DESCRIPTION OF BIOLOGICAL CONDITIONS

Appendix C

INTRODUCTION

This appendix provides more detailed background information on the biological conditions found near the Barber's Point outfall and other areas monitored by the City and County of Honolulu. Supplement information generated by the monitoring program provides some perspective on the resources that may be potentially influenced by the presence of the outfall and discharge of treated effluent. Appendix C and the various supplemental attachments contain more detailed information to support the Questionnaire and the biological conditions summary. The material covered from 1986 to 2004. The biological studies varied depending upon the nature of the surveys conducted and data collected.

OFFSHORE ENVIRONMENT

Description of Ocean Bottom off Ewa Beach

The ocean bottom in the vicinity of the 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 Ewa Plain. The distance from the shoreline to the 20 meter depth contour is approximately 2 kilometers, 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. 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 averaging about 35 percent coverage while sand and rubble cover approximately 62 percent of the area surveyed by the Ewa Marine Biological Monitoring Program. This is characteristic of the nearshore regions. Offshore, the entire ocean floor consists of sand and rubble.

Phytoplankton

Phytoplankton populations are not required to be monitored as part of the CCH Barbers Point Outfall monitoring program. A study to characterize and assess phytoplankton populations near the Barbers Point Outfall were completed in 1983 by AECOS (AECOS, 1979). These studies were used to support the original 301(h) applications filed in 1979 for both the Sand Island and Barber's Point discharges (AECOS, 1979). The results of the study were included in the 1979 and 1983 Applications for the Honouliuli WWTP and reviewed and summarized by EPA's contractor Tetra Tech (Tetra Tech, 1987). The studies concluded the following:

"Although data on phytoplankton species composition and community structure at the discharge site are unavailable, the observed variations in productivity and chlorophyll a among stations are not atypical, and are not expected to be associated with adverse ecological effects. It should be noted that effluent flow during the study conducted by Laws (1982) was less than or equal to

4.48 mgd. Because effluent flow of the altered discharge will be considerably greater than that existing during the period studied by Laws (1982), the phytoplankton results cannot be used to predict the effects of the modified discharge. Based on monitoring results from the Sand Island discharge area (Tetra Tech, 1984), however, adverse effects of the modified Barber's Point discharge on phytoplankton are highly unlikely".

In its 1987 Tetra Tech concluded the following:

In Laws (1982) measured primary productivity, chlorophyll a concentrations, nutrient concentrations, Secchi depth, and standard water quality variables on six dates from 17 December 1981 to 8 October 1982. Samples were collected at 5-m (16-ft), 25 m (82 ft), and 50 m (164 ft) depths at four stations: one within the mixing zone of the Barber's Point diffuser (MZ), one upcurrent from the diffuser site, one downcurrent from the diffuser site, and one control site.

Tetra Tech (1987) noted that the study conducted by Laws (1982) spanned a period when the flow of the discharge was less than or equal to 0.20 m^3/sec (4.48 mgd). Laws' 1982 study also included one sampling date before the operation of the outfall.

Zooplankton

Zooplankton populations are not required to be monitored as part of the CCH Barbers Point Outfall monitoring program. A study to characterization and assess phytoplankton 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 both the Sand Island and Barber's Point discharges (AECOS, 1979). The results of the study were included in the 1979 and 1983 Applications for the Honouliuli 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 Barber's Point discharge on zooplankton and larval fishes cannot be established, given the limitations on the available data."

As will become evident in the following review of AECOS' (1983a) study, conclusions pertaining to measurable effects of the discharge on the zooplankton community are premature and lack valid quantitative substantiation.

As in the case of the earlier Sand Island studies reviewed by Tetra Tech (1980), 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 for the Sand Island outfall which also apply to the Barber's Point outfall:

"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 C-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 C-2. Over half of the species found at the outfall are also found in the near shore waters. Those fish species common to both areas are listed in Table C-3.

The following sections discuss what is known about fish populations near the outfall and at reference sites. They have been studied for comparative purposes. Also, the studies done in the past to assess the potential impact of the Barber's Point outfall on nearshore coral reef areas are described and summarized.

Outfall Fish Observations

Biomonitoring of the Barber's Point outfall was initiated in 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 a contract with 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.

An excellent summary of the survey work completed over the years (1992-03) is presented in the last report (Brock 2003). The key summary of the findings over the eleven year period surveyed is presented below:

Because the diffuser of the Barbers Point Ocean Outfall lies below safe diving depths, a remotely controlled video camera system was used to determine the status of the marine fish communities and selected diurnally exposed macroinvertebrate species residing on the diffuser. Video reconnaissance was completed over the entire 534-m length. Three visual "transects," which "sampled" approximately 31% of the total diffuser length, were established on the diffuser pipe. Commencing in 1992, video samplings of the diffuser fish communities have been carried out annually, except in 2000 when the equipment malfunctioned. The results of the eleven annual surveys to date indicate that the diffuser fish communities are dominated by species that are either small as adults or juveniles of larger species, probably as a result of the presence of only small-scale shelter created by small armor rock and gravel used in constructing the discharge pipe. Because of poor camera resolution, differing angles of the camera, small fish sizes, and the fishes' nature to flee from the approaching camera, the fish census data are highly variable and should be viewed as more qualitative than quantitative in nature. Despite this variability from transect to transect and year to year, the mean number of individual fish per transect showed statistically significant changes over the twelve-year period. Not unexpectedly, a related parameter, the mean number of square meters examined to find an individual fish also showed statistically significant changes.

The size of the area searched to find an individual fish is directly related only to the number of fishes counted because the area searched on a given transect does not vary among the different survey years. Thus, if the mean number of fishes censused per transect shows a statistically significant change, the measure of the mean number of square meters examined to find an individual fish should show a similar significant change, which it does. However, application of another statistical test (Student–Newman–Keuls test) did not find a clear statistical separation among the means over the eleven sampling years. This lack of clear statistical separation among the means for the different years, as well as the fact that the decrease in numbers of fishes seen per transect does not follow any temporal trend, suggests that the changes are due to factors such as water clarity or camera angle and resolution and not due to any real change occurring in the diffuser fish communities. The application of statistical procedures to the data derived using a video camera to census fish and invertebrates is probably not appropriate because of a number of drawbacks inherent with the use of a remotely operated video camera, including variability due to water clarity, camera angle relative to the substratum, and camera resolution. Thus little significance should be attached to any change noted in this study of the fish or macrobenthic communities residing on the Barbers Point diffuser because of the variable quality of the data generated by use of the remotely controlled video system.

As indicated, the ROV fish survey has not been a reliable way of counting the number of fish species in the vicinity of the outfall diffuser. However, because of the great depths encountered, it is the most practical way.

A listing of the species observed by remote sensing near the outfall is summarized in Table C-1. A total of 16 families representing 59 species have been observed in the offshore waters near the outfall. The most numerous species were from the families Libridae (Wrasses, 14 species), Tetraodontidae (Puffer fish, 12 species), Acanthuridae (Surgeonfish, 10 species) and Pomacentridae (Damselfish, 8 species).

Other surveys of fish are made as part of shallow neashore 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 number of fish species in common between both locations. These include 5 species of wrasses (Labridae), 4 species of puffer fish (Tetraodontidae) 2 species of triggerfishes (Balistidae), 2 species of butterflyfishes (Chetododontidae), 2 species of file fish (Monacanthidae), 2 species of goatfishes (Mullidae), 2 species of damselfish (Pomacentridae), one specie of surgeonfish (Acanthuridae), one specie of jack fish (Carangidae) and one specie of porcupinefish (Diodontidae) (See Table C-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 Barbers Point ocean outfall and at reference stations (data is collected at seven stations for each survey at sampling stations in the zone of initial dilution (Z1D), on the boundary of the Z1D, and at distances from 0.5 - 3 km from the diffuser) . The outfall sampling was initiated in 1986, with subsequent surveys completed in 1990, 1991, February 1992, June 1993, January-February 1994 and January 1995 and 1996 through 2003 (Nelson, et al, 1987, 1990, 1991, 1992, 1994a, 1994b,1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003 and 2004. 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. Sampling and analytical methods used for the sediment survey are disclosed in the City's Annual Assessment Report (CCH 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002 and 2003). It should be noted that the sampling strategy employed in the vicinity of the Barber's Point outfall and other Hawaiian outfalls differs from that generally recommended and used on mainland sites because the benthic fauna are known to be both small and abundant with large numbers of "micromolluscs" (Nelson, et al. 1987).

