-diffuser station (C2A). There were no significant differences in mollusk abundance or taxa richness among transects or between the near-diffuser station group and the beyond-diffuser station group, except for greater taxa richness for the near-diffuser station group. Depth-related differences in mollusk taxa composition resulted in station clusters primarily associated with transects. Transect C stations were grouped in an individual cluster. A second cluster included the five stations on Transect D and three stations on Transect E. A third cluster included beyond-diffuser stations E1 and E6. There was no between-transect grouping of stations that might reflect a common influence of the outfall on either the mollusks or nonmollusks. There were no significant pairwise contrasts in the abundance and taxa richness of mollusks at Transect C, D, or E in 1999 and 2000, nor at Transect B in any previous sampling year. The abundance and taxa richness of nonmollusks and crustaceans were significantly greater at Transect D in 1999 and 2000 than at Transect B in several previous years, and significantly less at Transects C and E in 1999 and 2000 than at Transect B in many previous years. The temporal differences in nonmollusks among Transects B, C, D, and E are probably associated with water depth. There is no indication of a negative temporal trend over the thirteen study years of the diffuser effluent on the macrobenthos. In summary, the response patterns of benthic fauna near the Sand Island Ocean Outfall in 2000 showed little or no indication of a significant influence by the diffuser effluent."

More specific results of relevance to determining if there are discernible impacts from the Sand Island discharge on the benthic community including the following:

Sediment Quality

Sediment grain-size distribution differed among stations with sediments at all stations composed of less than 17% silt and clay.

The direct electrode measurements of ORP were positive in the range of 35 to 185 mV and at these levels showed no evidence of strongly reducing conditions at either the near-diffuser or beyond-diffuser stations. Mean ORP was significantly higher at Transect C stations (159 mV) than at Transect D stations (112 mV) and Transect E stations (111 mV). Statistical evaluation showed that there were no significant differences between beyond-diffuser stations (126 mV) and near-diffuser stations (129 mV) (t = 0.257, p = 0.799). Values of ORP measured in 2000 on the C, D, and E transects were similar to those measured in 1997 and 1998 on the B transect and in 1999 on the C, D, and E transects. The similarity of ORP measurements at beyond-diffuser stations and near-diffuser stations indicates the effluent is not causing an increase ill reducing conditions in the vicinity of the outfall.

TKN values ranged from 126 to 332 mg/kg at beyond-diffuser stations and from 127 to 338 mg/kg at near-diffuser stations. Statistical comparisons are limited because of the lack of replicate samples at stations on Transect E. However, there were no significant difference in mean TKN among Transect C (226.1 mg/kg), Transect D (226.9 mg/g), and Transect E (252.2 mg/kg) (ANOVA. F = 0.339, p = 0.716) or between beyond-diffuser stations (220.2 mg/kg) and near-diffuser stations (248.8 mg/kg) (t = 1.163, p = 0.257). The monitoring report concluded that there was no evidence of nitrogen enrichment in sediments at stations near the outfall.

Sediment TOC values ranged from 0.24% to 2.08% with the TOC concentrations ranging from 0.28% to 2.08% at beyond-diffuser stations and from 0.24 to 1.21% at near-diffuser stations. The highest TOC value was recorded at beyond-diffuser station D5 (2.08%). Statistical comparisons are limited because of the lack of replicate samples at stations on Transect E. However, there *were* significant difference in mean TOC among transects. TOC was significantly higher at Transect D (mean 1.06%) than at Transect C (0.60%) and Transect E (0.37%) (ANOVA, with square root transformation, F = 8.392, p = 0.002). There were no significant differences in TOC between beyond-diffuser stations (0.76%) and near-diffuser stations (0.7051) (t = 0.294, /~: 0.772). There is no evidence of organic carbon enrichment in sediments at stations near the outfall.

Biological Parameters

The nonmollusk fraction of the benthic fauna included polychaetes, oligochaetes. nematodes, platyhelminths, chaetognaths, sipunculans, nemerteans, echinoderms, anthozoans. a hydrozoan species, priapulids, a bryozoan species, a kinorhynch species, hemichordates. urochordates, chordates, insect larvae, amphipods, copepods, cumaceans, decapods, isopods. ostracods, tanaids, and a mysid. The insect larvae, possibly originating in the sewage treatment facility or nearby environment, but definitely not marine in origin, were found at Stations C3A. C5A, D1, and D6.

The polychaete community, comprised of the most abundant and speciose soft-bodied invertebrates at this site, is comparable to that reported annually from 1991 through 1999 (Nelson et al. 1992a, 1992b, 1994, 1995. 1996, 1997: Swartz et al. 1998, 1999, 2000). Polychaetes are such a diverse group of invertebrates in tropical ecosystems that analysis of their role in benthic communities is essential to understand ecological conditions at this ocean outfall site. How polychaetes feed and what they eat, how they move around, how they stabilize and redistribute sediments, and what is known about their reproduction and life history are aspects of their biology that are relevant to this community analysis.

The five most abundant molluscan taxa were *D. scorpulum, Cerithidium perparvulum, Finella pupoides, Scaliola* spp., and *Balcis* spp. Together, these five taxa accounted for 58.9% of the total mollusk abundance. The same five taxa were the numerically dominant mollusks collected on Transect B from 1994 through 1998 (Nelson et al. 1995, 1996, 1997; Swartz et al. 1998. 1999).

The most abundant mollusks were four species of detritivores and the parasite *Balcis,*which feeds on holothurians and sea cucumbers. The presence of so many *Balcis* shells on Transects D and E may be interpreted as an indication of numerous sea cucumbers and/or sea urchins in the area.

The low overall similarity reflects the new survey design initiated in 1999, i.e., sampling of stations along three different depth contours represented by Transects C, D, and E. The dendrogram shows two primary clusters of stations: one corresponds to Transect C; the other contains a mixture of the five Transect D stations and three Transect E stations (E2, E3, and E5).

There was no well-defined, between-transect grouping of stations that might reflect a common influence of the outfall. The cluster pattern in 2000 is associated primarily with the direct and indirect influences of water depth on the mollusks.

There were no significant differences in the number of mollusk individuals or taxa among Transects C, D, and E (Table 2). There were no significant differences in the abundance of mollusks ($t = 1.97$, $p = 0.055$) between beyond-diffuser stations and near-diffuser stations. There were significantly more mollusk taxa at near-diffuser stations than at beyond-diffuser stations ($t = 2.25$, $p = 0.030$).

The crustacean community across the expanded study area can still be characterized as relatively abundant and moderately diverse, dominated by small forms (copepods, ostracods, tanaids, isopods, and amphipods) with scattered, occasionally abundant collections of small decapods. Collections in 2000 yielded 41 discrete crustacean taxa, the same as in 1999. This is not significantly higher than the average number of taxa (about 39) collected at Transect B from 1990 through 1998. There were only two newly collected taxa in 2000. This brings the total number of discretely identified/reported taxa in eleven years to 95. Copepods are enumerated as a single taxon, although several different species are present. Cumaceans also have not been identified to the species level, even though several species may be present.

A rather comprehensive picture of the crustacean community in the study area has been developed for specimens smaller than 1 cm over the last eleven years, despite the rather small aerial coverage (45.4 cm^2) of the sediment samples. This is demonstrated by the fact that the two new records for 2000 were represented only by one specimen. Although neither of the new species *(Pandanus* cf. *brevis* and Dorippe sp. A. had previously been collected, they are not unexpected members of a deep reef-slope community. These new records do not indicate any significant change in the picture of the crustacean community which has been developed over the previous ten years. Larger (>2 cm) shrimps and crabs, while certainly present in the sampling area, have little chance of being collected by the van Veen grab. In general, the crustacean fauna in the Sand Island study area is somewhat less diverse than that in comparable study areas near the Honouliuli and Wai'anae WWTP outfalls.

The influence of environmental factors associated with water depth on crustacean abundance and taxa richness is evident in the differences among transects in 2000. Crustacean abundance and taxa richness were higher at most stations on Transect D than at most stations on Transect C or Transect E. These differences were not usually statistically significant because of the low number of replicate samples (three) per station and the inherent variability in the depauperate crustacean assemblages at most stations on Transects C and E. Comparisons of pooled samples on each transect showed that both crustacean abundance and taxa richness were significantly greater at Transect D than at Transects C and E. It also showed that crustacean taxa richness was significantly greater at Transect E than at Transect C.

Shallower depth, greater wave-induced sediment perturbations, and coarser sediment grain size may have contributed to the depauperate crustacean fauna on Transect C, but these factors do not explain the reduced abundance and diversity of crustaceans on Transect E. Comparison of mean crustacean abundance between beyond-diffuser stations (28.0 individuals) and near-diffuser stations (30.9 individuals) revealed no significant difference ($t = 0.278$, $p = 0.782$). Similarly, there was no significant difference in mean number of crustacean taxa between beyond-diffuser stations (5.6 taxa) and near-diffuser stations (5.3 taxa) ($t = 0.262$, $p = 0.794$). Proximity to the outfall does not appear to be related to the reduced crustacean fauna on Transects C and E.

Amphipod crustaceans are considered good biological indicators for the effects of wastewaters discharged from ocean outfalls. No amphipods were collected at Stations C1A, C2A, and C6 in 2000, but a relative large number of amphipod individuals (49) and taxa (6) were collected at Stations C3A and C5A, respectively. Amphipods were collected at all stations on Transects D and E. The most amphipod individuals (70) and taxa (8) were collected at near-diffuser station D2. The presence of phoxocephalid amphipods at near-diffuser stations has been used as an additional indicator of significant sediment contamination (Swartz et al. 1998,1999). In 1997 and 1998, collections on Transect B included individuals of *Paraphoxus* sp. A. Phoxocephalids were rare throughout the study area in 1999 and 2000; a single specimen of *Paraphoxus* sp. A was collected at Station E1 in both years.

In summary, there is no evidence that crustaceans, including stress-sensitive amphipods, are negatively affected by proximity to the Sand Island Ocean Outfall. Station D2, immediately inshore of the end of the outfall, had the highest mean crustacean abundance and taxa richness recorded at any of the fifteen stations. Beyond-diffuser station D1 had the lowest mean crustacean abundance and taxa richness on Transect D. The low level of sediment organic enrichment on Transects C and E indicates that noncontaminant factors may be responsible for the depauperate crustacean assemblage on those transects.

Summary of August 2002 Benthic Sampling Report

August 2002 Benthic Sampling Results Abstract from Swartz, et. al., 2003 PR-2002-04 WRRC, University of Hawai'i at Manoa.

> "In August 2002, benthic fauna in the vicinity of the Sand Island Ocean Outfall was sampled at fifteen stations established in 1999. Five stations were located on each of three transects along isobaths of approximately 20 m (Transect C), 50 m (Transect D), and 100 m (Transect E). Each transect included two stations near the diffuser at or inshore of the boundary of the zone of mixing (ZOM) and three stations beyond the diffuser at distances of approximately 2.4 to 2.7 km west, 4.4 to 4.9 km east, and 5.9 to 6.5 km east of the center of the diffuser. The 2002 survey followed the design initiated in 1999. The eleven surveys at this site prior to 1999 were based on seven stations located on one transect (herein called Transect B) at 58 to 77 m, the approximate depth of the outfall diffuser. Measurements of total organic carbon, total Kjeldahl nitrogen, and oxidation-reduction potential showed no indication of significant organic buildup in sediments at any station. The biological data indicate that there are few, if any, negative effects of the Sand Island outfall on the macrobenthic community. Most statistically significant differences in nonmollusk abundance and taxa richness among the fifteen stations were associated with differences among the three transects and reflect the influence of depth-related factors. The abundance and number of taxa of polychaetes, crustaceans, and all nonmollusks were usually significantly greater at several Transect D stations than at many stations on Transects C and E. When stations were pooled by proximity to the outfall, there were no significant differences between the near-diffuser station group and the beyond-diffuser station group in the abundance or taxa richness of polychaetes, crustaceans, and all nonmollusks. Taxa composition, diversity, and evenness of nonmollusks were also more closely associated with water depth than proximity to the outfall. Cluster analysis of nonmollusk taxa composition and abundance resulted in station groups that were associated primarily with the three transects. Most of the statistically significant differences in mollusk abundance and taxa richness among the fifteen stations were associated with high values at two near-diffuser stations (C3A and E3) and one beyond-diffuser station (E5), as well as low values at three beyond-diffuser stations (EI, E6, and C1A) and one near-diffuser station (C2A). There were no significant differences in mollusk abundance or taxa richness among transects or between the near-diffuser station group and the beyond-diffuser station group. Depth-related differences in mollusk taxa composition resulted in station clusters generally associated with transects. Four Transect D stations were grouped in an individual cluster. Another cluster included three stations on Transect C. Stations E3 and E5 were also linked together. There was no between-transect grouping of stations that might reflect a common influence of the outfall on either the mollusks or nonmollusks. There were no significant pairwise contrasts in the abundance and taxa richness of mollusks at Transect C, D, or E in 1999, 2000, and 2002, nor at Transect B in any previous sampling year. The abundance and taxa richness of nonmollusks and crustaceans were often significantly greater at Transect D in 1999, 2000, and 2002 than at Transect B in several previous years, and often significantly less at Transect C in 1999, 2000, and 2002 and at Transect E in 1999 and 2000 than at Transect B in many previous years. The abundance and

taxa richness of nonmollusks and crustaceans were greater at Transect E in 2002 than in 1999 and 2000. The temporal differences in nonmollusks among Transects B, C, D, and E are probably associated with water depth. There is no indication of a negative temporal trend over the fourteen study years of the diffuser effluent on the macrobenthos. In summary, the response patterns of benthic fauna near the Sand Island Ocean Outfall in 2002 showed little or no indication of a significant influence by the diffuser effluent."

