kūki'o

May 13, 2013

Mr. Daniel E. Orodenker
Executive Director
Land Use Commissions
DBEDT
P. O. Box 2359
Honolulu, HI 96804-2359

Ms. BJ Leithead Todd
Planning Director
County of Hawaii – Planning Dept.
Aupuni Center
101 Aupuni Street, Ste. 3
Hilo, HI 96720

RE: Annual Water Quality and Marine Life Monitoring Report
LUC Docket A93-701 – Conditions 3(d) and 21
SMA Permit No. 389 – Conditions 7 and 8
Applicant: WB KD Acquisition, LLC
<u>TMK: 7-2-003: 001 Ka`ūpūlehu, North Kona, Hawai`i</u>

LAND USE COMMISSION
STATE OF HAWAII
2013 MAY 1[illegible] A 9:39

Dear Mr. Orodenker and Ms. Leithead Todd,

Pursuant to LUC Docket A93-701 (Conds. 3d and 21) and SMA Permit No. 389 (Conds. 7 and 8), the following environmental monitoring reports have been reviewed by the Ka`ūpūlehu Development Monitoring Committee (KDMC) and are being submitted for your file in compliance with the above:

1. *2012 Annual Water Quality Monitoring Report, Kalaemanō, North Kona (Jan. 2013; EAC Report No. 2013-01)*

2. *Quantitative Assessment of the Marine Communities Fronting the Kalaemanō Development - 2012 Annual Survey (Jan. 2013; EAC Report No. 2013-02)*

Should there be any questions, please do not hesitate to contact me at (808)325-4102 or cbean@kukio.com.

Sincerely,

Christine E. Bean

Christine E. Bean
Construction & Development Manager

Enclosures

cc w/reports: Alec Wong, P.E., Clean Water Branch, Department of Health
William J. Aila, Chairperson, Department of Land & Natural Resource

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LAND USE COMMISSION
STATE OF HAWAII

2013 MAY 16 A 9:40

2012 ANNUAL
WATER QUALITY MONITORING REPORT IN SUPPORT OF THE DEVELOPMENT AT KA LAE MANO, NORTH KONA

Prepared For:

WBKDA, LLC
P.O. Box 5349
Kailua-Kona, Hawai'i 96745

By:

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January 2013
EAC Report No. 2013-01

EXECUTIVE SUMMARY

The Ka Lae Mano project site is just north of Kona Village in the North Kona District. This project site extends for more than 2.7 km along the coastline at Ka Lae Mano, Kaupulehu. The first phase of the Ka Lae Mano project is situated on a recent a'a lava flow (part of the Kaupulehu flow of 1800-1801) and the development is comprised of about 75 residential lots with supporting infrastructure (roads, utilities, etc.). Unlike many of the coastal developments in North Kona which occur directly adjacent to the shoreline, the Ka Lae Mano development is set back approximately 100 m inland of the shoreline with the intervening land left in a natural state to serve as a buffer. Later phases of the project may include additional residential development and a golf course which would be built at a inland site.

A marine life and water quality monitoring program has been established to insure that these resources are not impacted by the residential development at Ka Lae Mano. This monitoring program is being undertaken to insure that the development will not impact the quality of the ground, anchialine pool and near shore marine waters or the marine biota resident to waters fronting the project site. Five field surveys were carried out comprising the baseline water quality data set. These studies commenced in 1993 and continued through September 2004 after which construction (preliminary grading) commenced. At the start of construction in 2005 the quarterly water quality monitoring program commenced and this sampling has continued to the present. However, the fourth quarter 2009 and first quarter 2010 sampling were not carried out due to near-continuous surf emanating from the south-southwest through north-northwest directions starting in October 2009 and continuing through March 2010. This document presents the results of the four most recent quarterly surveys carried out in 2012 in the during construction period.

Along the Kona coast, the concentration of many nutrient parameters is usually much greater in groundwater relative to oceanic waters which establishes a concentration gradient in marine waters where groundwater enters the sea. Thus the presence of groundwater in the near shore marine environment appears to have a major influence on the quality of these near shore waters. At Ka Lae Mano when groundwater is present in the marine coastal waters, the geometric means of many parameters do not meet the state Department of Health regional water quality standards and when absent, most parameters other than turbidity and total nitrogen are in compliance. Hence the presence or absence of groundwater in the marine environment may play a pivotal role in meeting or exceeding state water quality standards at Ka Lae Mano. Tide state plays an important role in the presence or absence of groundwater in the near shore marine environment. Falling tides serve to draw groundwater in a seaward direction. Local surf and wind conditions may serve to mask the presence of groundwater by increasing the mixing and dilution of effluxing groundwater in the near shore marine environment. The waters fronting Ka Lae Mano have high exposure to wind and surf relative to many other parts of the West Hawai'i coast, thus compliance of these waters to state water quality standards may be affected.