The benthic monitoring program to monitor potential changes in sediments surrounding the Barber's Point ocean outfall of the Honouliuli Wastewater Treatment Plant (HWWTP) 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, Ph.D) through consultation with EPA Region IX. The objectives of the monitoring program were 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 exist and determine if these could be attributed to the discharge of treated effluent from the outfall.

Specific locations of the seven existing sampling stations were established along the 61-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 (1986 station names are in parenthesis) are as follows:

1) Station HBl (A). Located approximately 3,500 m southwest of the zone of initial dilution (ZID) boundary to evaluate far field, beyond ZID effects.
2) Station HB2 (B). Located at the northeast ZID boundary 352 meters from HZ (ZID station).
3) Station HB3 (C). Located at the southeast ZID boundary 37 meters from HZ.
4) Station HB4 (D). Located at the southwest ZID boundary 297 meters fron HZ.
5) Station HB6 (E). Located approximately 500 m southwest of the ZID boundary as a near-field reference station some 815 meters from HZ.
6) Station HB7 (F). Located approximately 3,500 m southwest of the ZID boundary as a near-field reference station, which is 3,799 meters from HZ.
7) Station HZ (Z) (in-lieu of a Station HB5). Located in the zone of initial dilution (ZID) for the diffuser.

In 1993, Walter G. Nelson, Ph.D. summarized the findings of the benthic monitoring that had been conducted since 1986 near the Honolululi Wastewater Treatment Facility ocean outfall (Barber's Point outfall). Since that time, ten additional benthic surveys have been completed. The results to date have also been summarized in the latest of a series of annual reports summarizing the benthic surveys done for the Barber's Point outfall (Swartz, et al 2004). The benthic environment near the Barber's Point outfall has remained relatively stable over the past ten 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 (Swartz, et. al, 2004). 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 Barber's Point outfall.

The benthic community in the area of the Barbers Point Outfall is generally similar in species composition to that in the area of the higher volume discharge from the Sand Island outfall some 12 kilometers to the south. The benthic community in the area of the Sand Island ocean outfall, like that in the region of the Barber's Point outfall, has shown no indications of changes attributable to the diffuser effluent. The Sand Island benthic studies used the same methods, analysts and same assessment methods. The studies provide further support to the conclusions drawn from the Barber's Point ocean outfall benthic studies that wastewater discharge of primary effluents into the deeper waters of Mamala Bay are not having significant impacts on the benthic communities. It also stated that the "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 Barber's Point ocean outfall diffuser.

Such a finding 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 125.62(c)(2). Furthermore, "conditions 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 125.62(c)(3)].

The results of the benthic monitoring program conducted to date were summarized in biological reports submitted to EPA and DOH. They provide a comprehensive overview and discussion on all findings to date. Survey results for each year are summarized in the sections below. For details, those interested should review the individual annual reports submitted to the U. S. EPA and State of Hawaii Department of Health.

1986 Benthic Survey

The results section for the 1986 benthic community survey (Nelson et al., 1987) was submitted to the regulatory agencies. The raw data and all statistical analysis tables referred are found in the appendices to the original report (Nelson et al., 1987) previously submitted to EPA Region IX and reviewed are part of the Technical Review conducted by Tetra Tech in 1987.

1990-1995 Benthic Surveys

The results section for the 1990, 1992, 1993,1994 and 1995 benthic community surveys (Nelson et al., 1991, 1992, 1994a, 1994b and 1995) were reproduced in their entirety in Attachment C-2. The 2004 Benthic Survey report (Swartz, et. al, 2004) provides a comprehensive overview and discusses all findings to date. Note that the raw data and all statistical analysis tables referred to in the Attachments are found in the Appendices to the original reports. Figure and table numbers referred in the text of Attachment C-2 are those of the original documents which have all been provided to EPA Region IX in the past. Data is also submitted to ODES for EPA access.

1990 Benthic Survey Results

In February of 1990, the second in the sampling series of benthic studies for the Barber's Point outfall was completed. Results from this study showed no clear pattern of macrofaunal abundance that could be related to discharge. The eastern most ZID boundary station (HB2) had significantly fewer non-mollusk individuals than two ZID stations (HB4, HZ), as well as one nearfield station (HB6) (Nelson et al., 1991), but none of these stations differed significantly from another ZID boundary station (HB3) or the two reference stations (HB1, HB7). While there was some evidence of significant spatial heterogeneity in non-mollusk macrobenthic abundance, the spatial pattern did not indicate an outfall effect.

There were significant difference in abundance among stations with HB4, HB6 and HZ having significantly more individuals than HB2. No other differences of significance were found.

No significant differences among stations were observed in the mean numbers of species. Diversity and evenness values were similar at all stations. Furthermore, cluster analysis using the quantitative Bray-Curtis dissimilarity index indicated the abundance/species composition at all stations was very similar, except for some suggestion of a grouping of stations based on an east to west gradient. Cluster analysis of the 1986 stations showed no discernable pattern to the number.

The proportion of deposit feeding polychaetes at the ZID and near ZID stations was 2-3 times greater than at the reference station HB7, but this was not the case with HB1. The dominant deposit feeders were oweniids, *Myriochele* spp and spiroids of the genus *Prionospio*. But there was no clear pattern of abundance among the various organisms that could be related to the outfall diffuser.

1991 Benthic Survey Results

The July 1991 survey results showed that there were significant differences in the mean abundances among stations with HB3 having fewer individuals than the other ZID boundary stations and the near-field station HB4. Station HB3 has significantly fewer nonmollusk species than all other stations. There were similar patterns of variation in diversity and evenness with values similar to those found in 1990 with no ZID-proximity signal.

Cluster analysis showed the stations to be similar in nonmollusk abundances with three groups forming an east-to-west gradient.

Polychaetes were the dominant taxon and most abundant at HB6. They had the lowest abundance at HB3, with rank order abundances showing no clear outfall-related pattern. Deposit-feeding polychaetes were most abundant and speciose at HB6. There was little difference in distribution between the four ZID stations and the three non-ZID stations.

The mean number of nonmollusk species ranged from 14.6 at HB3 to 45.6 at HB6.

Crustaceans had abundances ranging from 2.2 at HB3 to a high of 62.2 at Station HB6 with few differences between ZID and non-ZID stations. A total of 51 taxa of crustaceans were collected of which about half were amphipods. HB4 and HZ have fewer crustaceans than HB6 otherwise there were no differences among stations.

Mollusk abundance was relatively uniform except for higher abundances at HB3 and HB6, the later of which also had the lowest number of species.

1992 Benthic Survey Results

Results from the 1992 survey showed that the ZID boundary station HB4 had significantly more non-mollusk individuals than all other stations except Station HZ (Nelson et al., 1992b). Nematode abundance at this station was two to four times greater than at other stations and was the primary factor contributing to the high abundance recorded at this station. Abundances of other non-mollusk taxa were found to be similar among all the stations.

In 1992, mollusk abundance was significantly greater at reference Station HBl than for all other stations. Both ZID boundary stations HB2 and HB4, while not different between each each other, had significantly higher abundances than all other stations (except HBl). The remaining stations, including the near ZID stations HZ and HB3 and the reference stations HB6 and HB7 did not differ in mollusk abundance. Overall, there was no statistically significant pattern found with respect to mollusk abundance and proximity to the outfall diffuser (Nelson, 1993).

The 1992 survey showed that for the non-mollusk species and crustaceans, there were no significant differences among stations in number of species and no clear pattern with regard to mollusk species richness. The two reference stations HBl and HB7 had a greater number of mollusk species than some, but not all, near-ZID stations, while reference station HB6 did not differ significantly from the near-ZID stations. Both diversity and evenness values were similar among stations for both the non-mollusks and mollusks (Nelson, 1993). Station HB2 had a somewhat lower mollusk diversity and evenness than other stations, yet had the highest non-mollusk diversity and evenness values. Based on all of the biological data obtained, Nelson (1993) concluded that there was "little evidence that the outfall was having an overall effect on species richness of the macrobenthos in the vicinity of the diffuser pipe."

As in the past, the 1992 Bray-Curtis cluster analysis indicated that the abundance/species composition of the non-mollusks was broadly similar at all stations with stations near the diffuser grouped together with more distant reference stations. Cluster analysis results continued to show that ZID, near-ZID, and reference stations were all grouped similarly and in a manner consistent with previous results for earlier surveys (1991, 1990, 1986). The 1992 survey showed no evidence of community structure changes at ZID and near ZID stations that could be associated with the Barber's Point outfall discharge.