Summary of Results to Date

The 1986 Sand Island study (Nelson et al., 1987) was the first for the Sand Island outfall and was one of three studies of the benthic communities conducted in 1986 in proximity to ocean outfalls on the Island of O'ahu as part of a newly developed ocean monitoring program. The other two reports (Nelson, 1986; Nelson et al., 1987) described benthic communities around the Honouliuli WWTP's Barbers Point Ocean Outfall 12 kilometers to the north in Mamala Bay and the smaller Mokapu ocean outfall discharging secondary effluent from the Kailua-Kaneohe WWTP on the windward side of the island. The studies showed that data for Mamala Bay were consistent and the Mamala Bay outfalls were relatively comparable (Nelson et al, 1988). Benthic conditions in Mamala Bay are relatively uniform (protected south shores with sandy bottoms) and both the Sand Island and Honouliuli discharges are at the same relative depth (61 meters) compared to the shallower (33 meters) Mokapu outfall on the more exposed coastal area off Kailua Bay, thus the results are not unexpected.

These and subsequent benthic studies done over a period of years have revealed that faunal composition and abundance of individuals documented in the Sand Island study were similar to those found in the Honouliuli discharge area with both the abundance and number of species dominated by polychaetes.

Sediment Characteristics

The 1986 Sand Island survey showed that there was increase in sediment organic load as a result of wastewater discharge (Nelson et al. 1987b) as measured by the gradient of the percentage of total volatile solids (TVS) measured with distance from the outfall. Sediment oxidation-reduction potential (ORP) values revealed that the sediments at all stations were oxygenated. Similar patterns of TVS and ORP were seen at the other two ocean outfalls (Dollar, 1986; Nelson, 1986; Nelson et al., 1987a). Since that time, there has been no evidence collected of an increased loading of organics to sediments near Sand Island outfall (Swartz, et. al., 2003).

Sediment Organic Enrichment

Overall, sediment analysis has shown that the ORP values were significantly higher at near-diffuser stations than at beyond-diffuser stations. This indicates that the effluent is not promoting anaerobic conditions near the outfall.

There were no significant differences in sediment TKN among transects or between the near or beyond-diffuser stations with the range of concentrations (133 to 336 mg/Kg) indicative of low organic content with no indication of build-up within the ZOM.

Sediment total organic carbon (TOC) values ranged from 0.23 -2.08% in recent years (1999-2002) with lower values in 2002 (0.23-0.578%). There were no significant differences in mean TOC among transects or between near-versus-beyond diffuser stations in 2002 indicating that there continues to be no sediment organic enrichment.

Macrobenthic Community Measures

The studies of the benthos done annually show that the taxa composition and abundance in the study area is determined primarily by factors related to water depth and natural factors rather than outfall effects. There is no clear segregation found between near- and -beyond diffuser stations for almost all parameters measured. The high faunal similarity index observed at Sand Island does not indicate substantial biological perturbation that could be attributable to outfall-related factors.

The evaluation of the molluscan community showed no well-defined between-transect grouping of stations that might reflect a common influence of the outfall. The same applied to the non-molluscan community.

Temporal changes were evaluated at was found that any differences among the mean number of taxa and their abundance and it was found that for the major groups analyzed (molluscs, polychaetes, and crustaceans) all differences were not related to proximity to the outfall and a probably related to water depth and other non-outfall factors.

Overall, there is no evidence from the 14 years of study that there are negative impacts on the benthic community associated with the Sand Island outfall discharge.

Other Community Parameters

Results of the sampling done at the seven benthic stations (B Stations) from 1986 through 1998 showed no indication of trends in either abundance or species richness for any of the three faunal fractions examined (Nelson et al., 1997 and Swartz, et. al., 2003) and supports the finding that the Sand Island outfall benthic sampling area was not receiving excessive organic matter input sufficient enough to change conditions such that stress was induced on the biological community as described in the Pearson and Rosenberg (1978) model. Key biological indices calculated from the data showed that diversity (H.) and evenness (J) indices showed little relationship to abundance and species richness values, with no distinct pattern attributable to proximity to the outfall (Swartz, et. al., 2003).

~~Mollusks were the only group of species to show a consistent, although only minor,~~ reduction in diversity that compared to the reference stations. This trend observed in 1986 was supported by the relative percentage dominance of the most abundant mollusk species. However, such trends among mollusks have not been observed in subsequent years (Nelson et al., 1991, 1992a, 1992b, 1994a and 1994b).

Tetra Tech in its review of the first benthic studies conducted in 1984 and 1985 concluded that diversity values were nearly the same for each station indicating that the diversity at the three stations near the outfall was similar to the diversity at the control station. Values of the dominance index (defined as the minimum number of taxa that account for 75 percent of the total abundance) also exhibit no significant differences ($p > 0.05$) among stations. This conclusion was consistent with the observations made through 1998 at the B Stations. With the new stations and variable-depth transects, the diversity values have changed and can be attributable to natural variations in habitat.

Indicator Species

Indicator species are always of interest in studying the effects of outfalls. Early findings from Honouliuli (Nelson et al. 1987a) initially suggested that the polychaete *Pionosyllis gesae* (*Pionosyllis* sp. A; Nelson, 1986) might be a potential indicator organism for sewage outfalls in Hawai'i waters. It was observed that this species had slightly elevated abundances at ZID stations at Mokapu and Sand Island but not at the Barbers Point outfall stations. Nelson (1993) indicated that in subsequent studies, his initial suggestions were not supported and this species turned out not to be a consistent indicator organism in Hawaiian waters.

Another species, the chordate *Branchiostoma sp.* A (= *Amphioxus* sp A., in Nelson 1986) tended to have increased abundance at near-ZID stations in the Sand Island study area and was a potential indicator. However, data from Barbers Point showed this species to be a dominant organism but there was no significant differences among stations, thus the lack of a a consistent pattern of response showed that the outfall is not the primary influence on the abundance of *Branchisotoma.*

Two other dominant species examined in the Barbers Point outfall study exhibited patterns of abundance that might have been outfall related. These were gastropods (*Cerithidium perparvulum* and *Diala scopulorum*). *Cerithidium perparvulum* was a dominant species at the Mokapu and Sand Island study areas (Nelson, 1986, 1987a), as well as at Barbers Point (Nelson et al., 1987b). At the Sand Island and Mokapu study areas , this species tended to be present in lower abundances at the ZID and near-ZID stations, although in patterns were not statistically significant (Nelson, 1993). Although not analyzed statistically, mean abundance number for Sand Island (Nelson, 1986), suggested a trend that was exactly the opposite of the other two outfalls. *Diala scopulorum* was a dominant species at both the Sand Island and Barbers Point areas, but was absent from the Mokapu area. At Barber's Point, analysis suggested a trend towards increasing abundance at ZID and near-ZID stations with the opposite trend occurring at the Sand Island area (Nelson, 1986). After studying the two species over the years, Nelson (1993) conclude that "the lack of a consistent pattern of response indicates the Barber's Point outfall probably does not have the primary influence on the abundance of these two mollusk species."

In summarizing the abundances of individual species and the use of indicator species near the three Oahu outfalls performed in 1986, Nelson (1988) concluded that:

> " The contradictory indications of patterns in mollusk shell abundance from different study areas suggested that neither of the two species examined above responded in a reliable fashion to the proximity of an outfall diffuser. The species of non-mollusk taxa also appeared inconsistent in their spatial pattern of abundance in relation to outfall location. It would appear that individual species patterns of abundance are generally an unreliable indicator of outfall effects in Hawai'i waters. This may occur because such effects are extremely minimal and the abundance of benthic organisms in these systems are instead responding primarily to other factors unrelated to the outfalls."

Indicator Species

Ophryotropha adherens is regarded as an indicator species and was abundant at all near-diffuser stations from 1993 through 1998 and absent at some beyond-diffuser stations in 1997 and 1998. With the new sampling regime, this species was not collected at eleven of the fifteen stations with abundances much reduced over past sampling surveys (Swartz, et. al. 2003).

Another dominant near-diffuser worm *Neanthes arenaceodentata* was once dominant at Stations B3 and Z prior to 1993, was virtually absent from 1993 to 1995 but again dominant in 1996, 1997 and 1998, especially at Station Z. Only two specimens were collected in 1999 (one each at Station E2 and E3), none in 2000 and only one at station E1 in 2002. This further confirms the findings that organic enrichment and biological effects are minimal or non-existent near the outfall diffuser.

The presence of crustaceans, particularly stress-sensitive species, near the outfall in the same relative abundance as beyond-diffuser stations shows there is an absence of outfall-related effects.

Distinctive Habitats

There are no distinct habitats of limited distribution, either within or beyond on the ZID of the Sand Island outfall. The outfall pipe's armored rock form the most distinctive habitat in the area and provide habitat, holes, crevices, and attachment sites for various species. It forms a large artificial reef which increases productivity and faunal diversity. However, observations on the Sand Island discharge site have revealed no coral formations near the diffuser (Russo, 1981 and Brock,1998). Most of the bottom at the discharge site appears to consist of sandy sediments with little bathymetric relief. The most prominent feature is the armor rock which forms an artificial reef. Invertebrates observed living on the pipeline and armor rock have included spiny lobsters, sea urchins and sea cucumbers.

NEARSHORE ENVIRONMENT

Reefs are derived from the processes of living animals and plants that colonize rocky islands and shorelines. Therefore, in order to understand the distribution and history of reefs in Hawaii an understanding of the distribution and history of the islands they live on is important to put the impacts of human activities in perspective.

Coral Reefs

The Hawaiian islands are one of the largest and most isolated island chains in the world, stretching from Hawaii island in the south-east to Kure atoll in the north-west, a distance of over 2300 kilometers. Geological evidence suggests that all of the islands were formed over a volcanic "hot spot" at a location similar to where the island of Hawaii lies today (Macdonald and Abbott, 1970). Due to continental drift, the ocean floor moves to the north-west, forming a chain of islands over the hot spot. As a result, the islands of Hawaii vary in age from less than a million years (Hawaii island) to over 26 million years (Midway). Because of this volcanic origin and remoteness, biological communities, particularly coral reefs, developed slowly.

Coral reefs are formed over long periods of time by the accumulation of skeletons and sediments from algae, corals, snails, urchins and other calcareous organisms which become accreted together by the actions of encrusting coralline algae. Over hundreds to thousands of years these accretions form a solid framework, or reef, close to shore called a fringing reef. Most of the reefs in the main Hawaiian islands (Hawaii to Kauai) are fringing reefs. However, as time progresses and an island moves off the volcanic hot-spot, they begin to sink and erode and reefs grow outward, away from shore, to form a barrier reef. The only true barrier reefs in the main Hawaiian islands are in Kaneohe Bay on Oahu and on the north coast of Kauai. Over time, some islands sink below the surface of the ocean and all that remains above the surface is a ring of living reef and its accumulated sediment which is an atoll.