There have been thirty-five water quality surveys carried out in the marine environment fronting Ka Lae Mano over the last nineteen years; the tide state and local weather/surf conditions are unknown for the first four surveys (29 August 1993, 16 January 1994, 8 April 1998 and 15 April 2002) but are known for the last thirty-one surveys (20 September 2004 through 16 November 2012). The ocean conditions during the time of the first five surveys was generally rough with winds blowing from the NNW from 15 to 30 mph and the seas very choppy. These conditions serve to rapidly mix effluxing groundwater in the near shore area. The salinity data also support the hypothesis that mixing was high (i.e., having high salinities) despite favorable tide states (sampling has been carried out on falling, near zero, weakly rising tides). The ocean conditions were more favorable being calm but tides weakly falling at the time of the four 2006 surveys. Despite these favorable conditions, evidence of effluxing groundwater along the shoreline resulting in lower salinities was not particularly obvious. In the four 2007 surveys the tides were near ebb or were falling but some surge was present which served to partially mask the presence of effluxing groundwater. The 2008 surveys were carried out during falling tides (on three of four surveys) and only one had much surf and wind present. In 2009 winds created choppy conditions in the ocean on two of the three surveys and only on one was the tide strongly ebbing at the time of sampling, but groundwater signatures were not readily apparent. The April 2010 survey was undertaken under a tradewind swell and the tide was rising. Both the three 2010, four 2011 and four 2012 surveys were not carried out during ideal conditions (i.e., strongly falling tide near ebb and calm seas) that serve to draw groundwater in a seaward direction as well as minimizing mixing due to wind and waves for the detection of effluxing groundwater adjacent to shore. The presence of winds, surf and weakly falling or rising tides increases mixing and reduces the rate of non-compliance which was the case in 2009 and 2010 but less so in 2011 when conditions were more favorable for detecting effluxing groundwater. Similarly, data from 2008 show high non-compliance thus the falling tides and relatively low surf reduced mixing and these conditions favored the identification of incoming groundwater and increased the rate of non-compliance among the parameters. In three of the four earlier baseline surveys (29 August 1993, 8 April 1998 and 15 April 2002) conducted by Marine Research Consultants, mean salinities were reduced and many parameters were out of compliance on those dates resulting in a high rate of non-compliance during the baseline period. It is surmised that besides tide state which is the usual driver for groundwater flow, the local wind and surf conditions play a large role in the detecting compliance/non-compliance in many water quality parameters at Ka Lae Mano.

In the preconstruction period non-compliance occurred at a frequency of 50% among the parameters/sample dates/locations while in the during construction period the frequency of non-compliance in parameters/sample dates/locations was 17% in 2005, 35% in 2006, 50% in 2007, 65% in 2008, 39% in 2009 and 32% in 2010, 49% in 2011 and 57% in 2012 for the marine waters fronting the Ka Lae Mano project site. Despite focusing field sampling during periods of falling or low tides in the during construction period, it is surmised that prevailing wind and surf conditions favored more mixing thus decreasing non-compliance in the measured parameters. Furthermore, the 50% baseline non-compliance rate covers all baseline surveys carried out over an eleven year period while the subsequent during construction survey non-compliance rates are calculated for each survey. If the eight-year during construction non-compliance rate is calculated as an overall mean, the rate of non-compliance among the parameters falls to 43% which is less than the rate of non-compliance during the preconstruction period.

Groundwater sampled in the five Ka Lae Mano coastal monitoring wells shows this water to have high concentrations of inorganic nutrients and relatively low salinity when considering their proximity to the coast. The high nutrient signature of this groundwater is very similar to that sampled at Kukio about 3.9 km to the southeast which suggests that the source of the high nutrient Kukio groundwater may be from Ka Lae Mano.