Sediment grain size data collected in 1992 showed that there was strong similarity among stations except for relatively lower percentages of fine sand at Stations HB2 and HB6 (Nelson, et al 1993) when compared to samples taken at these stations in 1991. The year-to-year variation in grain size suggests some degree of spatial heterogeneity of sediments. The percent fine sediments at the ZID and ZID boundary stations showed no increase versus samples taken in 1991, 1990 and 1986 (Nelson et al. 1987, 1991, 1992a) indicating no organic enrichment from the small size effluent particles. Sediment oxidation-reduction potential measurements showed no evidence of reducing conditions at the surface of sediments at all station sampled with no evidence of a diffuser related trend. There was no trend in the concentration of sediment oil and grease values and the highest values were observed at the reference station (HBl) supporting a finding of no outfall-derived influent. The sediment percentage of total organic carbon (TOC) was similar at all stations with only a minor variation (0.17%) among stations.

1993 Benthic Survey Results

Analytical methods changes made this year included analyzing for COD and converting the results to TOC to account for problems experienced in prior years due to the carbonate-rich sediments in the samples. (NOTE: The methodological problems experienced resulted in what may have resulted in up to an order of magnitude increase in the TOC resulting from making a determination of COD and converting the values to TOC (Nelson, 1994). Subsequent data show that the values reported were too high.

Biologically, the data was well within the range recorded for previous studies.

1994 Benthic Survey Results

This survey continued to show that there was no pattern of significant differences among stations in species or abundances. Cluster analyses of the nonmollusk biota continued to confirm that all the stations are relatively similar in species composition and relative abundance. The only noteworthy observation is the high abundances at four of the seven stations for crustaceans which have shown strong depressions in species richness and abundance in 1991 (Nelson, et al 1994). There is a strong intrastation variability for crustaceans in which an order-of-magnitude variation can occur among replicate samples, which is indicative of a very heterogenous benthic environment that responds results in the community changing in response to small-scale bottom topography and sediment differences which may not be apparent in bulk sediment analyses (Nelson, et al. 1994). There is no evidence that such depressions could be related to toxicity since the effect is not localized near the outfall.

Grain size data was lost for several stations making comparisons impossible for some stations. The continuing increase in the silt and clay fraction observed in 1993 was noted and since it was found at all stations, it was not deemed to be an outfall effect (Nelson, et al, 1994). However, all sediment characterization showed that there is no indication of significant organic buildup at any station surveyed. While this survey showed that the values for total organic carbon were lower than in 1993 at all stations, this was hypothesized to be the result of problems with the analytical techniques used in 1993 (Nelson, et. al 1994).

Again, the authors of the report concluded that there were no outfall-related changes of significance and evidence of organic enrichment of sediments that significantly influence community structure or function.

1995 Benthic Survey Results

Results were very similar to previous years with no major changes noted in sediment characteristics and no indication of elevated organics or toxics. Biological parameters continued to show no major pattern in relation to the discharge. There were some statistically significant differences among stations in the number of nonmollusk species, mainly crustaceans and mollusks, but these did not appear to be outfall related and were similar to those noted in prior years. Cluster analysis on nonmollusk data showed all stations to be similar in species composition and abundance.

1996 Benthic Survey Results

Measurements of physical parameters continue to show no evidence of a buildup of organic matter in the vicinity of the Barbers Point Ocean Outfall diffuser. This conclusion is confirmed by each of the physical and chemical parameters measured. Sediment TOC was not detected in any sample in 1996. The lack of evidence for organic buildup near the Barbers Point Ocean Outfall suggests that little particulate matter from the diffuser ever reaches the sediment surface. The spatial patterns of organism abundance and species richness in relation to the outfall varied depending on the taxonomic grouping. No pattern of reduction of either abundance or species richness at stations near the diffuser was observed for total nonmollusks, crustaceans, or

mollusks in 1996. Cluster analysis of nonmollusk data indicated that all stations were similar to one another in terms of species composition and relative abundance (similarity >70%).
There has been a significant trend of increased abundance of nonmollusks within the study area since 1990, although no trend has been seen either for the crustacean component of the nonmollusks or for the mollusks. Significantly elevated abundances of nonmollusks over the entire study period have occurred at two stations near the diffuser relative not only to two of the reference stations but also to a third near-diffuser station. Despite this elevated abundance, which may be related to the effluent discharged from the diffuser, there is no indication of any marked alteration of the benthic community at these stations in terms of species composition.
Species diversity (H') and evenness (J) were very similar among all stations for both total nonmollusks and mollusks. The model of benthic organic enrichment by Pearson and Rosenberg (1978) proposes that in the transition zone on an enrichment gradient, a few species increase and are extremely dominant, while overall diversity and evenness are low. The response patterns of the benthic fauna and the sediment chemical analyses show no indication of the types of changes in bottom communities predicted by the organic enrichment hypothesis. Maurer et al. (1993) proposed that the Pearson–Rosenberg model may be inappropriate for erosional continental shelf environments. Their study of an outfall on the continental shelf off California found that even with some organic enrichment near the diffuser, there was no evidence of elimination of rare species, even though three species did achieve numerical dominance. The response of the benthic community near the Barbers Point Ocean Outfall does not show the alternate response pattern described by Maurer et al. (1993), presumably because sediment organics there do not show even the moderate enrichment found near the Orange County outfall.

1997 Benthic Survey Results

Measurements of physical parameters continue to show no evidence of a buildup of organic matter in the vicinity of the Barbers Point Ocean Outfall diffuser. Sediment TOC was not detected in any sample in 1997. As in previous years, the lack of evidence for organic buildup near the Barbers Point Ocean Outfall suggests that little particulate matter from the diffuser ever reaches the sediment surface in the study area.

The spatial patterns of organism abundance and species richness in relation to the outfall varied depending on the taxonomic grouping. No pattern of reduction of either abundance or species richness at stations near the diffuser was observed for total nonmollusks, crustaceans, or mollusks in 1997. Cluster analysis of nonmollusk data indicated that all stations were similar to one another in terms of species composition and relative abundance (similarity >60%).

There has been a significant trend of increased abundance of nonmollusks within the study area since 1990, whereas the trend for the crustacean component of the nonmollusks appears to be negative since 1994. However, the significantly lower crustacean taxa counts in 1997 may have been due to methodological problems with the collections instead of environmental impacts. The trend for the mollusks has been toward increased abundance since 1994. Significantly elevated abundances of nonmollusks over the entire study period have occurred at two stations near the diffuser, relative not only to two of the reference stations but also to a third near diffuser station. Despite this elevated abundance, which may be related to the effluent discharged from the diffuser, there is no indication of any marked alteration of the benthic community at these stations in terms of species composition.

1998 Benthic Survey Summary

Sediment TOC was not detected in any sample in 1996 or 1997 and in only 3 of 21 replicates in 1998. In previous years, mean sediment TOC was in the narrow range of 0.04% to 0.47%, except in 1993 when methodological problems were experienced with the analyses and values ranged from 0.56% to 1.40%. The ocean outfall in Orange County, California, discharges onto the continental shelf in an erosional benthic environment (Maurer et al. 1993) which may be somewhat similar to that found in Mamala Bay, O'ahu. In the vicinity of the Orange County outfall, sediment TOC ranged from approximately 0.3% to 0.9% (Maurer et al. 1993). In areas which possess more depositional benthic environments, the percentage of organic content in the sediments is typically much higher. For example, this percentage ranged from 1.2% to 10.9% for sediments of the Kattegat (Pearson et al. 1985) and 0.6% to 8.9% for sediments off the coast of Maine (Bader 1954). The percentage of TOC ranged from 1.4% to 4.1% for stations near the Los Angeles County ocean sewage outfalls (Swartz et al. 1986). In Kingston Harbour, Jamaica, the percentage of sediment TOC ranged from 4.0% to 10.7% in a semi-enclosed bay subject to organic pollution (Wade 1972; Wade et al. 1972). The lack of evidence for organic buildup near the Barbers Point Ocean Outfall suggests that little particulate matter from the diffuser ever reaches the sediment surface in the study area.

The spatial patterns of organism abundance and taxa richness in relation to the outfall varied depending on the taxonomic grouping. There were no consistent, statistically significant patterns of reductions of either organism abundance or taxa richness of nonmollusks and mollusks near the diffuser in 1998. The macrobenthos was much more similar than dissimilar among the seven sampling stations. Cluster analysis of nonmollusk data indicated that all stations were similar to one another in terms of species composition and relative abundance (similarity >67%). The dominant mollusk species were almost identical at all stations. Only six taxa are on the list of mollusks that rank among the five most abundant taxa at any one of the seven stations.