All of the Hawaiian islands northwest of Gardener Pinnacles, the last rocky island in the chain, are either atolls or submerged shoals (Grigg, 1983). Thus, due to their geologic history, there is considerable variation in reef structure in Hawaii.

In comparison to the islands themselves, the current reefs are geologically young due to changes in sea level which expose or drown living reefs. About 17,000 years ago sea level was as much as 121 meters less than today and has been rising ever since (Jackson, 1992). Most living reefs in the world are 7,000-9,000 years old, a time when sea level change slowed to less than 2 meters per century, which is generally considered to be the maximum rate of reef growth (Jackson, 1992). However, in many cases coral re-colonizes older drowned reefs and continue the historical pattern of reef development thus helping to preserve the long-term patterns of fringing reef, barrier reef, and atoll development.

Because corals grow slowly it would take many decades to directly observe how they develop into mature coral communities. However, on the island of Hawaii, reef development can be inferred by comparing reefs that colonized lava flow of varying age. Grigg and Maragos (1974) describe the variation in coral reef communities among lava flows in Puna and Kona that varied in age from 1.6 to 102 years. These researchers found that reefs generally take 20-50 years to develop, but that the process is influenced by the degree of exposure to ocean waves. Reefs on the wave-exposed

Puna coast were fully developed after 20 years, while it took over 50 years for reefs to fully develop in the more wave-protected Kona coast (Grigg and Maragos, 1974). The younger reefs were characterized by a low abundance (or bottom cover) of coral, which consisted primarily of the highly branched cauliflower coral or *koa* (*Pocillopora meandrina*). On older reefs, coral cover was higher, and other species had colonized and increased in abundance such as the massive lobe coral or *puna* (*Porites lobata*) and flat, encrusting rice corals (*Montipora verrucosa* and *M. patula*). Thus, reef communities will vary due to differences in age and the exposure to waves which play a major role in their ecological interactions and transport of nutrients and particulate materials.

On Oahu, the best developed reefs occur on wave-protected leeward coasts, such as Hanauma Bay (UNEP/IUCN, 1988). Corals have a very low tolerance for fresh-water and terrestrial sediments and hence do not form well-developed reefs near large steams and rivers. In addition, coral growth rates are highest in the main Hawaiian islands and decrease in the northwest Hawaiian islands with decreasing temperatures and available sunlight (Grigg, 1983). Towards the northwest end of the island chain rates of reef growth and accretion are insufficient to keep up with reef erosion and island subsidence and reefs drown. This threshold is known as the "Darwin Point" (Grigg, 1982).

Over 80% of reefs in Hawaii lie among the northwest Hawaiian Islands, which extend some 1,300 miles from Kauai to Kure Atoll. The condition of reefs off of these remote islands are presumed to be good and reef fish standing stocks are also higher than the exploited areas near the bigger, populated islands such as Oahu. The coral reefs in nearshore state waters are generally overfished and some reefs are degraded due to coastal development. A 1997 review of coral reef health in Hawaii concluded that 90% of coral reefs in the main Hawaiian Islands are healthy with the best developed reefs are in state waters located in embayments sheltered from damage caused by storms and open ocean swells (Grigg, 1997). Embayments, such as Kaneohe Bay are sites of reef degradation due to coastal pollution from nutrient enrichment from nonpoint sources.

The biodiversity of reef corals in Hawaii is low with 47 species, compared to Indo-West-Pacific region where over 500 species have been identified (Maragos, 1995). Storm damage and habitat depths are major factors that affect species diversity and the community structure of reefs in Hawaii (Grigg and Dollar, 1980; Grigg and Maragos, 1974; Grigg, 1983) as has been noted in the nearshore dive surveys conducted off Sand Island and other areas (Brock, 1998). Human-caused problems have an important impact on coral reefs in selected areas such as Haunama Bay (Grigg, 1997).

Ecological interactions among reef organisms and their relationship with the physical environment also have a strong effect on the abundance and distribution of organisms on coral reefs. Dollar (1982) described zonation patterns typical of Hawaiian reefs which consists of a boulder zone, a reef bench, a reef slope zone and a reef rubble zone.

The boulder zone is close to shore in shallow water, and is characterized by a low cover of cauliflower coral intermixed with algal-covered boulders. There is high wave energy and natural terrestrial runoff (fresh water and sediments) prevents most reef development. It serves as habitat many species of *limu* (algae), small invertebrates and shore-fishes. Immediately *makai* (seaward), at 2-4 m depths is the reef bench zone which is a wave-swept area dominated by a higher cover mostly lobe coral, which builds massive wave-resistant colonies. In Hawaiian waters, the greatest diversity of corals is found in this area including lobe coral, cauliflower coral, rice corals, and at least 5 other common coral species. A wide variety of seaweeds, other invertebrates, and shore fishes is found in this habitat.

Burrowing worms such as the Christmas tree worms (*Spirobranchus gigantea*) which are commonly found burrowed into lobe coral and feather duster worms (*Sabellastarte sanctjosephii*) which burrow into rocks and rubble are common. Both of these species filter suspended particles in seawater to obtain food. Other burrowing invertebrates are the boring urchins or *'ina* (*Echinometra mathaei* and *E. oblonga*) which help create sediments which ultimately contribute to reef growth. In contrast, collector urchins or (*Tripneustes gratilla*) (species used for bioassay testing of Sand Island effluent) are common out in the open grazing on encrusting and filamentous seaweeds which cover the rocks. Laying around on sand patches are *loli* or black sea cucumbers (*Holothuria atra* and *H. nobilis*) and brown speckled sea cucumbers (*Actinopyga mauritiana*) which obtain food by digesting organic material in ingested sediments. Under rocks and in caves are slipper lobsters or *ula papa* (*Paribaccus antarcticus*) and spiny lobsters or *ula* (*Panulirus marginatus*) a species sought after as food. Fishes are abundant and diverse in this area and are dominated primarily by parrotfish or *uhu* and surgeonfishes, such as convict tangs or *manini* (*Acanthurus triostagus*), brown surgeonfish or (*Acanthurus nigrofuscus*), orange-band surgeonfish or *nanae* (*Acanthurus olivaceus*), goldring surgeonfish or *kole* (*Ctenochaetus stigosus*), and yellow tangs or *lau'pala* (*Zebrasoma flavescens*). These fishes are herbivores and graze the rocks and dead coral clean of seaweeds. Some parrotfish also eat live coral and contribute to the generation of sediment which contributes to beach development and reef growth (Randall, 1996). Other common nearshore fishes are moray eels or *puhi* (mostly *Gymnothorax meleagris* and *G. flavomarginatus*), several types of wrasses, triggerfish, puffers and butterflyfishes of all types.

Green sea turtles or *honu* (*Chelonia mydas*) , a listed threatened species can be found sleeping under ledges and in caves in this region of the reef. Large numbers of green sea turtles are found in Kaneohe Bay.

Further seaward the reef drops off steeply to the reef slope zone, which is dominated by a very high cover of finger coral or (*Porites compressa*) to a depth of 20-30 m (Dollar, 1982). In this zone, wave forces are minimal and conditions for reef growth are optimal. Hawaiian reefs protected from waves are almost always dominated by finger coral, whose thin vertical branches quickly overgrow other coral species which indicate ~~finger coral is the dominant coral competitor on Hawaiian reefs (Maragos, 1972). In~~ holes on the reef are found herbivorous slate-pencil urchins (*Heterocentrotus mammillatus*) and black sea urchins or *wana* (*Echinothrix calamaris* and *E. diadema*).

Crown-of-thorns seastar (*Acanthaster planci*) or cushion seastar (*Culcita novaeguineae*), both of which consume live coral polyps are sometimes observed.

Commonly observed are the variety of butterflyfishes, notably threadfin butterflyfish (*Chaetodon auriga*), four-spot butterflyfish (*C. quadrimaculatus*), raccoon butterflyfish (*C. lunula*), ornate butterflyfish (*C. ornatissimus*) and multi-band butterflyfish (*C. multicinctus*). Several of these fish species are obligate coral eaters and their presence signifies a "healthy" reef (Reese, 1993). Other fishes commonly found in this deeper area include hawkfish (*Cirrhitus* and *Paracirrhites*), snappers (*Lutjanus*), and damselfish such as Hawaiian sergeants or *mamo* (*Abudefduf abdominalis*), the Pacific gregory (*Stegastes fasciolatus*), the Hawaiian dascyllus or *alo-'ilo'i* (*Dascyllus albisella*), which is commonly found in cauliflower coral heads, and a diverse mix of wrasses (Family Labridae). Goatfish (*Parupeneus* and *Mulloidichthys*) are also frequently seen digging in sand patches on the reef for worms, crustaceans and small mollusks. In some areas, white-tipped reef sharks (*Traenodon obesus*) can be found resting in caves and ledges or swimming slowly along the reef.

Below 20-30 m is the rubble zone which is characterized by accumulations of broken coral fragments intermixed with a small amount of live lobe coral and sand (Dollar, 1982). Common invertebrates in this area include black sea cucumbers and many types of burrowing worms. Hawaiian dascyllus may occur here on isolated coral heads along with an occasional triggerfish. On sand flats in areas with moderate currents you may see garden eels (*Gorgasia hawaiiensis*) extending out of their sand burrows.

Impacts of Wastewater, Urban Runoff, and Stormwaters on Corals

Because corals contain internal microscopic plants called zooxanthellae, they receive much of their energy from sunlight via photosynthesis. In addition, their calcareous skeletons are fragile and grow slowly. As a result, corals are easily broken are sensitive to changes in the quality of coastal waters.
For example, pollution from sewage and a variety of non-point source contaminants changes the nutrient content of local waters and can alter the community structure of our reefs. In the past , the large sewage discharge of untreated wastewater in the shallow waters off of Oahu had major negative impacts on coral reefs which have taken many years to recover (Grigg, 1995). In Kanehoe Bay, changes in nutrient concentration associated with sewage discharges are responsible for the proliferation of bubble algae (*Dictosphaeria caveronasa*), which overgrew reefs and killed coral (Maragos, et al., 1985). Perhaps a similar mechanism is responsible for the west Maui "algal problem" where species of the green alga *Cladophora* and the introduced red alga *Hypnea* are covering corals and killing the reef.

Reefs are also damaged by the runoff of terrestrial sediments, which smother and kill reefs (Rogers, 1990). Sugar mills can produce large amounts of sediments and can create a "sludge bank" devoid of coral in an area 0.5 km from the mills discharge ~~(Grigg, 1972). On Kaho'olawe, bombing by the military and grazing by feral animals has~~ stripped the land of terrestrial vegetation resulting in massive amounts of sediments washing into the ocean and destroying reefs (KIR, 1997).

Other Activities that Impact Reefs

Other problems include damage by boat anchors (Davis, 1977) and swimmers (Talge, 1990), which smash and crush reefs; and the massive removal of herbivorous fishes through overfishing. Perhaps of greater long-term concern is that we are slowly increasing the Earth's temperature through global warming, which promotes reef destruction through coral bleaching (Glynn, 1991, 1993).

Coral Reef and Nearshore Transect Studies

Prior to the 1998 NPDES permit for Sand Island, the City had been required to conduct nearshore biological surveys to assess habitat and biological conditions. The City had contracted with Richard E. Brock, Ph.D., to conduct studies to determine the status and impacts of shallow marine communities inshore of the Sand Island diffuser which are focused largely on the impact on coral reef communities. These studies were designed and work inititated in 1990 and were done annually for nine years. Three permanent sites were selected and marked with two transects each, for repeated sampling over time (See Attachment G-4 for details. It contains a summary report for the last year of the program completed in 1998). These sites, designated Station A (Kewalo Landfill) (Transects 1 and 2), Station B (Kalihi Channel) (Transects 3 and 4) and Station C (Reef Runway) (Transects 5 and 6) (Figure 1 in Attachment G-4). Station A located some 600 meters offshore of the old Kewalo Landfill served as a control area. This station lies east of the Sand Island outfall in 17-18.2 meters of water with the substratum dominated by limestone and moderate coral community development. Station B was located about 2.2 km seaward of Mokauea Island in Ke'ehi lagoon and about 900 meters west of the old shallow water outfall near the entrance to Kalihi Channel. Water depths range from 13.7 to 15.0 meters in depth with a sand and rubble bottom. Station C was called the Reef Runway Station and lies between 760 and 840 meters seaward of the runway of Honolulu International Airports Reef Runway in waters with a depth of 7.5 to 12 meters in depth. The substrate in this area is a mosaic of emergent limestone spur and groove formations grading seaward into a series of low limestone mounds with sand in between.