Statistical analyses address the question, "Has there been any significant change in quality of marine waters fronting the Ka Lae Mano project site between the preconstruction period and since the commencement of construction?" and found that the means for nitrate nitrogen, orthophosphorous, silica, turbidity, temperature and pH were significantly greater in the preconstruction period relative to the during construction period. During construction means that were significantly greater include ammonia nitrogen and salinity while the changes in total nitrogen, total phosphorus, chlorophyll-*a* and the percent saturation of dissolved oxygen were not significant. The ammonia nitrogen means are not particularly elevated (preconstruction mean = 1.67 ug/l; during construction mean = 2.28 ug/l; both are within state regional standards) and the presence of well-developed fish communities (community metabolism) may be responsible for these differences. Another statistical approach is to examine the means of parameters from each sampling event, looking for chronological change. In this case the question addressed is, "has there been any significant change in the means of parameters over the 230-month period of this study?" The Kruskal-Wallis ANOVA found statistical differences among the thirty-five sample dates for all water quality parameters. It should be noted that for many of the parameters that have their greatest mean concentrations occurring in the during construction period, these mean concentrations are typical of Hawaiian coastal waters and at these concentrations are biologically insignificant.

In no case is there any evidence of a trend of increasing concentrations with time; indeed, the during construction means (2005 through 2012) are spread with no order through the range for most parameters. However the March 2009 survey means for orthophosphorous and total phosphorus were significantly greater than any other over the course of this study but by the next survey (in August 2009) decreased and by the 2010 surveys were in the lower half of their respective ranges demonstrating the natural variability in these data. To further bring this point home, the mean of total phosphorus in the March and June 2012 surveys were the third and fourth highest to date; by the November 2012 survey mean total phosphorus was in the middle of the range. In the case of ammonia nitrogen, a statistically greater mean concentration was encountered in October 2008 but as noted above, this mean is not particularly elevated. Ammonia nitrogen is a product of organism metabolism (excretion) and can be an indicator of sewage input if concurrent measurements of nitrate nitrogen, silica and orthophosphorous are likewise high and salinity significantly less which has not been the case at Ka Lae Mano. Ammonia nitrogen is frequently out of compliance with state water quality standards along undeveloped coastlines and this may be due to excretion by locally abundant fish (Brock and Kam 2000) as has been encountered over the last twenty years along much of the undeveloped coastline of Lana'i Island. (Brock 2007b).

It is virtually impossible that the development at Ka Lae Mano is having impact to ground or near shore water chemistry at this point in time. For impact to occur, two components are necessary; a source of pollutant materials applied in sufficient excess on the soil surfaces and a transport mechanism to carry these excess materials to the underlying groundwater. A potential source of impact is the application of fertilizers applied to landscaping. At this early point in this development, less than one percent of the total project site has been landscaped. Plant palettes used at Ka Lae Mano have focused on using xerophytic native species and efficient drip irrigation methods have been employed and only so until plants are established. With the groundwater lying from 10 to more than 25 m below the surface, a substantial near-continuous source of water would be necessary to transport any excess fertilizers to the underlying groundwater. Besides drip irrigation, the only other anthropogenic source of water has been for dust control purposes and only enough is used to settle dust during construction activities in a very arid, low rainfall (average = 10 inches/year) setting. Since 2009 the use of water for dust control has almost completely stopped for there are few ongoing activities that require it. Thus changes in water quality in ground and near shore marine waters measured in this study are from natural, highly variable sources.

In summary, the quality of the marine waters fronting Ka Lae Mano from the five baseline (1993-2004) and thirty during construction (2005-2012) surveys show them to be typical of well-flushed, West Hawai'i sites. The 2005-2012 quarterly during construction monitoring surveys have not found any evidence of materials leaching to or otherwise entering the groundwater or near shore marine waters fronting the project site. The fact that some parameters are out of compliance with the West Hawai'i regional water quality standards is not unexpected in light of the lack of compliance noted at many other undeveloped (Kealakekua Bay) and formerly undeveloped sites (Hokuli'a, Kukio) along the Kona coast. However, detecting the groundwater signature in the near shore marine environment fronting Ka Lae Mano is more difficult than found at many other West Hawai'i sites due to the natural rapid mixing that occurs there via frequent local wind and waves.

INTRODUCTION

The Ka Lae Mano project site is just north of Kona Village in the North Kona District. This project site extends for more than 2.7 km along the coastline at Ka Lae Mano, Kaupulehu. The first phase of the Ka Lae Mano project is situated on a recent a'a lava flow (part of the Kaupulehu flow of 1800-1801, MacDonald *et al.* 1990) and the development is comprised of about 75 residential lots with supporting infrastructure (roads, utilities, etc.). Unlike many of the coastal developments in North Kona which occur directly adjacent to the shoreline, the Ka Lae Mano development is set back approximately 100 m inland of the shoreline with the intervening land left in a natural state to serve as a buffer. The overall project site is comprised of approximately 1,071 acres with 876.5 acres that could be developed and the remainder to be placed in preservation. Later phases of the development may include more residential development and a golf course which would be built in the more inland area.