The abundance of nonmollusks and mollusks in the study area has increased in recent years. However, there is no consistent spatial pattern in the historic abundance or taxa richness of either nonmollusks or mollusks. More mollusk taxa were collected in 1998 than in any previous survey year. The number of nonmollusk taxa collected in 1998 was near the middle of the historic range. The abundance and taxa richness of crustaceans increased in 1998, reversing a temporal decline that began in 1994. There is a pattern of reductions in crustacean abundance and taxa richness at the four ZID and ZID-boundary stations relative to each of the three reference stations. This pattern is evident in the historic (1986, 1990 through 1997) and 1998 data sets. This pattern may indicate a trend related to proximity to the diffuser. However, it is important to realize that despite the quantitative reductions in crustacean abundance and taxa richness, 42 of the possible 48 pairwise station comparisons between the reference station and both the ZID and ZID-boundary stations in the historic and 1998 data sets were not statistically significant. Also, the pattern is not consistent for total crustacean taxa collected at each station. For example, more crustacean taxa were collected at ZID station HZ than at two of the reference stations in 1998. Also, more amphipod species were collected at the ZID and ZID-boundary stations than at the reference stations in 1998. The presence of pollution-sensitive taxa like amphipods (especially the phoxocephalid Paraphoxus sp. A) indicates that the diminished crustacean fauna at the ZID and ZID-boundary stations may be related to a noncontaminant factor. Taxa diversity (H') and evenness (J) were very similar among all stations for both total nonmollusks and mollusks. The model of benthic organic enrichment by Pearson and Rosenberg (1978) proposes that in the transition zone on an enrichment gradient, a few taxa increase and are extremely dominant, while overall diversity and evenness are low. The response patterns of the benthic fauna and the sediment chemical analyses show no indication of the types of changes in bottom communities predicted by the organic enrichment hypothesis. Maurer et al. (1993) proposed that the PearsonÿRosenberg model may be inappropriate for erosional continental shelf environments. Their study of an outfall on the continental shelf off California found that even with some organic enrichment near the diffuser, there was no evidence of elimination of rare species, even though three species did achieve numerical dominance. The response of the benthic community near the Barbers Point Ocean Outfall does not show the alternate response pattern described by Maurer et al. (1993), presumably because sediment organics there do not show even the moderate enrichment found near the Orange County outfall.

Thus, there is little evidence of adverse effects of the Barber Point Ocean Outfall on the macrobenthic community in 1998. The only significant indication of an effect lies in the crustacean component where there were significantly fewer individuals at ZID-boundary stations HB2 and HB3 than at any of the three reference stations, and significantly fewer taxa at ZID-boundary station HB3 than at any of the reference stations. However, other analyses do not suggest an adverse effect of the outfall on crustaceans. There were no significant differences in abundance or taxa richness between ZID station HZ or ZID-boundary station HB4 and all reference stations. In fact, the total number of crustacean taxa was greater at ZID station HZ than at two of the reference stations. The presence of nine amphipod species at the ZID and ZID-boundary stations indicates that alterations in the crustacean component may be related to a noncontaminant factor. The analyses of the noncrustacean fauna clearly demonstrate the presence of a diverse and abundant macrobenthos within and near the ZID of the Barber Point Ocean Outfall.

1999 Benthic Survey Summary

Benthic infauna in the vicinity of the Barbers Point Ocean Outfall was sampled at seven stations on April 13 and 14, 1999 with a modified van Veen grab sampler. The stations were located along the diffuser isobath (61 m) as follows: Station HZ within the zone of initial dilution (ZID); Stations HB2, HB3, and HB4 on the ZID boundary; Station HB6 at 0.5 km from the ZID; and Stations HB1 and HB7 at 3.5 km from the ZID.

Sediments were predominantly (>90%) fine to coarse sands at all stations, although the proportion of medium and coarse sand was greater at Stations HB1, HB2, HB4, HZ, and HB7 than at Stations HB3 and HB6. Total organic carbon in the sediments at all stations was less than 0.02%. Values for oxidation-reduction potential and sediment oil and grease (O&G) showed no indication of significant organic buildup in sediments at any station except Station HB2. The high O&G values at Station HB2 were not associated with any biological alterations.

A total of 9,679 nonmollusk individuals from 183 taxa were collected. Polychaetes represented 44.0%, nematodes 17.2%, crustaceans 14.2%, oligochaetes 9.9%, and sipunculans 9.5% of total nonmollusk abundance. Mean total nonmollusk abundance ranged from 152.6 individuals per sample (33,639/m^2, at Station HB1) to 355.8 individuals per sample (78,431/m^2, at Station HB6). Mean crustacean abundance ranged from 16.2 (3,571/m^2, at Station HB3) to 65.6 (14,461/m^2, at Station HB7). Mollusks were analyzed separately because they represent time-averaged collections of live and dead shells. Mean mollusk abundance ranged from 139.0/10 cm^3 (at Station HB6) to 317.6/10 cm^3 (at Station HZ). There were no significant differences among the seven stations in mean nonmollusk abundance, number of nonmollusk taxa, crustacean abundance, and number of crustacean taxa. There were significant differences in mollusk abundance and richness, but they do not indicate a spatial pattern related to the outfall. For example, reference station HB7 and ZID station HZ had more molluscan individuals and taxa than the other reference stations and the ZID-boundary stations. There has been a significant trend of increased abundance for nonmollusks within the entire study area since 1990. Since 1994, there has been a trend of increased abundance for mollusks. A temporal trend of decreased abundance for crustaceans that began in 1994, reversed itself in 1998 and 1999, when the density of crustaceans increased substantially over the 1997 level. Mean crustacean abundance averaged over the entire study period (1986 to 1999) was significantly lower at ZID-boundary station HB3 than at reference station HB6. However, for the 1999 collection the difference between these two stations was not significant. Both diversity and evenness values for both nonmollusks and mollusks were generally similar among all stations in 1999. Cluster analysis of nonmollusk data confirmed that all stations were relatively similar to one another in terms of species composition and relative abundance. There is no indication of any marked alteration of the benthic community composition related to station proximity to the diffuser.

2000 Benthic Report Summary

Benthic infauna in the vicinity of the Barbers Point Ocean Outfall was sampled at seven stations on 9–10 February, 15–17 February, and 8 March 2000 with a modified van Veen grab sampler. The stations are located along the diffuser isobath (61 m) as follows: Station HZ within the zone of initial dilution (ZID); Stations HB2, HB3, and HB4 on the ZID boundary; Station HB6 at 0.5 km from the ZID; and Stations HB1 and HB7 at 3.5 km from the ZID.

Sediments were predominantly (>90%) sand at all stations. The coarse-sediment fraction was moderately higher and the fine-sand fraction moderately lower at Stations HB1, HB2, and HB7 than at the other stations. Total organic carbon in the sediments at all stations was less than 0.12%. Values for oxidation-reduction potential showed no evidence of reducing conditions at the surface of sediments at any station.

A total of 7,736 nonmollusk individuals from 164 taxa were collected. Polychaetes represented 45.1%, nematodes 19.4%, oligochaetes 11.7%, sipunculans 10.7%, and crustaceans 7.8% of total nonmollusk abundance. Mean total nonmollusk abundance ranged from 169.8 individuals per sample (37,430/m^2, at Station HB1) to 312.6 individuals per sample (68,908/m^2, at Station HB4). Mean crustacean abundance ranged from 8.4 (1,852/m^2, at Station HZ) to 25.4 (5,599/m^2, at Stations HB6 and HB7). Mollusks were analyzed separately because they represent time-averaged collections of live and dead shells. Mean mollusk abundance ranged from 123.2

individuals/10 cm^3 (at Station HB6) to 406.8 individuals/10 cm^3 (at Station HB1). There were no significant differences among the seven stations in crustacean abundance or the number of crustacean taxa. Mean crustacean abundance averaged over the entire study period (1986 to 2000) was significantly lower at ZID-boundary station HB3 than at reference station HB6. There is a historic pattern of reductions in crustacean abundance and taxa richness at the four ZID-area stations relative to each of the reference stations, although the differences are usually not statistically significant. This pattern may indicate a trend related to proximity to the diffuser. Relatively low values of crustacean abundance and taxa richness were recorded in 2000 at ZID station HZ and ZID-boundary stations HB3 and HB4, but these values were not significantly different from those of the reference stations. Crustacean abundance and taxa richness were relatively high at ZID-boundary station HB2. The collection of a variety of pollution-sensitive amphipod taxa at the ZID or ZID-boundary stations in 2000 and earlier years indicates that the diminished crustacean fauna at the ZID stations may be due to a noncontaminant factor. Crustacean abundance and taxa richness declined in 2000 from record levels observed in 1999. There were significant differences in abundance and taxa richness for both mollusks and nonmollusks, but they do not indicate a spatial pattern related to the outfall. There has been a significant trend of increased abundance for nonmollusks within the entire study area since 1990. Since 1994, there has been a trend of increased abundance for mollusks. Both diversity and evenness values for both nonmollusks and mollusks were generally similar among all stations in 2000. Separate cluster analyses of nonmollusk and mollusk data confirmed that all stations were relatively similar to one another in terms of species composition and relative abundance. Except for statistically insignificant differences in the spatial distribution of crustaceans, there is no indication of any marked alteration of the benthic community composition related to station proximity to the diffuser.