Results of the surveys are contained in reports prepared for the CCH by Dr. Brock each year with the latest in 1998 which contained a summary of the results for the entire survey period (Brock, 1998)(Entire report presented in Attachment G-4).

This report summarizes what is known about the nearshore area surveyed and includes a variety of community measures. Measures taken included the percent coral cover, number of coral species, number of coral species, number of macroinvertebrate species, number of macroinvertebrate individuals, number of fish species, total number of fish individuals and the estimated biomass of fishes at each of the survey stations).

The biological parameters measured in the nine annual surveys are summarized in Table 9 of Attachment G-4. The data showed that the most diverse marine community was found at the Kewalo Landfill station followed by the Reef Runway station with the least diverse site being the Kalihi Entrance Channel station. This condition has not materially changed over the years with the notable exception of the high number of

Christmas tree tubeworms (*Spirobranchus giganteus corniculatus*) in 1998 due to what appears to be enhanced recruitment to the local coral (*Porites lobata*) colonies.

What is noteworthy is that these studies showed no significant changes through the period of this study that could be attributable to wastewater discharge practices of the Sand Island Ocean Outfall.

Reef Fish Community Structure

A total of 85 species from 23 families were observed in the nearshore areas over a nine year period in which annual diving surveys along defined transects were performed (Brock, R. E., 1998). This area has a greater abundance of fish than found in the deeper offshore waters near the outfall because there is more structure and habitat in the form of coral reefs. A listing of the species observed over the years is presented in Table G-2. Over half of the species found at the outfall are also found in the nearshore waters. Those fish species common to both areas are listed in Table G-3. Table G-4 contains the listing of all the species observed over the years along with their Hawaiian names.

The nearshore fish community observations over the years showed on individual transects where fish were counted that the number of species ranged from 10 to 38 with the number of individuals ranging from 20 to 554. The most abundant fish was the black finned chromis (*Chromis vanderbilti*). The black finned chromis is a small, planktivorous damsel fish that forms feeding schools numbering into the hundreds of individuals.

The reef community of fish is dependent upon the physical structure of the bottom and areas with little structural relief and coral cover, such as occur in the areas surveyed are poor habitats for reef fish. Few fish are noted in most of the area and those that are observed include triggerfishes and hawk fish which often inhabit barren areas and take shelter in small crevices or in isolated coral colonies. A listing of the fish found during the surveys is shown in Table G-3. Of particular note is that only a few food fish (fish taken by commercial and/or recreational fishermen) were observed during the survey. These included a school of blue-lined snapper (*Taape lutjnus kasmira*) which were observed at one site. This is the same species that the city collects near the outfall by hook-and-line fishing for bioaccumulation analyses. Other fish observed include grouper, squirrel fish, goat fish and surgeon fish. However, these tend to be quite rare and small. During the course of the historical survey work it was noted that the area was experiencing substantial fishing pressure which has had a noticeable impact on abundance, size, and behavior of sought after species.

Shellfish Resources

There are about 1,000 species of marine mollusks in Hawaii ranging in size from the giant triton (16 inches) to such tiny forms as *Tricolia variabilis* at 0.10 inches.

Off of Sand Island and near the outfall area there are no edible shellfish resources according to Dr. Alison Kay, the recognized expert on Hawaiian mollusks. Offshore in deeper water there have been Pinna beds, but many of them were wiped out in 1982 by hurricane EWA and they have never recovered. The only mollusks found offshore are those associated with the coral and limestone reefs which consist of miters and cone shells. Some mussels may be found, but they are not eaten.

According to Title 13, Subtitle 4, Part 5 of Chapter 85 of the Department of Land and Natural Resources codes, collecting Japanese littleneck (*Tapes philippinarum*) are prohibited unless an open season is declared. This would commence at 7:00 am on the first Monday of September and continue to the last day of October. The limit would be one gallon of calm, with shell on, per day and they must be at least one inch in size. Cannot use a large digging implement (six by eight inches size limit).

Algal Community Structure

The reef flat is characterized by a low species diversity but a high biomass. A total of 30 species of algae were observed during the Ewa Marina Surveys with as many as 23 species being found in a single area. Algae form an important local food for populations of green sea turtles (*Chelonia mydas*) that inhabit the area. Turtles are known to feed on algae in intertidal areas and prefer to feed on *Codium*, *Ulva*, *Caulerpa*, *Turbinaria*, and *Spyridia* (Balazs, 1980). In the Hawaiian Islands the dominant turtle forage species are *Pterocladia spp.* and *Amansia spp.* which are not found in the area. *Hypnea*, the predominant algal species observed in the Ewa area has been cited as a minor component of turtle grazing (Balazs, 1980).

Nearshore Benthic Invertebrate Communities

The nearshore areas off Sand Island are considered deficient in marcroinvertebrate abundance compared to other areas of the south coast of Oahu. This lack of organisms appears to be due to the lack of suitable substrate complexity which offers shelter and the constant abrasion from shifting sand and force of breaking waves that is found on the nearshore platform which adjoins areas which have been substantially altered by man over the years through fill and use. A listing of the invertebrate species and algae observed during the diving surveys is presented in Table G-5. A listing of the species noted during the localized quadrat studies along the transects is presented in Table G-6. Details on the methods and findings are contained in the 1998 report included as Attachment G-4.

Algal Collecting

The shallow coastal waters along Ewa Beach and a few other areas host a variety of algal species, some of which are gathered and used for making local Hawaiian foods. These seaweeds referred to a "limu" include a variety of species.

Dr. Isabella Aiona Abbott of the Department of Biology of the University of Hawaii at ~~Manoa is the recognized expert on algae. She authored a 21 page book on limu in~~ 1974 with Williamson entitled "Limu - An Ethnobotanical Study of Some Edible Hawaiian Seaweeds." Published by the Pacific Tropical Botanical Garden in Lawai, Kauai.

In the past, when Dr. Abbott was asked her if she knew if anyone had ever gotten sick from eating Limu contaminated by bacteria or toxic substances derived from sewage, she said she had not heard of any reports.

She said most the commercial limu or ogo is grown in aquaculture at ponds on the north end of the island. There are four species of *Gracilaria* that are grown. Two are native species, a third has been brought in from Florida, and a fourth is now entering the market.

The old name *Gracilaria bursapastoris* is now *Gracilaria parvispora*. This is the most widely used species. Other species include *G. cornipafolia* (sp?), *G. ticki* (sp?) and *G. cornia* (sp?). All are used in a finely chopped state with raw fish.

Offshore Aquaculture Operation

Development of open ocean aquaculture was established in July of 1999, with the passage of a revised version of Chapter 190D of the Hawaii Revised Statutes, Ocean and Submerged Lands Leasing that permits aquaculture leases.

A pilot project was initiated by Catus International, Inc. to determine the feasibility of growing native marine species in deeper offshore waters. This fish farming project was called the Hawaii Offshore Aquaculture Research Project(HOARP) and was the first U.S. experiment to successfully grow 40,000 pounds of the native Pacific Threadfin *(Polydactyus sexfilis),* locally known as Moi in a completely submerged deep water net cage. Moi indigenous to Hawaii and studies indicate that the fish from around the islands are of one genetic stock. Moi are currently being grown for release for stock enhancement purposes and thus an accidental release of fish from the cage would have no adverse genetic impacts on wild populations. Plans call for the possible introduction of other native species as feasibility and market demand established.

Results from the HOARP and model calculations indicated that a larger commercial scale operation could be economically viable and be done without adverse environmental impacts (Catus International, 2000). Catus, a the local company, provided operational and technical support for the recent offshore experiment that resulted in proceeding with a full scale operation that was approved and now in operation off EWA beach near the Honouliuli outfall.

Catus applied for a received a lease from the Department of Land and Natural Resources [with a land use designation of Conservation District, Submerged Lands, Subzone (R) Resource] for a period of 15 years commencing in the fall of 2000 after completing environmental documentation and a variety of permits for a 28 acre, 15 year lease on a submerged lands ocean lease to deploy a maximum of 4 net cages. The submerged land area covered by the four suspended net cages will be 0.46 acres. The land area covered by the mooring apparatus of the four cages system is 468 sq. feet or 0.01 acres.

The waters at the site have a Department of Health Class A. Each cage has a rated potential of producing 150,000 pounds every eight months. Initially the operation will begin with 2 cages stocked with Moi and this will doubled to increase production as market demand dictates, provided that conformance with water quality and other environmental standards can be maintained. Annual production is now targeted at 100,000 pounds a year.

One of the requirements for permit issuance was that a monitoring and reporting program be undertaken. Results from this work are not known, but it will be interesting to see if there are any impacts from the operation. There have been concerns about the impacts this project will have on water quality.

The operation is located about two nautical miles offshore in water which is 150 feet deep. The cages used are moored at a depth of 40 feet below the surface as a single unit and tethered to the bottom by a system of Danforth type anchors and a central cement block weight for each cage. Daily operations consist of stocking, feeding, harvesting, maintenance and environmental monitoring with personnel equipped with SCUBA gear from one or more service vessels.

The species chosen for the initial use is the Pacific Threadfin *(Polydactylus sexfilis),* locally known as Moi, is the only marine species in that is currently being cultured in numbers Hawaii sufficient for commercial production. Further research and development of culture technologies may eventually allow the introduction other native species to offshore aquaculture.

The Operation Plan uses juvenile fish growth to a length of about three inches in land-based tanks from a hatchery supplier which are then transferred to the net cage at sea via tank truck and service boat. Fish are raised and harvested in a six month cycle.

Feeding operations occur on a daily basis with every effort made to avoid having excess feed accumulate on the sea floor from the feed system consisting of a pumped seawater "blow" system to feed pellets through a 4 inch hose. Research will continue on the optimal feeding frequency, feed formula for offshore species and conditions, and feed amount. Feed is a high cost item for the operation. Harvesting operations are conducted in a similar way; the fish are pumped up through a flexible hose to the deck of the service vessel for transfer to shore.

Probable long-term impacts of concern for are the effect of effluent fish feces and metabolic wastes) released into the sea and the cumulative effect of unconsumed feed deposits on the sea floor. It is anticipated that these wastes will dissipate in one of three ways. Some will be consumed in the water column and produce a "bloom" of phytoplankton and zooplankton. These become a source of food for other marine animals. Some will fall to the bottom and become a food source for bottom dwelling marine animals, and some will be carried away by the current and diluted to a point of minimal impact.

Another concern is that unconsumed feed that falls through the cage would be eaten by fish outside the cage resulting in the attracted abundance of fish will become a nuisance to the natural marine community. Catus has responded to this concern that it is economically detrimental for the feed to be "wasted" on fish out side the cage due to the high cost of feed.

Monitoring of the water quality in and around the sea cages and benthic sampling of the sea floor under and around the cages will be conducted. No review of any available data or review for compliance has been brought to the attention of the CCH staff.

Endangered and Threatened Species and Species of Special Concern

Of all the states, Hawaii has the highest number of listed endangered species with 317 listings which include 44 animals (mostly endemic bird species) and 273 plants.

Included in the listed species are those which live in or use marine waters in the vicinity of Oahu or have the potential to use these waters. These include a limited number of marine mammals and sea turtles. The four listed species: the threatened green turtle (*Chelonia mydas*) and the endangered humpback whale (*Megaptera novaeangliae*), hawksbill turtle (*Eretmochelys imbricata*) and Hawaiian monk seal *(Monachus schauinslandia*). It should be noted, that in the past, the NMFS (1994 letter referenced in EPA's 1998 Tentative Decision Document) stated that based on available information, the Sand Island discharge is not likely to adversely affect listed threatened or endangered species. NMFS also states that no designated or proposed critical habitat for these species exists near the outfall.