A previous owner/developer had commenced on preliminary environmental work in accordance with conditions as specified in permits issued for the project site. These conditions include:

State Land Use Commission (A93-701; 18 October 2001)

"LUC 3d. Water Quality Monitoring: Petitioner shall initiate and fund a nearshore water quality monitoring program. The parameters of the monitoring program shall be approved by the State Department of Health (DOH). Petitioner shall provide regular reports and the Land Use Commission and KDMC as to the findings of this water quality monitoring program."

"LUC 21 - Groundwater Monitoring Program: Petitioner shall initiate and fund a groundwater monitoring program as determined by the State Department of Health. Mitigation measures shall be implemented by Petitioner if the results of the monitoring program warrant them. Mitigation measures shall be approved by the State Department of Health."

Besides these water quality requirements, conditions were also imposed requiring marine community monitoring as well as monitoring related to the salt pans located along the shoreline that were used by Hawaiians in the past for the making of salt. The results of these other monitoring programs will be presented separate documents.

Under the earlier land owner/developer, marine water quality monitoring was carried out in August 1993, January 1994, April 1998 and April 2002 (see Marine Research Consultants 1993, 1994, 1998 and 2002). These earlier data along with one field survey completed in September 2004 under the present program just before the commencement of construction (preliminary grading) have been used here in establishing the baseline conditions of water quality for the groundwater and marine waters fronting the project site. Construction commenced after the September 2004 survey and four quarterly field surveys were completed in 2005, 2006, 2007 and

2008 to monitor the status of marine and groundwater quality. In 2009 the first three of the four quarterly surveys were completed; the fourth quarter 2009 survey was not done because of near-continuous high surf events with waves emanating from the south-southwest through the north-northwest directions from October 2009 through March 2010. In 2010 because of the high surf early in the year, the first quarter water quality sampling was not completed and the second, third and fourth quarter field sample efforts were completed in April, June and November 2010 representing the second, third and fourth quarters of the year. Near-continuous surf recommenced in late October 2010 carrying through to late February 2011. The 12 November 2010 survey was undertaken during a short (3-day) lull in the surf. In 2011 the field collection of samples occurred on 13 April, 26 May, 15 September and 8 November and in 2012 field sampling was undertaken on 22 March, 25 June, 18 September and 16 November 2012. This document reports on the findings of the four quarterly monitoring program surveys carried out in 2012.

METHODS

1. Sample Site Locations

The Department of Health had developed regional water quality standards for the marine waters of the West Hawai'i coast. The regional criteria require that sampling in the marine environment be conducted along onshore to offshore "transects." These transects are to be established at points along the shoreline where there is greater likelihood of groundwater escaping into the sea. Along the Kona coast, these areas are usually found at the heads of bays rather than offshore of points (escaping groundwater follows the line of least resistence in its flow to the sea). Establishing sample points in an onshore-offshore transect will allow the delineation of any concentration gradients that may be present due to inputs coming via groundwater from land.

Marine Research Consultants (1993, 1994, 1998) established four onshore-offshore transects spaced roughly equidistant along the coast. These transects were sampled in August 1993, January 1994 and April 1998. A fifth transect (E) located offshore of the northern boundary of the project site was established in the 15 April 2002 survey (Marine Research Consultants 2002). Under the present monitoring program these five transects were sampled in September 2004 as well as in the 2005-2012 quarterly during construction monitoring program. The transect locations are shown in Figure 1.

Along each transect Marine Research Consultants (1993, 1994, 2002) sampled at six distances from the shoreline; these were 0.1 m from shore, 2 m, 5 m, 10 m, 50 and 100 m from the shoreline. Bottom samples (~1 m above the bottom) were collected at all stations except the 0.1 m station. The strategy for the present survey collects samples at 1, 10, 50, 100, 200, 300, and 500 m from the shoreline from the surface (within 20 cm of the air-water interface) and bottom samples (~1 m above the bottom) are taken at the 10, 50 and 100 m distances. Thus ten water quality samples are collected on each of the five marine transects located along the Ka Lae Mano shoreline in the present monitoring program. The marine surface samples and their spacing conform to the requirements of West Hawai'i Regional Water Quality Standards as delineated in HAR§11-54-06(d)(1). Samples collected at depth provide information on the *in situ* generation of some measured parameters such as ammonia nitrogen which is a product of organism metabolism.