2001 Benthic Summary Report

Benthic infauna in the vicinity of the Barbers Point Ocean Outfall was sampled at seven stations on 13–15 January 2001 with a modified van Veen grab sampler. The stations are located along the diffuser isobath (61 m) as follows: Station HZ within the zone of initial dilution (ZID); Stations HB2, HB3, and HB4 on the ZID boundary; Station HB6 at 0.5 km from the ZID; and Stations HB1 and HB7 at 3.5 km from the ZID.

Sediments were predominantly (>93%) sand at all stations. The coarse-sediment fraction was moderately higher and the fine-sand fraction moderately lower at Stations HB1, HB2, and HB7 than at the other stations. Total organic carbon in the sediments at all stations was less than 0.20%. There were no significant differences among stations in mean oil and grease measurements. Values for oxidation-reduction potential showed no evidence of reducing conditions at the surface of sediments at any station.

A total of 8,818 nonmollusk individuals from 186 taxa were collected. Polychaetes represented 45.9%, nematodes 20.8%, crustaceans 12.7%, oligochaetes 9.1%, and sipunculans 6.0% of total nonmollusk abundance. Mean total nonmollusk abundance ranged from 181.6 individuals per sample (40,031/m2, at Station HB1) to 399.6 individuals per sample (88,086/m2, at Station HB4). Mean crustacean abundance ranged from 17.6 (3,880/m2, at Station HB4) to 60.6 (13,358/m2, at Station HZ). Mollusks were analyzed separately because they represent time-averaged collections of live and dead shells. Mean mollusk abundance ranged from 189.2

individuals/10 cm3 (at Station HB6) to 529.8 individuals/10 cm3 (at Station HB1). Crustacean abundance and taxa richness increased in 2001 from the low levels recorded in 2000. Crustacean abundance and taxa richness recorded in 2001 at ZID-boundary stations HB2, HB3, and HB4 were low relative to the reference stations. However, crustacean abundance at ZID station HZ was significantly higher than at all three reference stations (HB1, HB6, and HB7). Mean crustacean abundance averaged over the entire study period (1986 to 2001) was significantly lower at ZID-boundary station HB3 than at reference station HB6. There is a historic pattern of reductions in crustacean abundance and taxa richness at the four ZID-area stations relative to each of the reference stations, although the differences are usually not statistically significant and the pattern has not been observed in every previous sampling year. This pattern may indicate a trend related to proximity to the diffuser. The very high crustacean abundance and taxa richness at ZID station HZ in 2001 is a major exception to this historic pattern. The collection of a variety of pollution-sensitive amphipod taxa at the ZID or ZID-boundary stations in 2001 and earlier years indicates that the diminished crustacean fauna at the ZID-area stations may be due to a noncontaminant factor. There were significant differences in abundance and taxa richness for both mollusks and nonmollusks, but they do not indicate a spatial pattern related to the outfall. There has been a significant trend of increased abundance for nonmollusks within the entire study area since 1990. Since 1993, there has been a trend of increased abundance for mollusks. Diversity and evenness values were generally similar among all stations in 2001, although lowest values occurred at ZID-boundary stations HB3 and HB2 for nonmollusks and mollusks, respectively. Separate cluster analyses of nonmollusk and mollusk data confirmed that all stations were relatively similar to one another in terms of species composition and relative abundance, although the similarity of mollusks among stations may have been enhanced by the inclusion of empty shell counts in the analysis. Except for a diminished crustacean fauna at ZID-boundary stations, there is no indication of any marked alteration of the benthic community composition related to station proximity to the diffuser. The analyses of the noncrustacean fauna clearly demonstrate the presence of a diverse and abundant macrobenthos within and near the ZID of the Barbers Point Ocean Outfall.

2002 Benthic Summary Report

Benthic infauna in the vicinity of the Barbers Point Ocean Outfall was sampled at seven stations on 21–22 January 2002 with a modified van Veen grab sampler. Sediment samples for total organic carbon analysis were collected on February 7 and 13, 2002. The stations are located along the diffuser isobath (61 m) as follows: Station HZ within the zone of initial dilution (ZID); Stations HB2, HB3, and HB4 on the ZID boundary; Station HB6 at 0.5 km from the ZID; and Stations HB1 and HB7 at 3.5 km from the ZID.

Sediments were predominantly (>92%) sand at all stations. The coarse-sediment fraction was moderately higher and the fine-sand fraction moderately lower at Stations HB1, HB4, and HB7 than at the other stations. Total organic carbon in the sediments at all stations was less than 0.40%. There were no significant differences among stations in mean oil and grease measurements. Values for oxidation-reduction potential showed no evidence of reducing conditions at the surface of sediments at any station.

A total of 6,692 nonmollusk individuals from 191 taxa were collected. Polychaetes represented 42.5%, nematodes 18.2%, sipunculans 13.5%, oligochaetes 11.4%, and crustaceans 7.6% of total nonmollusk abundance. Mean total nonmollusk abundance ranged from 146.6 individuals per sample (32,316/m^2, at Station HZ) to 238.2 individuals per sample (52,508/m^2, at Station HB7). Mean crustacean abundance ranged from 5.4 individuals per sample (1,190/m^2, at Station HZ) to 30.6 (6,745/m2, at Station HB7). Mollusks were analyzed separately because they represent time-averaged collections of live and dead shells. Mean mollusk abundance ranged from 202.2 individuals/10 cm3 (at Station HB3) to 476.8 individuals/10 cm3 (at Station HB1). Crustacean abundance and taxa richness decreased in 2002 from the high levels recorded in 2001. Crustacean abundance and taxa richness recorded in 2002 at ZID-boundary stations HB3, HB4, and HZ were low relative to the reference stations. Very low mean values were recorded for crustacean abundance at Station HZ (5.4 individuals/sample) and for number of crustacean taxa at Station HB4 (1.4 taxa/sample). There is a historic pattern of reductions in crustacean abundance and taxa richness at the four ZID-area stations relative to each of the reference stations, although the differences are usually not statistically significant and the pattern has not been observed in every sampling year. This pattern may indicate a trend related to proximity to the diffuser. The collection of a variety of pollution-sensitive amphipod taxa at the ZID-area stations in 2002 and earlier years indicates that the diminished crustacean fauna at these stations may be due to a noncontaminant factor. There were significant differences in abundance and taxa richness for both mollusks and nonmollusks, but they do not indicate a consistent spatial pattern related to the outfall. There has been a significant trend of increased abundance for nonmollusks within the entire study area since 1990, although mean nonmollusk abundance in 2002 was the lowest since 1995. Since 1993, there has been a trend of increased abundance for mollusks. Diversity and evenness values were generally similar among all stations in 2002, although lowest values occurred at ZID-boundary stations HB3 and HB2 for nonmollusks and mollusks, respectively. Separate cluster analyses of nonmollusk and mollusk data confirmed that all stations were relatively similar to one another in terms of species composition and relative abundance, although the similarity of mollusks among stations may have been enhanced by the inclusion of empty shell counts in the analysis. Except for a diminished crustacean fauna at the ZID-area stations, there is no indication of any marked alteration of the benthic community composition related to station proximity to the diffuser. The analyses of the noncrustacean fauna clearly demonstrate the presence of a diverse and abundant macrobenthos within and near the ZID of the Barbers Point Ocean Outfall.2003 Benthic Summary. Benthic fauna in the vicinity of the Barbers Point Ocean Outfall was sampled at seven stations on 21-27 January 2003 with a modified van Veen grab sampler. The stations are located along the diffuser isobath (61 m) as follows: Station HZ within the zone of initial dilution (ZID); Stations HB2, HB3, and HB4 on the ZID boundary; Station HB6 at 0.5 km from the ZID; and Stations HB1 and HB7 at 3.5 km from the ZID.