Based on information obtained in 1994 and a recent review of the status of these local species, the re appear to be only four species that have the potential to be found in the vicinity of the Sand Island outfall. Only one of these has regularly been observed and was identified by the USFWS (the threatened green sea turtle (*Chelonia mydas*) as the only species found in the vicinity of the outfall

Marine Mammals

Hawaiian waters contain nineteen species of marine mammals, most of which are only occasionally sighted. There is little information on species other than the humpback whale, spinner dolphin, and monk seal (Shallenberger,1979). The humpback whale and other threatened or endangered species are discussed in the next section. The other species are briefly discussed below.

The Bryde's whale (*Balaenoptera edeni*) is rather rare in Hawaiian waters. This specie frequently occur in the NWHI than in the main islands. There have been no reliable observations of the Minke whale (*Balaenoptera acutorostrata*) in the main Hawaiian Islands, but sightings in the NWHI have been frequent enough to indicate it is a regular visitor. The goosebeaked whale (*Ziphius cavirostris*) is very uncommon in the waters around the Islands. The densebeaked whale (*Mesoplodon densirostris*) has been observed in the NWHI and in the main islands, but is also uncommon.

Killer whales (*Orcinus orca*) are extremely rare in Hawaii, but have been seen in the NWHI and in waters around the main islands. The false killer whale (*Pseudorca crassidens*) is not in Hawaii, but has been observed in association with schools of yellowfin tuna. The pygmy killer whale (*Feresa attenuata*), one of the world's rarest marine mammals that has been observed around the main Hawaiian Islands. The melon-headed whale or "Hawaiian Blackfish" (*Peponocephala electra*) is seen in the main Hawaiian Islands, but not much is know about the species. The pilot whale or "Blackfish" (*Globicephala macrorhynchus*) is the most common small whale in the NW Hawaiian Islands and around the main islands. The pygmy sperm whale (*Kogia breviceps*) has been observed in the main islands, but is not common.

There are a number of species of dolphins in Hawaiian waters including the following:

Bottlenose dolphin (*Tursiops truncatus*)
Spotted dolphin (*Stenella attenuata*)
Spinner dolphin (*Stenella longirostris*)
~~Rough-toothed dolphin (*Steno bredanensis*)~~
Risso's dolphin (*Grampus griseus*)
Striped dolphin (*Stenella coeruleoalba*)

The bottlenose dolphin frequents the seaward edges of banks and is not commonly seen off Oahu. The spotted dolphin is very common and probably the most abundant Hawaiian cetacean. It is found in large herds throughout the islands generally offshore at distances of at least 3 km. The spinner dolphin is found throughout the islands and can put on delightful displays of aerobatics (particularly the juveniles learning to jump and spin completely out of the water). Spinner dolphins feed primarily on mesopelagic fish and epipelagic /mesopelagic squid and are observed locally (Cates International, Inc. 2000). The rough-toothed dolphin is rarely seen and prefers deep waters. Other rarely observed species are the Risso's and striped dolphin.

Spinner porpoises (*Stenella longrisostris*) have been observed in the area of the Sand Island outfall on occasion, but they are transient visitors to the area as the pods move through the area (Brock, R. E., 1998 and A. Muranaka, personal communication). They are more commonly observed at other islands.

Humpback whale, *Megaptera noveaeangliae*

Another listed species is the humpback whale, *Megaptera noveaeangliae*, of which there are about 1000 animals inhabiting the north Pacific many of which winter in Hawaiian waters, particularly in the deeper waters off of Maui. Humpbacks have been recorded off Oahu during the months of November through April (Tomich, 1986).

The great mobility of marine mammals requires that their habitat utilization must be considered much beyond the local study area of the Sand Island. Some cetaceans can transit the local study area in a few hours.

The waters off the island of Oahu host few species of marine mammals compared to other islands in the Hawaiian chain, particularly the more remote islands to the north (Tomich, 1986). They occur as year-round residents, seasonal migrants, occasional visitors, or as rare occurrences. They may migrate over extensive distances, forage over large areas, and consume substantial quantities of food (averaging 1000 tons/day). Marine mammals are an important element of the marine food web and represent the top carnivores. The most important marine mammal (due to its listing as an endangered species) is the Hawaiian monk seal.

Hawaiian Monk Seal (*Monachus schauinslandi*) (`Ilio holo I ka uaua or (the dog that goes in rough water)

Hawaiian Monk Seals were first recorded in 1825 at the Hawaiian archipelago's northernmost island, Kure Atoll. Most Hawaiian Monk Seals live in the northwestern islands of the Hawaiian archipelago: Kure Atoll, Midway Atoll, Pearl and Hermes Reef, Lisianski Island, Laysan Island, French Frigate Shoals, Gardner Pinnacles, Necker Island, and Nihoa Island. These atolls and islands are very remote and are either uninhabited or have little impact by humans, thus providing an ideal habitat for these ~~easily disturbed creatures. Recent estimates place the entire population at about 1,300~~ to 1,400 animals with an estimated rate of population declined at approximately 11% per year since 1989. The Hawaiian Monk Seal is the most endangered U.S. marine mammal based on population size.

Hawaiian monk seals are distributed throughout the northwestern Hawaiian Islands (NWHI) in six main reproductive populations at French Frigate Shoals, Laysan Island, Lisianski Island, Pearl and Hermes Reef, Midway Atoll, and Kure Atoll (NMFS, 1995). The Midway population has not contributed significantly to pup production since the 1950s. Additional populations, with limited reproduction and maintained by immigration, are found at Necker Island and Nihoa Island, and a small number of seals are distributed throughout the main Hawaiian Islands.

The different island populations have exhibited considerable independence and variations in population size over time. For example, abundance at French Frigate Shoals grew rapidly during the 1950s to the 1980s, while other populations declined rapidly. Current demographic variability among the island populations probably reflects a combination of different histories and varying environmental conditions. While management activities and research focus on single island and atoll populations, this species is managed as, and considered to be, a single stock.

Total abundance of the Hawaiian monk seal was estimated to be 1,580 (Standard Error =147) in 1992. Mean counts of animals found on beaches are used as the primary index of abundance. Between 1992 and 1993, the total mean count at the main reproductive population centers (excluding Midway) declined by 11%. If the decline in mean counts represents a similar decline in the total number of seals, then the best estimate of abundance for 1993 would be 1,406 (SE=131) (NMFS, 1995).

Between 1958 and 1993, the average beach counts at the main reproductive populations declined by 60% and more recently (1985 to 1993), the counts declined by 5% per year Humans have killed much of the population in the 1800s when the monk seal was decimated by sealers, surviving sailors of wrecked ships, and guano and feather hunters. A survey done in 1958 indicated at least partial recovery of the species from the early 1900s,however, subsequent surveys documented a second major decline beginning in 1958 (or earlier), during which several populations (Kure Atoll, Midway Atoll, and Pearl and Hermes Reef) decreased by 80-100%. Population trends at Kure Atoll, Midway Atoll, and French Frigate Shoals appear to have been determined by the pattern of human disturbance at their breeding grounds. Human activities have, among other effects, caused pregnant females to abandon prime pupping habitat and nursing females to abandon their pups. Since 1979, disturbance from human activities on land has declined, but disturbance at sea from fishing activities, may be impeding recovery (NMFS, 1995). Development and expansion of fisheries during the 1970s in the NWHI has lead to interactions detrimental to monk seals. These interactions fall into four categories: 1) operations and gear conflict, 2) entanglement in fisheries debris, 3) seal consumption of potentially toxic discard, and 4) competition for prey. The Hawaiian monk seal interacts with four fisheries: the NWHI lobster fishery, the NWHI bottomfish fishery, the pelagic longline fishery, and recreational fisheries in the main Hawaiian Islands and at Kure Atoll.

Monk seals spend most of their time in the ocean and are known to be high performance swimmers and divers. In fact, one seal was recorded diving into depths in the range of 66 and 96 fathoms (396 to 576 feet). The average monk seal dives 51.2

times per day. The coral reefs found around these atolls and islands provide the monk seal with its food supply: spiny lobsters, octopuses, eels, and various reef fishes. The life span of the Hawaiian Monk Seal is from 25-30 years. They do like to rest on sandy beaches, and sometimes use beach vegetation as shelter from wind and rain.

Factors that threaten the persistence and recovery of monk seal populations include disturbance by human activities, interactions with fisheries, mobbing of females by males, and shark predation. Although not directly responsible for monk seal mortality, human activities on beaches, even at low levels, can cause monk seals to abandon haul-out areas. Such disturbance is particularly disruptive to mother-pup pairs. In the 1800s, shipwrecked crews ate them in order to survive. By the early 1900s, humans were developing commercial and military facilities in monk seal habitat. Bottomfish, longline, and lobster fisheries have all directly affected monk seals. Indirectly, fisheries may affect seals through competition for prey or entanglement in fisheries debris, such as lost or discarded net and line. Monk seals have been found dead with apparent shark-inflicted wounds, and sharks have been observed feeding on dead seals.

The Hawaiian Monk Seal recovery efforts are overseen by the National Marine Fisheries Service, in cooperation with other government and private organizations and universities. The U.S. Fish and Wildlife Service manages many remote islands as National Wildlife Refuges to protect their habitat. Research includes monitoring monk seal reproduction, survival techniques, and behavior. In the main Hawaiian islands, volunteer groups routinely remove marine debris from the ocean and the beaches; in remote areas, the U.S. Coast Guard and U.S. Navy lend a helping hand. The Hawaiian Monk Seal was listed as an endangered species in 1976 under the Federal Endangered Species Act. Critical habitat was designated in 1988 from beaches to a depth of 20 fathoms (120 feet) around the northwestern Hawaiian islands.

Other Endangered and Threatened Species and Species of Special Concern

Of the four species of turtles, only the Green Sea Turtle is commonly found in Oahu with a large population in Kaneohe Bay which has been the subject of much study including its high incidence of tumors. This is discussed in more detail below.

Green Sea Turtle (Chelonia mydas)

The threatened Green Sea Turtle is found world wide in warm seas including Hawaii where it can occupy three habitat types: open beaches, open sea, and feeding grounds in shallow, protected waters. Adults can measure more than three feet (one meter) in straight carapace length, and weigh 220 pounds (100 kilograms). Eggs are laid in beach sands and upon hatching, the young turtles crawl from the beach to the open ocean. As shells grow to about 8-10 inches long, they move to shallow feeding grounds in lagoons, bays, and estuaries. The turtles graze in pastures of sea grasses or algae but may also feed over coral reefs and rocky bottoms. Young turtles are omnivorous (eating both animal and plant matter) while the adults are vegetarians.

In Hawaii, nesting occurs throughout the Hawaiian archipelago, but over 90 percent occurs at the French Frigate Shoals in the northwestern Hawaiian Islands.

Approximately 200-700 females are estimated to nest annually. Lower level nesting occurs in American Samoa, Guam, Commonwealth of the Northern Mariana Islands, Lisianski Island, and Pearl and Hermes Reef.

Green Sea Turtle populations have declined dramatically in the Pacific islands. Overharvest of turtles and eggs by humans is by far the most serious problem, but there are other threats such as habitat loss, capture in fishing nets, boat collisions, and a disease known as fibropapillomatosis.

Fibropapillomatosis (FP), a tumor-forming and debilitating transmissible disease of sea turtles, has emerged in recent years as a serious threat in the Hawaiian Islands, Australia, Florida, and the Caribbean (Balazs, et.al, 1998). A herpes virus and retrovirus have been identified in association with FP, but the causes of the disease, the environmental co-factors required for its occurrence, and modes of transmission in the wild have not been determined. The earliest verifiable case of FP from the Hawaiian Islands involved a green turtle in Kaneohe Bay killed by fishermen in 1958 (Balazs, 1991). The disease was known to occur in the Florida turtle population since at least the 1930's, but was rarely reported in the scientific literature as a rare occurrence. The manifestation of FP at high prevalence in both Hawaii and Florida occurred almost simultaneously during the mid-1980's. To date, there has been no association with pollutants or changes in water quality since the disease is widespread in areas remote from human activities.

While this species is declining throughout most of the Pacific, in the Hawaiian Islands, Green Sea Turtles are demonstrating some encouraging signs of population recovery after some 20 years of protective efforts.