To obtain information on the status of groundwater as it passes under the Ka Lae Mano project site on its way to the sea, five coastal monitoring wells were drilled for monitoring purposes. Two of these wells are at inland locations (no. 4 at about 1.56 km inland and no. 5 at about 1.1 km inland); these inland wells sample groundwater as it enters the inland or mauka portion of the project site and three makai (close to the shoreline) wells sample groundwater as it leaves the project site moving towards the sea. The three makai monitoring wells are located from 150 to about 225 m inland of the shoreline. Differences in parameter concentrations from the mauka wells to those measured in the makai wells provide information on possible inputs that may be occurring due to activities on the project site. Also present is a sixth well which was developed as a source of water for dust control during construction. This well was located about 528 m inland of the shoreline and it was sampled opportunistically when the pump was operating however, it is no longer in use. Another well developed for irrigation purposes (Well 7) located about 1.3 km inland of the shoreline is now operational and was first sampled in the September 2011 survey. Commencing in 2012, Well 7 is routinely sampled during the quarterly surveys but previously it was sampled only when the pump was operating. Finally a single anchialine pool is present at Ka Lae Mano and is sampled in this program.

2. Laboratory Methods

Water quality constituents that are evaluated include the specific criteria as designated in Chapter 11-54, Section 06 State of Hawai'i, Department of Health Water Quality Standards which were amended in July 2000 and reiterated again in August 2004 for West Hawai'i coastal waters. The criteria include ammonia nitrogen (NH_4), nitrate + nitrite nitrogen ($NO_3 + NO_2$, hereafter referred to as nitrate or NO_3), total nitrogen (TN), orthophosphorous (PO_4), total phosphorus (TP), chlorophyll-*a* (chl-*a*), turbidity, as well as the nonspecific criteria of temperature, pH, and salinity. In addition, dissolved silica (Si) is measured due to its usefulness as a conservative groundwater tracer. Total organic nitrogen (TON) is calculated as the difference between total nitrogen from ammonia nitrogen plus nitrate nitrogen and total organic phosphorus (TOP) is calculated as the difference between orthophosphorous from total phosphorus.

Marine surface water samples are collected by opening 500 ml polyethylene bottles at the desired depth. Marine samples collected at depth are done so using a Niskin bottle. Monitoring well samples are collected using a one-liter well bailer and the sample from the anchialine pool is collected from just under the water's surface. As previously stated, water samples from the old dust control well (well 6) as well as from the new irrigation well (Well 7) were collected opportunistically when the well pump was operational but commencing in 2012, Well 7 is routinely sampled. All sample bottles are all triple rinsed using the sample water prior to sample collection. Samples are held on ice until in the laboratory where further processing occurs. Subsamples for nutrient analyses are held in 125 ml acid-washed, triple-rinsed polyethylene bottles which are stored chilled until analysis. Analysis entails filtering through Whatman glass fiber filters (GF/F, 0.7 um particle retention) with filters being retained for chlorophyll-*a* analysis. Analyses for ammonia nitrogen, orthophosphorous and nitrate are performed using a Technicon autoanalyzer following standard methods for seawater analysis (Strickland and Parsons 1972, Grasshoff 1983). Total nitrogen and total phosphorus are measured from non-filtered sample water (see Dore *et al.* 1996) and similarly analyzed following digestion using unfiltered sample water (Standard Methods 1999).

The limits of detection (precision) and accuracy of nutrient determinations are as follows: total nitrogen accuracy = 0.5 uM or 7.00 ug/l, limits of detection = 0.2 uM or 2.8 ug/l; total phosphorus accuracy = 0.04 uM or 1.24 ug/l, limits of detection = 0.02 uM or 0.62 ug/l; orthophosphorous accuracy = 0.02 uM or 0.62 ug/l, limits of detection = 0.01 uM or 0.31 ug/l; nitrate+nitrite nitrogen accuracy = 0.05 uM or 0.70 ug/l, limits of detection = 0.03 uM or 0.42 ug/l; ammonia nitrogen accuracy = 0.08 uM or 1.12 ug/l, limits of detection =0.03 uM or 0.42 ug/l; and silica accuracy = 0.5 uM or 14.00 ug/l, limits of detection = 0.2 uM or 5.60 ug/l.