Sediments were predominantly (>92%) sand at all stations. The coarse-sediment fraction was moderately higher and the fine-sand fraction moderately lower at Stations HB1 and HB7 than at the other stations. Total organic carbon in the sediments at all stations was less than 0.30%. There were no significant differences among stations in mean oil and grease measurements. Values for oxidation-reduction potential showed no evidence of reducing conditions at the surface of sediments at any station.

A total of 7,007 nonmollusk individuals from 179 taxa were collected. Polychaetes represented 44.0%, nematodes 17.3%, crustaceans 12.7%, oligochaetes 11.2%, and sipunculans 8.0% of total nonmollusk abundance. Mean total nonmollusk abundance ranged from 109.4 individuals per sample (24,116/m^2, at Station HB1) to 321.2 individuals per sample (70,804/m^2, at Station HZ). Mean crustacean abundance ranged from 7.4 (1,631/m^2, at Station HB3) to 51.6 (11,375/m^2, at Station HZ). Mollusks were analyzed separately because they represent time-averaged collections of live and dead shells. Mean mollusk abundance ranged from 186.2 individuals/10 cm^3 (at Station HZ) to 485.2 individuals/10 cm^3 (at Station HB1). Crustacean abundance and taxa richness increased in 2003 from the low levels recorded in 2002, especially at ZID station HZ. Crustacean abundance and taxa richness recorded in 2003 at ZID-boundary stations HB3 and HB4 were low relative to the reference stations. Very low mean values were recorded at Station HB4 for noncopepod crustacean abundance (1.0 individuals/sample) and for number of crustacean taxa (1.8 taxa/sample). There is a historic pattern of reductions in crustacean abundance and taxa richness at the four ZID-area stations relative to each of the reference stations, although the differences are usually not statistically significant and the pattern has not been observed in every sampling year. This pattern may indicate a trend related to proximity to the diffuser. The collection of a variety of pollution-sensitive amphipod taxa at the ZID-area stations in 2003 and earlier years indicates that the diminished crustacean fauna at these stations may be due to a noncontaminant factor. There were significant differences in abundance and taxa richness for both mollusks and nonmollusks, but they do not indicate a consistent spatial pattern related to the outfall. There has been a significant trend of increased abundance for nonmollusks within the entire study area since 1990. Since 1993, there has been a trend of increased abundance for mollusks. Diversity and evenness values were generally similar among all stations in 2003, although lowest values occurred at ZID-boundary stations HB3 and HB4 for nonmollusks and Station HB2 for mollusks. Separate cluster analyses of nonmollusk and mollusk data confirmed that all stations were relatively similar to one another in terms of species composition and relative abundance, although the similarity of mollusks among stations may have been enhanced by the inclusion of empty shell counts in the analysis. Except for a diminished crustacean fauna at ZED-boundary stations HB3 and HB4, there is no indication of any marked alteration of the benthic community composition related to station proximity to the diffuser. The analyses of the noncrustacean fauna clearly demonstrate the presence of a diverse and abundant macrobenthos within and near the ZID of the Barbers Point Ocean Outfall.

2003 Benthic Summary

Benthic fauna in the vicinity of the Barbers Point Ocean Outfall was sampled at seven stations on 21-27 January 2003 with a modified van Veen grab sampler. The stations are located along the diffuser isobath (61 m) as follows: Station HZ within the zone of initial dilution (ZID); Stations HB2, HB3, and HB4 on the ZID boundary; Station HB6 at 0.5 km from the ZID; and Stations HB1 and HB7 at 3.5 km from the ZID.

Sediments were predominantly (>92%) sand at all stations. The coarse-sediment fraction was moderately higher and the fine-sand fraction moderately lower at Stations HB1 and HB7 than at the other stations. Total organic carbon in the sediments at all stations was less than 0.30%. There were no significant differences among stations in mean oil and grease measurements.

Values for oxidation-reduction potential showed no evidence of reducing conditions at the surface of sediments at any station.

A total of 7,007 nonmollusk individuals from 179 taxa were collected. Polychaetes represented 44.0%, nematodes 17.3%, crustaceans 12.7%, oligochaetes 11.2%, and sipunculans 8.0% of total nonmollusk abundance. Mean total nonmollusk abundance ranged from 109.4 individuals per sample (24,116/m^2, at Station HB1) to 321.2 individuals per sample (70,804/m^2, at Station HZ). Mean crustacean abundance ranged from 7.4 (1,631/m^2, at Station HB3) to 51.6 (11,375/m^2, at Station HZ). Mollusks were analyzed separately because they represent time-averaged collections of live and dead shells. Mean mollusk abundance ranged from 186.2 individuals/10 cm^3 (at Station HZ) to 485.2 individuals/10 cm^3 (at Station HB1). Crustacean abundance and taxa richness increased in 2003 from the low levels recorded in 2002, especially at ZID station HZ. Crustacean abundance and taxa richness recorded in 2003 at ZID-boundary stations HB3 and HB4 were low relative to the reference stations. Very low mean values were recorded at Station HB4 for noncopepod crustacean abundance (1.0 individuals/sample) and for number of crustacean taxa (1.8 taxa/sample). There is a historic pattern of reductions in crustacean abundance and taxa richness at the four ZID-area stations relative to each of the reference stations, although the differences are usually not statistically significant and the pattern has not been observed in every sampling year. This pattern may indicate a trend related to proximity to the diffuser. The collection of a variety of pollution-sensitive amphipod taxa at the ZID-area stations in 2003 and earlier years indicates that the diminished crustacean fauna at these stations may be due to a noncontaminant factor. There were significant differences in abundance and taxa richness for both mollusks and nonmollusks, but they do not indicate a consistent spatial pattern related to the outfall. There has been a significant trend of increased abundance for nonmollusks within the entire study area since 1990. Since 1993, there has been a trend of increased abundance for mollusks. Diversity and evenness values were generally similar among all stations in 2003, although lowest values occurred at ZID-boundary stations HB3 and HB4 for nonmollusks and Station HB2 for mollusks. Separate cluster analyses of nonmollusk and mollusk data confirmed that all stations were relatively similar to one another in terms of species composition and relative abundance, although the similarity of mollusks among stations may have been enhanced by the inclusion of empty shell counts in the analysis. Except for a diminished crustacean fauna at ZED-boundary stations HB3 and HB4, there is no indication of any marked alteration of the benthic community composition related to station proximity to the diffuser. The analyses of the noncrustacean fauna clearly demonstrate the presence of a diverse and abundant macrobenthos within and near the ZID of the Barbers Point Ocean Outfall.

Summary of Results to Date

Table C-4 shows the tabulation of nonmollusk abundance and total number of taxon from 1986 to 2002 at each sediment station, including the standard deviation, minimum and maximum figures Also statistical data is provided for the non-mollusk population in Table C-5. The greatest mean in abundance was observed at ZID stations namely HB4, HZ and HB6. HB1 and HZ had the greatest number of diversity, i.e., taxons. Table C6 provide similar statistical figures for the various chemical measurements including Oxidation Reduction Potential (ORP), O&G

(oil and grease) and Total Organic Compound (TOC). The variation, i.e., standard deviation, in the ORP is about the same for all stations except HB1. Station HB2 has the lowest average ORP.

Over the years, station HZ has the largest O&G deposit and the greatest variation in the O&G figures for the surveyed years. Other stations appear to be similar. TOC is low at all stations.

Sediment grain size data over the sixteen (16) years are provided in Table C-7. In general, sediments were predominantly (>92%) sand at all stations. TOC in the sediments at all stations was relatively low throughout the years. There were no significant differences among stations in mean oil and grease measurements. Values for oxidation-reduction potential showed no evidence of reducing conditions at the surface of sediments at any station.

REVIEW OF OTHER STUDIES AND CONCLUSIONS

Sediment Data.

Organic enrichment of sediments is a driving force for benthic changes near ocean outfalls (Pearson and Roseburg 1985, Dollar, 1986, and Gray). The parameter most indicative of sediment enrichment by organics is the measurement of total organic carbon (TOC). It is important to recognize that sediment organic content at all stations near the Barber's Point outfall has consistently been below 0.5% at all stations (Nelson et al., 1994b). The 1992 increase which is noted, even if real and not an artifact of analytical method changes as suggested, still shows that sediment organic values remained low at all stations, including those closest to the diffuser. Carbon inputs have to be much higher to initiate stress in benthic communities.