Green Sea Turtles are listed as threatened under the U.S. Endangered Species Act (ESA) throughout all areas under U.S. jurisdiction including Hawaii. The species has been included into the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) which makes it illegal to trade any products made from this species in the U.S. and 130 other countries. The final Recovery Plans for both species have been completed by the National Marine Fisheries Service and serve as guidance in actions to their recovery.

Prior the habitat destruction (resting areas were covered with coral rubble) that occurred as a result of Hurricane Iniki in 1991, green sea turtles were usually seen in the vicinity of nearshore areas near sand island Transect T-6 (Brock, R. E., 1998). They are still occasionally observed in the area along the shallower coastal waters of Honolulu.

Marine Birds

Twenty-two seabird species breed in the Hawaiian Archipelago, but three are restricted ~~to the more remote islands except for some threatened and endangered species on the~~ main islands. Species of seabirds in the NWHI include two albatrosses, two petrels, two shearwaters, three boobies, six terns, a frigate bird, a tropic bird, and a storm-petrel. NWHI populations of four species in particular--the black-footed albatross (*Diemedia* *nigripes*), Laysan albatross (*Diemedia immutabilis*), Bonin petrel (*Pterodrcma hypoleuca*), and the sooty storm-petrel (*Oceanodroma tristrami*), contain a significant proportion of the worldwide populations.

Most of the seabirds birds found in the NWHI are not endemic. There are more than 5.4 million seabirds of 18 species which use these remote islands. Most are opportunistic feeders, taking primarily surface shoaling fish and squid. It has been shown that they feed on some 56 families of fish, 8 families of squid and 11 groups of crustaceans. The Hawaiian seabird community consumes many juvenile goatfishes, juvenile lizard fishes and mesopelagic fishes.

There are four marine bird species in Hawaii which are listed as Species of Concern. These are shown below. None of these species is found on Oahu.

Scientific Name	Common Name
Asio flammeus sandwichensis	Pueo
Diomedia abatrus	Short-tailed Albatross
Numenius tahitiensis	Bristle-thighed curlew
Oceanodroma castro cryptoleucura	Band-rumped Storm Petrel

Source: USFWS, Pacific Office: Hawaiian Islands Animals Listed and Candidate Species, March 1996

None of these birds is known to frequent the waters around the Sand Island outfall.

OTHER BIOLOGICAL CONDITIONS OF INTEREST

There are other biological conditions which have been asserted to have some relationship to wastewater discharges by the CCH over the years during litigation, in raising issues for an evidentiary hearing, at permit hearings, or in the press or newsletters of 301(h) permit protestors. Information on these issues is provided below.

Ciguatera Fish Poisoning in Humans

Ciguatera poisoning can occur in animals and humans that consume fish containing ciguatoxin is a lipid soluble, heat-resistant, acid-stable toxin. The ciguatoxin is caused by toxins produced by dinoflagellates (a primary one being *Gambierdiscus toxicus*) which attach themselves to the surface of marine algae which is eaten by fish that feed on plants. The algae grow on or near coral reefs in tropical and near-tropical regions. The toxin gets passed up the food chain from the small, plant eating fish; to large, carnivorous fish; to larger, predatory fish; and finally to humans.

Ecological disturbances to reefs cause the dinoflagellates, which normally reside under the sand, to be released and spread rapidly. These disturbances to the reef can be either man-made or natural. Underwater earthquakes, typhoons and tidal waves or tsunamis are some of the natural causes for outbreaks of ciguatoxin. Man-made causes include ship wrecks, explosions such as bombs or dynamite fishing and construction (docks and piers or swimming areas) which necessitates disturbing the reef. We know, for instance, that the incidence of ciguatoxin in the South Pacific greatly increased after World War II. Increased nutrients and water salinity have recently been noted as contributing factors.

The toxic is stable and boiling, salting, drying, freezing, marinating and cooking affected fish will not eliminate the toxin. There is no way to ell if a fish is affected, since the fish look, smell and taste normal. The toxin tends to accumulate more in the head, organs and roe of the fish and may be 100 times more concentrated in these parts than in the flesh.

It is the most common food borne condition due to a chemical toxin and is frequently misdiagnosed because it is not a reportable illness, is vastly under-diagnosed and frequently misdiagnosed as salmonella or a persistent flu. Research has shown that there are at least 27 different ciguatoxins. Fish are known to carry more than one of these toxins at the same time. In fact, it was reported that one moray eel was found to have 9 different ciguatoxins.

In Hawaii, the most commonly affected fish are jack, amberjack, eel, flagtail fish, mullet, wrasse, goatfish, surgeon fish, snapper, grouper, and parrotfish. Ciguatera Fish Poisoning is now the most commonly reported non-bacteria seafood related disease in the United States. Outbreaks of ciguatera have been reported in the mass media throughout the world.

There are several different types of fish poisoning not related to ciguatera. In addition to illnesses which come from high bacteria or virus counts, a partial list includes: Diarrheic Shellfish Poisoning (DSP) caused by okadaic acid and related to poor storage of the product; Scombroid Poisoning caused by spoiling of fish flesh by bacteria or a release of histamine-like compounds; Puffer Fish (fugu) Poisoning; and Paralytic Shellfish Poisoning (PSP) caused by red tide. DSP and PSP appear mostly in shellfish. The initial clinical symptoms in all these poisonings appear similar. The one symptom which may distinguish Ciguatera Poisoning is the hot/cold temperature sensory reversal.

There is no evidence of ciquatera poisoning incidents occurring from Mamala Bay fish or that wastewater discharge contributes to the disturbance of reefs to facilitate the conditions that foster the dinoflagellates to grow on algae.

Stinging Limu

In Hawaii, a variety of marine organisms are referred to as stinging limu (limu = seaweed) (such as hydrozoans), but only one true seaweed is known to commonly cause a rash in humans. This is the blue-green seaweed, *Lyngbya majuscula* (or sometimes *Microcoleus lyngbyaceus*) which usually grows in clumps, looking like dark, matted masses of hair or felt. Most often this seaweed is blackish-green or olive-green, but it also grows in shades of gray, red or yellow.

The filaments of this seaweed grow up to 4 inches long, and often becomes tangling with other seaweeds on reef flats, in tide pools or water as deep as 100 feet. When loose in the water, this seaweed looks like floating, tangled strands.

The toxicity of this seaweed varies greatly depending upon region, season, and type. Also, not all strains of this seaweed are toxic.

When toxic, stinging limu contains two potent, inflammatory toxins, both causing skin damage upon contact. Typically, seaweed fragments get caught inside swimsuits, rubbing these toxins into the skin.

Epidemics of this seaweed-induced rash occasionally occur in both Hawaii and the Island of Okinawa indicating the wide distribution of this species. In Hawaii, the highest number of cases occurs from June through September in windward swimming areas. Persistent trade winds blowing during these summer months may dislodge the seaweed from the bottom and these fragments can be carried into swimming bays and beaches.

The Health Department issues public warnings when outbreaks of this rash occur in swimmers. The most common areas where postings have been needed are Kaneohe Bay, Kailua Bay and waters off Laie and Ewa. However, the seaweed grows and drifts in other areas as well. There is no known relationship between deep-water discharge of treated effluent and the growth of limu.

Table G-1

Listing of Fishes Observed in the Vicinity of the Sand Island Ocean Outfall in Mamala Bay, Oahu, Hawaii by Remotely Operated Video Camera Observing along Defined Transects Based on Annual Surveys 1991-1998

Scientific Name	**Common Name**	**FAMILY**	**Family Name**
Acanthurid sp.	Surgeonfish	Acanthuridae	Surgeonfishes
Acanthurus dussumieri	Eye-strip surgeonfish	Acanthuridae	Surgeonfishes
Acanthurus xanthopterus	Yellowfin surgeonfish	Acanthuridae	Surgeonfishes
Alutera scripta	Filefish	Monocanthidae	Filefishes
Anampses chrysosephalus	Psychedelic wrasse	Labridae	Wrasses
Apogon kallopterus	Irridescent pennatnfish	Apogonidae	pennantfish
Arothron sp.	Puffer	Tetraodontidae	Puffers
Arothron hispidus	Stripebelly puffer	Tetraodontidae	Puffers
Arothron melaegris	Puffer	Tetraodontidae	Puffers
Aulostomus chinensis	Trumpetfish	Aulostomidae	Trumpetfishes
Bodianus bilunulatus	Hawaiian hogfish	Labridae	Wrasses
Cantherhines dumerili	Barred filefish	Monacanthidae	Filefishes
Canthigaster sp.	Toby	Tetraodontidae	Puffers
Canthigaster cinctus	Toby	Tetraodontidae	Puffers
Canthigaster coronata	Crown toby	Tetraodontidae	Puffers
Canthigaster jactator	Hawaiian whitespotted puffer	Tetraodontidae	Puffers
Centropyge fisheri	Fisher's angelfish	Pomacanthidae	Angelfishes
Centropyge sp.	Angelfish	Pomacanthidae	Angelfishes
Chaetodon ephippium	Saddled butterflyfish	Chaetodontidae	Butterflyfishes
Chaetodon keinii	Blacklip butterflyfish	Chaetodontidae	Butterflyfishes
Chaetodon miliaris	Milletseed butterflyfish	Chaetodontidae	Butterflyfishes
Chaetodon multicinctus	Multiband butterflyfish	Chaetodontidae	Butterflyfishes
~~*Chaetodon sp.*~~	~~Butterflyfish~~	~~Chaetodontidae~~	~~Butterflyfish~~
Chromis agilis	Agile chromis	Pomacentridae	Damselfishes
Chromis hanui	Chocolate-dip chromis	Pomacentridae	Damselfishes

Chromis sp.	Chromis	Pomacentridae	Damselfishes

Table G-1

Listing of Fishes Observed in the Vicinity of the Sand Island Ocean Outfall in Mamala Bay, Oahu, Hawaii by Remotely Operated Video Camera Observing along Defined Transects Based on Annual Surveys 1991-1998 (continue)

Scientific Name	**Common Name**	**FAMILY**	**Family Name**
Chromis verator	Threespot chromis	Pomacentridae	Damselfishes
Ctenochaetus strigosus	Goldring surgeonfish	Acanthuridae	Surgeonfishes
Gomphosus varius	Bird Wrasse	Labridae	Wrasses
Gymnothorax sp.	Moray	Muraenidae	Morays
Gymnothorax flavimarginatus	Yellowmargin moray	Muraenidae	Morays
Gymnothorax undulus	Moray	Muraenidae	Morays
Halichoeres ornatissimus	Wrasse	Labridae	Wrasses
Heniochus diphreutes	Pennant fish	Chaetodontidae	Butterflyfishes
Holacanthus arcuatus	Bandit angelfish	Pomacanthidae	Angelfishes
Labridae (unid)	Wrasse	Labridae	Wrasses
Lutjanus fulvus	Snapper	Lutjanidae	Snappers
Lutjanus kasmira	Bluestripe anapper	Lutjanidae	Snappers
Macropharyngodon geoffroy	Shortnose wrasse	Labridae	Wrasses
Mulloides vanicolensis	Yellowfin goatfish	Mullidae	Goatfishes
Naso brevirostris	Spotted unicornfish	Acanthuridae	Surgeonfishes
Naso hexacanthus	Sleek unicornfish	Acanthuridae	Surgeonfishes
Naso unicornis	Bluespine unicornfish	Acanthuridae	Surgeonfishes
Parupeneus multifasciatus	Manybar goatfish	Mullidae	Goatfishes
Parupeneus pleurostigma	Sidespot goatfish	Mullidae	Goatfishes
Plagiostremus sectroglyphidodonphus	Blenny	Blennidae	Blennies
Plectroglyphidodon johnstonianus	Blue-eye damselfish	Pomacentridae	Damselfishes
Pomacentrid sp.	Damselfish	Pomacentridae	Damselfishes
Priacanthus cruentatus	Bigeye	Priacanthidae	Bigeyes
Pseudanthias sp.	Anthias	Serranidae	Basses
Pseudanthias thompsoni	Anthias	Serranidae	Basses
Pseudocheilinus octotaenia	Eightline wrasse	Labridae	Wrasses
Pseudojuloides sp.	Wrasse	Labridae	Wrasses
Pseudojuloides cerasinus	Smalltail wrasse	Labridae	Wrasses