Turbidity samples are collected as unfiltered water and stored on ice in 125 ml polyethylene bottles until measurements are made (within 24 hours). Turbidity is measured on a Monitek Laboratory Model 21 nephalometer following the procedures as described in Standard Methods (1999). The instrument is calibrated as specified by the Environmental Protection Agency with standard formazin solutions prior to and after sample measurements. Prior to measurement, samples are throughly mixed to disperse particulate materials and measured in duplicate when all air bubbles disappear.

Chlorophyll-*a* samples are collected by filtering known volumes of sample water through glass microfiber filters (see above); filters are frozen in dark containers until laboratory analyses are carried out. Laboratory procedures follow Standard Methods (1999) and pigments are extracted in 90 percent acetone in the dark for 12 to 24 hours and fluorescence before and after acidification is measured on a Turner Designs fluorometer. Salinity samples are collected in triple-rinsed 125 ml polyethylene bottles in the field, filled completely and capped tightly until measurement on a AGE Model 2100 laboratory salinometer with a precision of 0.0001 ppt. In the field dissolved oxygen is measured using an YSI Model 58 meter with a readability of 0.01 mg/l, pH is determined using a Hanna Instruments pH meter model no. HI 9025 millivolt meter with a readability of 0.01 units and temperature is measured using a laboratory grade thermometer reading to 0.1°C.

All methods used in the Ka Lae Mano monitoring program comply with and follow those as outlined in the "West Hawai'i Coastal Monitoring Program Monitoring Protocol Guidelines" as formulated and prepared by the West Hawai'i Coastal Monitoring Task Force (May 1992, 30p.).

Statistical and other data procedures are described where used in the text. In general to avoid assumptions of normality in the data, non-parametric methods are used (Siegel 1956, SAS Institute, Inc. 1985) for the statistical treatment of the data.

RESULTS AND DISCUSSION

Marine Research Consultants (1993, 1994 and 1998) collected water quality data at four of the five marine transect sites fronting the Ka Lae Mano project site (transects A through D, Figure 1). In the 2002 survey (Marine Research Consultants 2002) a fifth transect was added approximately offshore of the northern boundary of the project site. These data are part of the preliminary baseline and are used in the present analysis. On 20 September 2004, we sampled the five transect sites (transects A through E, Figure 1) as well as the five monitoring wells located on the project site (as shown in Figure 2) drilled specifically for that purpose. These data comprise the preconstruction baseline data set against which all subsequent data are comparatively analyzed.

The baseline data are summarized as geometric means calculated for each parameter (marine surface collected samples only) by transect and date in Table 1. It should be noted that samples were collected from all sites in the 20 September 2004 final baseline survey but the five shoreline samples (collected within ~ 1 m of the shoreline) were misplaced by the laboratory processing the water samples, thus these data are missing in the data set. Data collected from the marine sites in the 2005 "during construction" quarterly program are summarized as geometric means in Table 2; Table 3 presents these same data for 2006, Table 4 summarizes the 2007 data, Table 5 shows the data collected in 2008, Table 6 presents the summary of the data collected in 2009, Table 7 summarizes the 2010 data, Table 8 presents the 2011 data and Table 9 summarizes the data collected in 2012. All data from the years prior to 2012 are presented in their entirety in Brock (2006, 2007a, 2008, 2009, 2010, 2011, 2012). The four 2012 quarterly surveys were carried out on 22 March, 25 June, 18 September and 16 November 2012 and these data are presented below in Appendices 1 - 4 and the marine data are summarized in Table 9. Commencing with the 20 September 2004 survey and continuing with all subsequent surveys, water quality samples were collected from five wells located on the Ka Lae Mano project site (Figure 2) and these data are summarized in Table 10 as means by survey date. The 2012 well data are given in their entirety in Appendices 1 - 4. Finally the single anchialine pool present at Ka Lae Mano is sampled during the quarterly surveys and these data are summarized in Table 11.