For comparison, percent organic content ranged from 1.2 - 10.9% for sediments of the Kattegat, the coastal ocean between Sweden and Denmark (Pearson et al. 1985) where the classical stress studies were conducted and between 0.6 - 8.9 % for sediments in colder climates such as off the coast of Maine (Bader 1954). Off the Southern California coast, another location where extensive monitoring studies have been completed, the percent total organic content ranged from 1.4 - 4.1% for stations near the Los Angeles County ocean sewage outfalls (Swartz et al. 1986). and 1 to 2 % near the new deep water San Diego outfall (City of San Diego, 1995). In other studies of tropical embayments, such as Kingston Harbour, Jamaica, the percent TOC of sediments ranged from 4 - 10.7% (Wade, 1972; Wade et al., 1972) in a bay subject to organic pollution.

In summary, the organic content of sediments in the vicinity of the Barber's Point outfall have remained at 1 - 2 orders of magnitude below values typical for areas which have received organic enrichment. Such a conclusion was reached by EPA's contractor Tetra Tech in the technical review that lead to the granting of the original waiver permit (Tetra Tech,1987) in their Technical Review Report which stated:

> Organic content of the sediments was similar for all stations (Dollar, 1984), suggesting that the increased flux of organic material resulting from the effluent discharge is efficiently metabolized, and that little or no organic material discharged in the effluent is

> incorporated into the surface sediments. However, the measured oxygen uptake could not account for the oxidation of all the deposited organic material, leading Dollar (1984) to hypothesize that the sediment trap was collecting resuspended sediments, or that some additional carbon sink was not accounted for.

The lack of organic buildup is supported by the temporal and spatial trends for ORP, sediment oil and grease, and fine sediments (See above). The lack of organic build-up was documented by Dollar (1986) who estimated from work on nutrient fluxes at the Sand Island and Barber's Point Point outfalls that only 1% of particulate effluent reaches the sediment surface, with the balance being dispersed by currents. The on-going sediment characteristics measured during the benthic surveys from 1986-2004 support the earlier measurements made by Dollar (1986).

As required by the Sand Island WWTP 301(h) NPDES Permit, the City conducted two regional monitoring of the Mamala Bay in 2001 and 2003. The summaries of both surveys are provided below.

Regional Monitoring 2001

Benthic fauna in Mamala Bay was sampled on 8–17 August 2001 at 22 stations with a modified van Veen grab sampler and at 18 stations with diver-operated sediment corers. Station locations were selected according to a random probabilistic sampling design. The depth ranges of the stations were 0.9 to 79.6 meters. Baseline conditions in Mamala Bay in 2001 are described with respect to the range in sediment and biological parameters; the spatial distribution of samples with minimal values of taxa richness; cluster analysis of stations based on faunal similarity; dominant species composition; quantitative changes in the abundance and taxa richness of nonmollusks, crustaceans, and mollusks in relation to water depth; and the frequency distribution of areal taxa richness.

Sediments were predominantly (>85%) sand at all stations. Total organic carbon in the sediments ranged from 0.21% to 0.76%. Total Kjeldahl nitrogen ranged from 59 to 665 mg/dry kg. Values for oxidation-reduction potential showed no evidence of reducing conditions at the surface of sediments at any station.

A total of 7,053 nonmollusk individuals from 234 taxa were collected. Nematodes represented 29.6%, polychaetes 28.4%, crustaceans 24.0%, oligochaetes 7.9%, and nemerteans 3.6% of total nonmollusk abundance. Total nonmollusk abundance ranged from 3 individuals/sample (661/m^2, at Station 62) to 594 individuals/sample (130,939/m^2, at Station 92). The number of nonmollusk taxa ranged from 2 (at Stations 62, 74, and 88) to 67 (at Station 67). Crustacean abundance ranged from 0 (at Station 98) to 215 (47,394/m2, at Station 77). The number of crustacean taxa ranged from 0 (at Station 98) to 29 (at Station 67). Mollusks were analyzed separately because they represent time-averaged collections of live and dead shells. Mollusk abundance ranged from 30 individuals/15 cm^3 (at Station 95) to 798 individuals/15 cm^3 (at Station 82). The number of mollusk taxa per 15 cm^3 ranged from 9 (at Station 96) to 64 (at Station 100). Index values for diversity and evenness were quite variable for both nonmollusks and mollusks. Correlation and cluster analyses indicated that the differences in the nonmollusks of Mamala Bay were associated primarily with depth. The data were therefore divided according to eight 10-m depth ranges. The abundance and taxa richness of both nonmollusks and the crustacean component of the nonmollusks were highest at depth ranges between 30 and 60 m and lower in deeper and shallower water. Most low values of nonmollusk taxa richness were recorded for shallow waters and were widely distributed along the bay. The frequency distribution of nonmollusk taxa richness reflected the dichotomy between the taxa-rich sites of intermediate depths and the taxa-poor sites in shallow and deep water. The relation to depth was less obvious for mollusks, which were more evenly distributed in the bay, especially in terms of taxa richness. However, the highest mean abundance for mollusks was recorded for the two deepest depth ranges between 60 and 80 m. Most low values of mollusk taxa richness were recorded at sites with rocks or thin sand layers. The frequency distribution for mollusk taxa richness reflected the relatively uniform distribution of mollusks in the bay.

The results of this study establish a baseline for benthic conditions in Mamala Bay in 2001. This baseline was used to assess previously reported conditions at the zone of initial dilution (ZID) of the Sand Island and Barbers Point ocean outfalls the last time they were surveyed in 1998 and 2001, respectively. Nonmollusk and mollusk abundance and taxa richness at the outfall ZIDs were close to expected values for comparable depths in Mamala Bay. Crustacean abundance and richness at the ZIDs were somewhat less than expected, a conclusion consistent with the historic evidence for a slightly diminished crustacean assemblage at the ZIDs. The frequency distributions for mollusk taxa richness for the ZID surveys fell within the frequency distribution for the bay survey. The frequency distributions for nonmollusk taxa richness for the ZID surveys followed the taxa-rich segment of the distribution for the bay, i.e., they did not include taxa-poor samples found inshore and offshore of the ZIDs. Comparison with the Mamala Bay 2001 baseline confirms the presence of a diverse and abundant macrobenthos in the immediate vicinity of the Sand Island and Barbers Point ocean outfalls.

Regional Monitoring 2003

Benthic fauna in Mamala Bay was sampled on 6–14 August 2003 at 10 stations with a modified van Veen grab sampler and at 30 stations with diver-operated sediment corers. Station locations were selected according to a random probabilistic sampling design. The depth range of the stations was 1.2 to 108.8 m. Baseline conditions in Mamala Bay in 2003 are described with respect to the range in sediment and biological parameters; the spatial distribution of samples with minimal values of taxa richness; cluster analysis of stations based on faunal similarity; dominant species composition; quantitative changes in the abundance and taxa richness of nonmollusks, crustaceans, and mollusks in relation to water depth; and the frequency distribution of areal taxa richness.

Sediments were predominantly (>66%) sand at all stations. Total organic carbon in the sediments ranged from 0.26% to 0.94%. Total Kjeldahl nitrogen ranged from 60 to 929 mg/dry kg. Values for oxidation-reduction potential showed no evidence of reducing conditions at the surface of sediments at any station.

A total of 6,908 nonmollusk individuals from 226 taxa were collected. Polychaetes represented 33.4%, crustaceans 24.7%, nematodes 22.8%, oligochaetes 8.4%, and nemerteans 3.8% of total nonmollusk abundance. Total nonmollusk abundance ranged from 9 individuals/sample (1,984/m^2, at Station 52) to 1,091 individuals/sample (240,496/m^2, at Station 57). The number of nonmollusk taxa ranged from 4 (at Stations 55 and 61) to 75 (at Station 47). Crustacean abundance ranged from 0 (at Stations 32, 49, and 70) to 432 (95,228/m2, at Station 57). The number of crustacean taxa ranged from 0 (at Stations 32, 49, and 70) to 27 (at Station 44). Mollusks were analyzed separately because they represent time-averaged collections of live and dead shells. Mollusk abundance ranged from 42 individuals/15 cm^3 (at Station 55) to 898 individuals/15 cm^3 (at Station 41). The number of mollusk taxa per 15 cm^3 ranged from 17 (at Station 52) to 89 (at Station 70). Index values for diversity and evenness were quite variable for both nonmollusks and mollusks. Correlation and cluster analyses indicated that the differences in the nonmollusks of Mamala Bay were associated primarily with depth. The data were therefore divided according to eleven 10-m depth ranges and three depth zones (shallow, 0 to 29.9 m; mid-depth, 30.0 to 69.9 m; and deep, >70.0 m). The abundance and taxa richness of both nonmollusks and the crustacean component of the nonmollusks were highest in the mid-depth zone. Most low values of nonmollusk taxa richness were recorded for shallow waters and were widely distributed along the bay. The frequency distribution of nonmollusk taxa richness reflected the dichotomy between the taxa-rich sites in intermediate-depth water and the taxa-poor sites in shallow and deep water. The relation to depth was less obvious for mollusks, which were more evenly distributed in the bay, especially in terms of taxa richness. However, cluster analysis showed that stations with the highest mean mollusk abundance and taxa richness were located in the deep-water zone. Several of the lowest values of mollusk taxa richness were recorded at sites in the surf zone or under the influence of ocean swells. The frequency distribution for mollusk taxa richness reflected the relatively uniform distribution of mollusks in the bay.