Ptereleotris heteropterus	Goby	Gobiidae	Gobies

Table G-1

Listing of Fishes Observed in the Vicinity of the Sand Island Ocean Outfall in Mamala Bay, Oahu, Hawaii by Remotely Operated Video Camera Observing along Defined Transects Based on Annual Surveys 1991-1998 (continue)

Scientific Name	**Common Name**	**FAMILY**	**Family Name**
Sufflamen fraenatus	Bridled triggerfish	Balistidae	Triggerfishes
Thalassoma duperreyi	Saddle Wrasse	Labridae	Wrasses
Thalassoma sp.	Wrasse	Labridae	Wrasses
Zanclus cornatus	Moorish Idol	Acanthuridae	Surgeonfishes

Table G-2

Listing of Fishes Observed in the Nearshore Areas Shoreward of the Sand Island Ocean Outfall in Mamala Bay, Oahu, Hawaii by Diving Survey Along Defined Transects

(1997and 1998 Surveys)

Scientific Name	**Common Name**	**FAMILY**	**Family Name**
Abudefduf abdominalis	Hawaiian sSergeant	Pomacentridae	Damselfishes
Acanthurus dussumieri	Eye-strip surgeonfish	Acanthuridae	Surgeonfishes
Acanthurus nigrofuscus	Brown surgeonfish	Acanthuridae	Surgeonfishes
Acanthurus nigroris	Bluelined surgeonfish	Acanthuridae	Surgeonfishes
Acanthurus olivaceous	Orangeband surgeonfish	Acanthuridae	Surgeonfishes
Acanthurus triostegus	Convict tang	Acanthuridae	Surgeonfishes
Anampses chrysocephalus	Psychedelic wrasse	Labridae	Wrasses
Apogon kallopterus (Apogon	Irridescent poacher	Apogonidae	Poachers
Aprion virescens	Grey snapper	Lutjanidae	Snappers
Arothron hispidus	Stripebelly puffer	Tetraodontidae	Puffers
Bodianus bilunulatus	Hawaiian hogfish	Labridae	Wrasses
Calotomus carolinus	Stareye parrotfish	Scaridae	Parrotfishes
Cantherhines dumerili	Barred filefish	Monacanthidae	Filefishes
Cantherhines sandwichiensis	Squaretail filefish	Monacanthidae	Filefishes
Canthigaster cinctus	Puffer	Tetraodontidae	Puffers
Canthigaster coronata	Crown toby	Tetraodontidae	Puffers
~~*Canthigaster jactator*~~	~~Hawaiian whitespotted puffer~~	~~Tetraodontidae~~	~~Puffers~~
Canthigaster rivulata	Maze toby	Tetraodontidae	Puffers
Caranx melamypgus	Blue crevally	Carangidae	Jacks
Centropyge potteri	Potter's angelfish	Pomacanthidae	Angelfishes

Cephalopholis argus	Bluespot grouper	Serranidae	Sea basses

Table G-2
Listing of Fishes Observed in the Nearshore Areas Shoreward of the Sand Island Ocean Outfall in Mamala Bay, Oahu, Hawaii by Diving Survey Along Defined Transects
(1997and 1998 Surveys)
(continue)

Scientific Name	Common Name	FAMILY	Family Name
Chaetodon miliaris	Milletseed butterflyfish	Chaetodontidae	Butterflyfishes
Chaetodon multicinctus	Multiband butterflyfish	Chaetodontidae	Butterflyfishes
Chaetodon ornatissimus	Ornate butterflyfish	Chaetodontidae	Butterflyfishes
Chaetodon quadrimaculatus	Fourspot butterflyfish	Chaetodontidae	Butterflyfishes
Chaetodon unimaculatus	Teardrop butterflyfish	Chaetodontidae	Butterflyfishes
Cheilinus bimaculatus	Twospot wrasse	Labridae	Wrasses
Chromis agilis	Agile chromis	Pomacentridae	Damselfishes
Chromis hanui	Chocolate-dip chromis	Pomacentridae	Damselfishes
Chromis ovalis	Oval chromis	Pomacentridae	Damselfishes
Chromis vanderbilti	Blackfin chromis	Pomacentridae	Damselfishes
Chromis verator	Threespot chromis	Pomacentridae	Damselfishes
Cirrhitops fasciatus	Redbar hawkfish	Cirrhitidae	Hawkfishes
Cirrhitus pinnulatus	Hawkfish	Cirrhitidae	Hawkfishes
Cirripectus variolosus	Blenny	Blenniidae	Blennies
Coris gaimard	Yellowtail coris	Labridae	Wrasses
Coris venusta	Elegant coris	Labridae	Wrasses
Ctenochaetus strigosus	Goldring surgeonfish	Acanthuridae	Surgeonfishes
Dascyllus albisella	Hawaiian dascyllus	Pomacentridae	Damselfishes
Exallis brevis	Shortbellied blenny	Blenniidae	Blennies
Forcipiger flavissimus	Forcepsfish	Chaetodontidae	Butterflyfishes
Gomphosus varius	Bird wrasse	Labridae	Wrasses
Gymnothorax eurostus	Brown moray	Muraenidae	Morays
Gymnothorax meleagris	Black moray	Muraenidae	Morays
Gymnothorax undulatus	Undulating moray	Muraenidae	Morays
Gymnomuraena zebra	Zebra moray	Muraenidae	Morays
Halichoeres ornatissimus	Ornate wrasse	Labridae	Wrasses
Heniochus diphreutes	Bannerfish	Chaetodontidae	Butterflyfishes
Labroides phthirophagus	Hawaiian cleaner wrasse	Labridae	Wrasses
Lutjanus kasmira	Bluestripe snapper	Lutjanidae	Snappers
Macropharyngodon geoffroy	Shortnose wrasse	Labridae	Wrasses
Melichthys niger	Black durgon	Balistidae	Triggerfishes
Melichthys vidua	Pinktail durgon	Balistidae	Triggerfishes
Monotaxis grandoculis	Bigeye emperor	Lethrinidae	Emperors
Mulloidichthys flavolineatus	Yellowstripe goatfish	Mullidae	Goatfishes
Naso brevirostris	Spotted unicornfish	Acanthuridae	Surgeonfishes
Naso hexacanthus	Sleek unicornfish	Acanthuridae	Surgeonfishes
Naso lituratus	Orangespine unicornfish	Acanthuridae	Surgeonfishes

Ostracion whitleyi	Trunkfish	Ostraciidae	Trunkfishes
Paracirrhitus arcatus	Arc-eye hawkfish	Cirrhitidae	Hawkfishes

Table G-2

Listing of Fishes Observed in the Nearshore Areas Shoreward of the Sand Island Ocean Outfall in Mamala Bay, Oahu, Hawaii by Diving Survey Along Defined Transects

(1997and 1998 Surveys)
(continue)

Scientific Name	**Common Name**	**FAMILY**	**Family Name**
Parupeneus multifasciatus	Manybar goatfish	Mullidae	Goatfishes
Parupeneus pleurostigma	Sidespot goatfish	Mullidae	Goatfishes
Pervagor melanocephalus	Blackheaded filefish	Monacanthidae	Filefishes
Pervagor spilasoma	Fantail filefish	Monacanthidae	Filefishes
Plagiostremus ewaensis	Ewa blenny	Blenniidae	Blennies
Plectroglyphidodon	Johnston Island damselfish	Pomacentridae	Damselfishes
Plectroglyphidodon	Blue-eye damselfish	Pomacentridae	Damselfishes
Pseudocheilinus octotaenia	Eightline wrasse	Labridae	Wrasses
Pseudocheilinus tetrataenia	Fourline wrasse	Labridae	Wrasses
Pseudojuloides cerasinus	Smalltail wrasse	Labridae	Wrasses
Psilogobius mainlandi	Mainland goby	Gobiidae	Gobies
Rhineacanthus aculeatus	Blackbarred triggerfish	Balistidae	Triggerfishes
Saurida variegatus	Lizardfish	Synodontidae	Lizardfishes
Scarus perspicillatus	Speckled parrotfish	Scaridae	Parrotfishes
Scarus psittacus	Palenose parrotfish	Scaridae	Parrotfishes
Scarus rubrioviolaceus	Redlip parrotfish	Scaridae	Parrotfishes
Scarus sordidus	Bullethead parrotfish	Scaridae	Parrotfishes
Scorpaenopsis cacopsis	Scorpionfish	Scorpaenidae	Scorpionfishes
Stegastes fasciolatus	Pacific gregory	Pomacentridae	Damselfishes
Stethojulis balteata	Belted wrasse	Labridae	Wrasses
Sufflamen bursa	Lei triggerfish	Balistidae	Triggerfishes
Sufflamen fraenatus	Bridled triggerfish	Balistidae	Triggerfishes
Thalassoma duperreyi	Saddle wrasse	Labridae	Wrasses
Zanclus cornatus	Moorish Idol	Acanthuridae	Surgeonfishes
Zebrasoma flavescens	Yellow Tang	Acanthuridae	Surgeonfishes

Table G-3

List of Fishes Observed at Both the Outfall Diffuser and Nearshore Areas During Sand Island NPDES Permit Monitoring 1991-1998

Scientific Name	Common Name	Family	Family Name
Naso brevirostris	Spotted unicornfish	Acanthuridae	Surgeonfishes
Ctenochaetus strigosus	Goldring surgeonfish	Acanthuridae	Surgeonfishes
Zanclus cornatus	Moorish Idol	Acanthuridae	Surgeonfishes
Naso hexacanthus	Sleek unicornfish	Acanthuridae	Surgeonfishes
Acanthurus dussumieri	Eye-strip surgeonfish	Acanthuridae	Surgeonfishes
Apogon kallopterus	Irridescent poacher	Apogonidae	Poachers
Chaetodon multicinctus	Multiband butterflyfish	Chaetodontidae	Butterflyfishes
Chaetodon miliaris	Milletseed butterflyfish	Chaetodontidae	Butterflyfishes
Heniochus diphreutes	Bannerfish	Chaetodontidae	Butterflyfishes
Anampses chrysocephalus	Psychedelic Wrasse	Labridae	Wrasses
Halichoeres ornatissimus	Wrasse	Labridae	Wrasses
Gomphosus varius	Bird wrasse	Labridae	Wrasses
Macropharyngodon geoffroy	Shortnose wrasse	Labridae	Wrasses
Thalassoma duperreyi	Saddle wrasse	Labridae	Wrasses
Bodianus bilunulatus	Hawaiian hogfish	Labridae	Wrasses
Pseudojuloides cerasinus	Smalltail wrasse	Labridae	Wrasses
Pseudocheilinus octotaenia	Eightline wrasse	Labridae	Wrasses
Lutjanus kasmira	Bluestripe snapper	Lutjanidae	Snappers
Cantherhines dumerili	Barred filefish	Monacanthidae	Filefishes
Parupeneus pleurostigma	Sidespot goatfish	Mullidae	Goatfishes
Parupeneus multifasciatus	Manybar goatfish	Mullidae	Goatfishes
Gymnothorax undulatus	Undulating moray	Muraenidae	Morays
Plectroglyphidodon johnstonianus	Johnson Island damselfish	Pomacentridae	Damselfishes
Chromis agilis	Agile chromis	Pomacentridae	Damselfishes
Chromis hanui	Chocolate-dip chromis	Pomacentridae	Damselfishes
Chromis verator	Threespot chromis	Pomacentridae	Damselfishes
Canthigaster coronata	Crown toby	Tetraodontidae	Puffers
Canthigaster cinctus	Puffer	Tetraodontidae	Puffers
Arothron hispidus	Stripebelly puffer	Tetraodontidae	Puffers
Canthigaster jactator	Hawaiian whitespotted puffer	Tetraodontidae	Puffers