1. Compliance with Department of Health Criteria

The Hawai'i State Department of Health (DOH) has developed specific criteria for different classes of water in the state (e.g., as for harbors, streams and marine waters). Up to July 2000, the waters fronting Ka Lae Mano were classed as "Open Coastal Waters" and are to remain "...in their natural pristine state with an absolute minimum of pollution or alteration of water quality from any human-caused source or action" (HAR§11-54-01). The most stringent standards have been set for open coastal waters. Since July 2000, revised standards have been imposed for the West Hawai'i coastline; these standards utilize a regression approach for marine sample sites where salinity is 32 parts per thousand (ppt) or less. This regression approach is used in determining the standard for nitrate+nitrite nitrogen, total nitrogen, orthophosphorous and total phosphorus. There are no standards set for anchialine pools or coastal brackish wells (used for monitoring and/or irrigation purposes), thus the standards apply only to ocean samples. Table 12 presents the three tiers of water quality criteria developed by the Hawai'i State Department of Health for the West Hawai'i regional standards with the applicable criteria for the present data set. Standards for three parameters under all salinity regimes have a single not to exceed criterion; these are for ammonia nitrogen, chlorophyll-*a* and turbidity. For the remaining parameters, two situations apply: if there is no substantial groundwater flow (as evidenced by a salinity depression near the shore), a geometric mean "not to exceed" value also applies (Table 12). Where groundwater flow is evident and depressing salinity to 32 ppt or less, a straight-line mixing relationship is specified and the water quality criterion is the slope of this regression line based on surface-collected samples taken at specific points along an onshore-offshore transect.

Application of these criteria to marine samples requires that sample sites be located in a "transect" commencing at the shoreline and sampling at various distances offshore. The regional standards as given in the DOH Administrative Rules require that only samples from the surface layer (i.e., within a meter of the surface) be used in making the analysis. Thus marine sample sites that do not conform to this sampling layout with measured salinities of 32 ppt or less at one of the sites and/or are collected at depth cannot be included in this regression analysis.

A. Baseline Period Compliance

There are five transects established to monitor the waters fronting Ka Lae Mano; inspection of the salinity data from the four reports (Marine Research Consultants 1993, 1994, 1998, 2002) notes no significant salinity depression (i.e., below 32.000 ppt) along any of the five transects; significant salinity depression is also absent in the 20 September 2004 final baseline survey. With this finding, the regional water quality standards require that sample sites with no significant salinity depression (or gradient) utilize single value "not to exceed" criteria as given in Table 12. In Table 1 the "not to exceed" criteria (as given in Table 12) are applied to each of the transect geometric means (for surface samples only) sampled in each of the five baseline surveys. Geometric means out of compliance with the regional standards are underlined in Table 1. Inspection of Table 1 shows that many parameters are out of compliance on many of the transects and sample dates. Specifically, nitrate nitrogen is out of compliance at all transects on the August 1993, April 1998 and April 2002 surveys as well as at transect B in January 1994. The geometric means for total nitrogen did not meet state standards for all transects in August 1993, April 1998, April 2002 and September 2004. Ammonia nitrogen geometric means were above state standards on transects A and B in August 1993, January 1994 and April 1998. The geometric means for orthophosphorous did not meet state standards on transects C and D in August 1993, B in January 1994, A, C and D in April 1998, A, C, D and E in April 2002 and total phosphorous geometric means were out of compliance on Transects C and D in August

1993, A, B, C and D in April 1998, and A, C. and E in April 2002. The geometric means for turbidity did not meet state standards on all transects in the August 1993, January 1994, April 2002 surveys an on transects A, C and D in April 1998 as well as at transects A and E in September 2004 surveys. Finally, chlorophyll-*a* was noncompliant on transects A and C in April 1998 and on C again in the April 2002 survey.

Summarizing the compliance with state regional standards during the baseline period, there are seven parameters where compliance/non-compliance applies and four transects in the first three surveys and five transects in the last two surveys which results in 154 opportunities for non-compliance to occur. In 77 instances (or 50%) of these 154 opportunities for non-compliance, parameters were not in compliance with state standards.

It is not surprising that the geometric means for many parameters have not met regional standards for marine waters in the preconstruction period. Water quality studies carried out at Kukio (about 3.9 km south of the Ka Lae Mano project site) found over a ten-year baseline period that the geometric means for marine waters were out of compliance for ammonia nitrogen, turbidity, nitrate nitrogen, orthophosphorous, total phosphorus and chlorophyll-*a* (see Table 13). This lack of compliance spans the period from August 1990 - November 1999 (Brock 2000a) and suggests that the "baseline" noncompliance at Ka Lae Mano is not to be unexpected. Indeed, many of the grand geometric means from the Kukio baseline period are greater than those calculated in the Ka Lae Mano data set (see Tables 1 and 13).