The results of this study, together with the 2001 survey results, establish a baseline for benthic conditions in Mamala Bay. This baseline was used to assess previously reported conditions at the zone of initial dilution (ZID) of the Sand Island and Barbers Point ocean outfalls in 1998 and 2001, respectively. Nonmollusk and mollusk abundance and taxa richness at the outfall ZIDs were close to expected values for comparable depths in Maˉmala Bay. Crustacean abundance and richness at the ZIDs were somewhat less than expected, a conclusion consistent with the historic evidence for a slightly diminished crustacean assemblage at the ZIDs. Relatively few crustaceans were collected at Station 64, which is located near the Sand Island ocean outfall in the 2003 survey. Station 64 was also characterized by the presence of the indicator species Ophryotrocha adherens and Neanthes arenaceodentata. The frequency distributions for mollusk taxa richness for the outfall ZID surveys were similar to those for the two bay surveys. The frequency distributions for nonmollusk taxa richness for the outfall ZID surveys followed the taxa-rich segment of the distribution for the bay, i.e., they did not include taxa-poor samples found inshore and offshore of the ZIDs. Comparisons with the Mamala Bay 2001 and 2003 baseline surveys confirm the presence of a diverse and abundant macrobenthos in the immediate vicinity of the Sand Island and Barbers Point ocean outfalls.

Biological Conditions Summary

In conclusion, the Barbers Point outfall benthic community studies over the years have shown that the values for total organic carbon, oxidation-reduction potential, and sediment oil and grease showed no indication of significant organic build-up or deposition in sediments near the outfall. Statistical comparisons of abundance and the number of species show no consistent pattern with regard to the proximity to the outfall diffuser. Annual cluster analyses of non-mollusk species composition and abundance show all stations are similar to one another. Diversity and evenness indices show no pattern that can be attributed to the impact of effluent discharge.

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 2,300 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, 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).

Most of what is known about the nearshore environment in recent years is a result of monitoring done by Dr.Richard Brock (Brock , 1993, 1994,1995, 1996, 1997, 1998,1999,2000,2001, 2002 and 2003) for CCH as part of the Barbers Point Outfall Ocean Monitoring Program.

Description of Shoreline and Ocean Bottom off Ewa Beach

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 Ewa Plain. The distance from the shoreline to the 20 meter depth contour is approximately 2 kilometers, 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. 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 averaging about 35 percent coverage while sand and rubble cover approximately 62 percent of the area surveyed by the Ewa Marine Biological Monitoring Program. This is characteristic of the nearshore regions. Offshore, the entire ocean floor consists of sand and rubble.

Corals

The City has contracted with Richard E. Brock, Ph.D, to conduct studies to determine the status and impacts of shallow marine communities inshore of the Barber's Point diffuser which are focused largely on the impact on coral reef communities. These studies were designed and initiated in August 1991. Three permanent sites were selected and marked with two transects each, for repeated sampling over time. (These sites are designated BP-1 (transects 1-A and 1-B), BP-2 (transects 2-A and 2-B) and BP-3 (transects 3-A and 3-B). BP-1 is located 2.2 km inshore and to the east of the outfall terminus at a depth from 14.9 to 15.8 meters; BP-2 is located inshore about 1.6 km and some 250 m each of the outfall pipeline in waters ranging from 11.3 to 11.9 meters, while BP-3 is located 2.9 km west of the diffuser terminus at a depth from 16.5 to 16.8 meters. The first survey was conducted in August 1991 for fish and macrobenthos with the corals being sampled in January 1992. All these parameters were surveyed a second time in May 1993 and subsequently the surveys have been conducted almost annually since that time.

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 Barber's Point Ocean Outfall.

Reef Fish Community Structure

A total of 116 species from 29 families were observed in the nearshore areas over a twelve year period in which annual diving surveys along defined transects were performed (Brock, R.E., 2004). 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 135 species observed over the years is presented in Table C-1. Twenty-two species were observed at both the outfall are also found in the nearshore waters (see Table C-2).

The nearshore fish community observations over the years showed on individual transects where fish were counted that the number of species ranged from 8 to 48. 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 trigger fishes 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 C-1. 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 Barber's Point area and near the outfall diffuser 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 a.m. 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. Large digging implements cannot be used (6 by 8 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 Barber's Point 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.

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 Barber's Point 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. The same should apply to the Barber's Point 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 Barber's Point 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 Barber's Point 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 Barber's Point. 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 represent 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 has, 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 which 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 manage 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 worldwide 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.

Green Sea Turtle Observations from Annual Nearshore Coral Reef Dive Survey

Three green sea turtles (*Chelonia mydas*) were encountered during the 1999 field survey nearshore diver survey (Brock, 1999). Two of these were seen in the vicinity of Station BP-1. One turtle was seen resting on the transect line for Transect BP-1-A on 11 January; the second turtle was seen swimming adjacent to Transect BP-1-B. The resting turtle had an estimated straight-line carapace length of 75 cm; it had no visible tumors or tags. The second turtle was approximately 45 cm in straight-line carapace length; it also showed no evidence of tags or tumors. The third turtle was encountered on 15 January in the vicinity of Transect BP-3-B. This turtle, which was about 55 cm in straight-line carapace length, also showed no evidence of tumors or tags.

Three green sea turtles (*Chelonia mydas*) were encountered during the 2000 field survey. Two of these were seen in the vicinity of Station BP-1 on 10 May. One turtle was resting about 5 m from the line for Transect BP-1-A; the second turtle was seen swimming adjacent to Transect BP-1-B. The resting turtle had an estimated straight-line carapace length of 70 cm; it had no visible tumors or tags. The second turtle was approximately 50 cm in straight-line carapace length; it also showed no evidence of tags or tumors. The third turtle was encountered on 12 May in the vicinity of Transect BP-3-B. This turtle, which was about 50 cm in straight line carapace length, also showed no evidence of tumors or tags.

Three green sea turtles (Chelonia mydas) were encountered during the 2001 field survey. Two of these were seen in the vicinity of Station BP-1 on 29 June. One turtle was resting on the line for Transect BP-1-A; the second turtle was swimming adjacent to Transect BP-1-B. The resting turtle had an estimated straight-line carapace length of 80 cm; it had no visible tumors or tags. The second turtle was approximately 60 cm in straight-line carapace length; it also showed no evidence of tags or tumors. The third turtle was encountered on 3 July in the vicinity of Transect BP-3-B. This turtle, which was about 75 cm in straight-line carapace length, also showed no evidence of tumors or tags.

Three green sea turtles (*Chelonia mydas*) were encountered during the 2002 field survey. Two of these were seen in the vicinity of Station BP-1 on 21 May. One turtle was resting on the line for Transect BP-1-A; the second turtle was swimming in the vicinity of the two transects about 20 minutes later. The resting turtle had an estimated straight-line carapace length of 70 cm; it had no visible tumors or tags. The second turtle was approximately 80 cm in straight-line carapace length; it also showed no evidence of tags or tumors. The third turtle, encountered on 30 May in the vicinity of Transects BP-1-A and BP-1-B during physical parameter measurements on the surface, is probably one of the two seen during the previous biological survey. This turtle, which was about 75 cm in straight-line carapace length, also showed no evidence of tumors or tags. In general, individual turtles are commonly seen surfacing for air while transiting from Honolulu Harbor to ‘Ewa Beach. Most of the individuals seen appear to be subadults.

In general, individual turtles are commonly seen surfacing for air while transiting from Honolulu Harbor to ‘Ewa Beach. Most of the individuals seen appear to be subadults. Recent year observation could suggest that the sightings are of resident turtles.

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 Honouliuli 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 not diagnosed and vastly under-diagnosed because it is not a reportable illness 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 are 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.