Table G-4

Hawaiian Names of Fishes by Family in Alphabetical Order

Scientific Name	Common Name	Hawaiian Name	FAMILY
Ctenochaetus strigosus	Goldring Surgeonfish	kole	Acanthuridae
Naso unicornis	Bluespine Unicornfish	kala	Acanthuridae
Acanthurus xanthopterus	Yellowfin Surgeonfish	pualu	Acanthuridae
Naso lituratus	Orangespine Unicornfish	umaumalei	Acanthuridae
Naso brevirostris	Spotted Unicornfish	kala lolo	Acanthuridae
Naso hexacanthus	Sleek Unicornfish	kala lolo	Acanthuridae
Zanclus cornatus	Moorish Idol	kihikihi	Acanthuridae
Acanthurus dussumieri	Eye-strip Surgeonfish	palani	Acanthuridae
Acanthurus nigrofuscus	Brown Surgeonfish	ma'i'i'i	Acanthuridae
Zebrasoma flavescens	Yellow Tang	lau'i-pala	Acanthuridae
Acanthurid sp.			Acanthuridae
Acanthurus olivaceous	Orangeband Surgeonfish	na'ena'e	Acanthuridae
Acanthurus triostegus	Convict Tang	manini	Acanthuridae
Acanthurus nigroris	Bluelined Surgeonfish	maiko	Acanthuridae
Apogon kallopterus	Irridescent Poacher	upapalu	Apogonidae
Aulostomus chinensis	Trumpetfish	nunu	Aulostomidae
Rhineacanthus aculeatus	Blackbarred Triggerfish		Balistidae
Melichthys niger	Black Durgon	humuhumu-'ele'el	Balistidae
Sufflamen bursa	Lei Triggerfish	humuhumu lei	Balistidae
Sufflamen fraenatus	Bridled Triggerfish	humuhumu-mimi	Balistidae
Melichthys vidua	Pinktail Durgon	humuhumu-hi'u-k	Balistidae
Plagiostremus ewaensis	Ewa Blenny		Blenniidae
Cirripectus variolosus			Blenniidae
Exallis brevis	Shortbellied Blenny	pao'o	Blenniidae
Caranx melamypgus	Blue Crevally	omilu,hosi ulua	Carangidae
Chaetodon ornatissimus	Ornate Butterflyfish	kikakapu	Chaetodontidae
Forcipiger flavissimus	Forcepsfish	lau-wiliwili-nukun	Chaetodontidae
Chaetodon miliaris	Milletseed Butterflyfish	lau-wiliwili	Chaetodontidae
Chaetodon multicinctus	Multiband Butterflyfish	kikakapu	Chaetodontidae
Chaetodon quadrimaculatus	Fourspot Butterflyfish	lau-hau	Chaetodontidae
Heniochus diphreutes	Pennant Fish		Chaetodontidae
Heniochus diphreutes	Bannerfish		Chaetodontidae

Chaetodon sp.	Butterflyfish	kikakapu	Chaetodontidae

Table G-4

Hawaiian Names of Fishes by Family in Alphabetical Order

(continue)

Scientific Name	Common Name	Hawaiian Name	FAMILY
Chaetodon unimaculatus	Teardrop Butterflyfish	lau-hau	Chaetodontidae
Chaetodon ephippium	Saddled Butterflyfish		Chaetodontidae
Chaetodon keinii	Blacklip Butterflyfish	kikakapu	Chaetodontidae
Paracirrhitus arcatus	Arc-eye Hawkfish	pili-ko'a	Cirrhitidae
Cirrhitops fasciatus	Redbar Hawkfish	pili-ko'a	Cirrhitidae
Cirrhitus pinnulatus	Hawkfish		Cirrhitidae
Psilogobius mainlandi	Mainland Goby		Gobiidae
Ptereleotris heteropterus			Gobiidae
Anampses chrysosephalus	Psychedelic Wrasse	-	Labridae
Macropharyngodon geoffroy	Shortnose Wrasse	-	Labridae
Coris venusta	Elegant Coris		Labridae
Stethojulis balteata	Belted Wrasse	omaka	Labridae
Thalassoma duperreyi	Saddle Wrasse	hinalea lau-wili	Labridae
Halichoeres ornatissimus	Wrasse	ohua	Labridae
Thalassoma sp.	Wrasse	hinalea	Labridae
Halichoeres ornatissimus	Wrasse	ohua	Labridae
Gomphosus varius	Bird Wrasse	aki-lolo,	Labridae
Bodianus bilunulatus	Hawaiian Hogfish	a'awa	Labridae
Labroides phthirophagus	Hawaiian Cleaner Wrasse	-	Labridae
Labridae (unid)	Wrasse		Labridae
Pseudojuloides sp.	Wrasse	-	Labridae
Cheilinus bimaculatus	Twospot Wrasse	-	Labridae
Coris gaimard	Yellowtail Coris	hinalea-'aki-lolo	Labridae
Pseudocheilinus octotaenia	Eightline Wrasse	-	Labridae
Pseudojuloides cerasinus	Smalltail Wrasse	-	Labridae
Pseudocheilinus tetrataenia	Fourline Wrasse	-	Labridae
Monotaxis grandoculis	Bigeye Emperor	mu	Lethrinidae
Aprion virescens	Grey Snapper	uku	Lutjanidae
Lutjanus fulvus	Snapper		Lutjanidae
Lutjanus kasmira	Bluestripe Snapper	ta'ape	Lutjanidae
Cantherhines dumerili	Barred Filefish	o'ili	Monacanthidae

Cantherhines sandwichiensis	Squaretail Filefish	o'ili-lepa	Monacanthidae
Cantherhines dumerili	Barred Filefish	o'ili	Monacanthidae

Table G-4

Hawaiian Names of Fishes by Family in Alphabetical Order (continue)

Scientific Name	**Common Name**	**Hawaiian Name**	**FAMILY**
Pervagor spilasoma	Fantail Filefish	o'ili-'uwi'uwi	Monacanthidae
Pervagor melanocephalus	Blackheaded Filefish	o'ili-'uwi'uwiMona	Monacanthidae
Alutera scripta			Monocanthidae
Mulloidichthys flavolineatus	Yellowstripe Goatfish	weke	Mullidae
Mulloides vanicolensis	Yellowfin Goatfish	weke'ula	Mullidae
Parupeneus multifasciatus	Manybar Goatfish	moano	Mullidae
Parupeneus pleurostigma	Sidespot Goatfish	malu	Mullidae
Gymnothorax flavimarginatus	Yellowmargin Moray	puhi-paka	Muraenidae
Gymnothorax meleagris	Black Moray	puhi-paka	Muraenidae
Gymnomuraena zebra	Zebra Moray	puhi-paka	Muraenidae
Gymnothorax eurostus	Brown Moray	puhi-paka	Muraenidae
Gymnothorax undulus	Moray	puhi-paka	Muraenidae
Gymnothorax undulatus	Undulating Moray	puhi-paka	Muraenidae
Gymnothorax sp.	Moray	puhi-paka	Muraenidae
Ostracion whitleyi	Trunkfish	moa	Ostraciidae
Centropyge sp.	Angelfish		Pomacanthidae
Centropyge potteri	Potter's Angelfish	-	Pomacanthidae
Holacanthus arcuatus	Bandit Angelfish	-	Pomacanthidae
Centropyge fisheri	Fisher's Angelfishnge	-	Pomacanthidae
Plectroglyphidodon johnstonianus	Johnston Island Damselfish		Pomacentridae
Plectroglyphidodon imparipennis	Blue-eye Damselfish		Pomacentridae
Stegastes fasciolatus	Pacific Gregory		Pomacentridae
Pomacentrid sp.	Damselfish		Pomacentridae
Abudefduf abdominalis	Hawaiian Sergeant	mamo	Pomacentridae
Chromis vanderbilti	Blackfin Chromis	-	Pomacentridae
Chromis sp.	Chromis		Pomacentridae
Dascyllus albisella	Hawaiian Dascyllus	alo'ilo'i	Pomacentridae
Chromis verator	Threespot Chromis	-	Pomacentridae
Chromis hanui	Chocolate-dip Chromis	-	Pomacentridae

Chromis agilis	Agile Chromis	-	Pomacentridae
Chromis ovalis	Oval Chromis	-	Pomacentridae
Priacanthus cruentatus	Bigeye	aweoweo	Priacanthidae

Table G-4

Hawaiian Names of Fishes by Family in Alphabetical Order

(continue)

Scientific Name	**Common Name**	**Hawaiian Name**	**FAMILY**
Scarus rubrioviolaceus	Redlip Parrotfish	palukaluka	Scaridae
Scarus psittacus	Palenose Parrotfish	uhu	Scaridae
Scarus perspicillatus	Speckled Parrotfish	uhu'ahu'ula,uhu-uli	Scaridae
Calotomus carolinus	Stareye Parrotfish	ponuhunuhu	Scaridae
Scarus sordidus	Bullethead Parrotfish	uhu	Scaridae
Scorpaenopsis cacopsis	Scorpionfish		Scorpaenidae
Pseudanthias sp.			Serranidae
Pseudanthias thompsoni			Serranidae
Cephalopholis argus	Bluespot Grouper		Serranidae
Saurida variegatus	Lizardfish	ulae	Synodontidae
Arothron sp.		keke	Tetraodontidae
Arothron hispidus	Stripebelly Puffer	keke	Tetraodontidae
Arothron hispidus	Stripebelly Puffer	keke	Tetraodontidae
Arothron melaegris	Puffer	keke	Tetraodontidae
Canthigaster jactator	Hawaiian Whitespotted Puffer	keke	Tetraodontidae
Canthigaster coronata	Crown Toby	pu'u oloa	Tetraodontidae
Canthigaster rivulata	Maze Toby		Tetraodontidae
Canthigaster cinctus	Toby	pu'u	Tetraodontidae
Canthigaster sp.	Toby	pu'u oloa	Tetraodontidae

Compiled by Kris Lindstrom, K. P. Lindstrom, Inc.

Table G-5

List of Species Observed at Nearshore Transect Surveys of Transects

Scientific Name	Common Name
Amansia glomerata	Algae
Spyridia filamentosa	Algae
Porolithon onkodes	Algae
Lyngbya majuscula	Algae
Tolypiocladia sp.	Algae
Desmia hornemannii	Algae
Sphacelaria furcigera	Algae
Chondrosia chucalla	Sponge
Spirastella coccinea	Sponge
Anthelia edmondsoni	Soft coral
Palythoa tuberculosa	Soft coral
Porites lobata	Yellow or lobate coral
Porites compressa	Finger coral
Pocillopora meandrina	Cauliflower coral
Montipora verrucosa	Coral
Montipora patula	Coral
Pavona duerdeni	Coral
Montipora verrilli	Coral
Psammocora stellata	Coral
Pavona varians	Coral
Pavona duerdeni	Coral

Table G-6

List of Species Observed at Nearshore Quadrat Surveys of Transects

Scientific Name	Common Name
Spirobranchus giganteus corniculatus	Christmas tree tubeworm
Sabellastarte sanctijosephi	Featherduster worm
Loimia medusa	Annelida
Spondylus tenebrosus	Mollusc
Vermiliopsis sp.	
Lithophaga sp.	
Conus miles	Cone (Mollusc)
Conus lividus	Cone (Mollusc)
Octopus cyanea	Blue octopus
Pinctada margaritifera	
Echinostrephus aciculatum	Echinoderm
Echinothrix diadema	Echinoderm
Echinometra mathaei	Sea urchin
Tripneustes gratilla	Collector urchin
Linckia diplax	Sea star
Pseudoboletia indiana	Echinoderm
Aniculus strigatus	Arthropod
Charybdis orientalis	Arthropod
Spirastella coccinea	Red sponge
Plakortis simplex	Grey sponge

Appendix G
Biological Conditions

Supporting Materials
Attachments with Documentation and Reports

Attachment G –1	Sediment Characteristics and Quality
Attachment G –2	An analysis of the Fish and Macrobenthos Along the Sand Island Ocean Outfall Using Remote Video: IX. 1998 Data (Richard E. Brock-Decmeber 1998)
Attachment G –3	Benthic Faunal Sampling Adjacent to Sand Island Ocean Outfall, O'ahu, Hawaii, August 2002 (Richard C, Swatz, Julie H. Baile-Brock, William J. Cooke, E. Alison Kay - March 2003)
Attachment G –4	Community Structure of Fish and Macrobenthos at Selected Sites Fronting Sand Island, O'ahu, Hawaii, in Relation to the Sand Island Ocean Outfall, Year 9-1998 (Richard E. Brock - December1998)