B. "During Construction" Compliance

"During construction" surveys have been carried out quarterly since the commencement of site grading in early 2005 (with the exception of 2009 and 2010 where three surveys were done), thus there have been 30 during construction field sampling events to date. Data for the four 2005 surveys are summarized as geometric means in Table 2, Table 3 presents the geometric mean summaries for 2006, Table 4 for 2007, Table 5 for 2008, Table 6 for 2009, Table 7 for 2010, Table 8 for 2011 and Table 9 for 2012. The data from the four 2012 surveys are given in full in Appendices 1 - 4. In no cases during any of the thirty during construction surveys has there been a significant (i.e., 32.000 ppt or less) salinity depression at any of the five transect sites adjacent to shore thus the not to exceed regional standards as given in Table 12 apply to these data.

As given above, the 2005 data are summarized in Table 2 as geometric means for each of the five transects sampled on each of the four dates. In Tables 2 through 9, non-compliant geometric means are underlined while parameter geometric means that are in compliance with state regional standards are not. Referring to Table 2 (2005 data), the non-compliance data can be summarized: there are seven parameters sampled on each of five transects on four dates resulting in 140 opportunities for non-compliance in these during construction data. In 2005, there are 24 instances (or 17%) where these data were not in compliance with the state regional standards.

Table 3 summarizes the 2006 data in the same way, i.e., where the geometric means for each of the five transects sampled on each of four dates in 2006. Again, underlined geometric means in Table 3 are those out of compliance with state regional standards. Again summarizing the non-compliance in the 2006 data, there were 49 instances (out of a possible total of 140 or 35%) where a parameter was out of compliance in 2006.

Table 4 summarizes the 2007 data as just above, where the geometric means for each of the five transects on the four surveys are given. Again, underlined geometric means are those out of compliance with state regional standards. Referring to Table 4, there are 70 instances where a parameter was out of compliance with state regional standards. This results in a 70/140 = 50% rate of non-compliance which is equal to the rate of non-compliance in the baseline data set.

Following the same procedure, Table 5 summarizes the geometric mean data for 2008 in the same manner as above where the underlined geometric means are those out of compliance with the West Hawai'i regional standards. In 2008 there were 91 instances of non-compliance which results in an overall non-compliance of 91/140 = 65% rate of non-compliance. The 2009 compliance/non-compliance data are given in Table 6 where there were (5 transects x 7 parameters x 3 surveys =) 105 opportunities for non-compliance to occur. There were 41 instances where the geometric means of parameters were not in compliance yielding a (41/105 =) 39% rate of non-compliance in 2009. Similarly, the compliance/non-compliance data for 2010 are presented in Table 7. Again there were (5 transects x 7 parameters x 3 surveys =) 105 opportunities for non-compliance to occur and there were 34 times that a parameter did not meet state standards resulting in a (34/105 =) 32% rate of non-compliance. The 2011 data are given in Table 8 and there were (5 transects x 7 parameters x 4 surveys =) 140 opportunities for non-compliance to occur and there were 68 instances of noncompliance (68/140 =) 49%. Finally in 2012 there were 80 instances of non-compliance thus 80/140 = 57% rate of noncompliance. The rate of non-compliance in the preconstruction period was 50% (above) while the grand mean during construction rate of non-compliance is 43%. These data show a decrease in non-compliance in the during construction period relative to the preconstruction period in the marine waters fronting the Ka Lae Mano project site.

Inspection of the grand geometric means derived for the transects in each sample period during the baseline period (Table 1) and comparing these to the same data from the 2005 - 2012 during construction period (Tables 2, 3, 4, 5, 6, 7, 8 and 9) finds that the greatest geometric means for four parameters occur in the baseline period (nitrate nitrogen, total nitrogen, total phosphorus and turbidity) and with the three remaining parameters (orthophosphorous, ammonia nitrogen and chlorophyll-*a*), the greatest geometric means have been found in the during construction period. However in total, there have been 35 surveys completed to date; five of these or (5/35 =) 14% were undertaken during the preconstruction phase and the remainder (or 86%) occurred in the during construction phase. With 86% of the surveys occurring in the during construction period and only 14% of the surveys done in the preconstruction phase, one would expect that (0.86 x 7 parameters =) 6.02 of the parameters would have the greatest geometric means in the during construction period and (0.14 x 7 parameters =) 0.98 of the parameters having the greatest geometric means in the preconstruction period if the distribution of greatest geometric means were occurring randomly. The fact that four of the seven geometric means (or 57%) occurred in the preconstruction period which occupied only 14% of the surveys suggests that the concentrations of water quality parameters as delineated by the distribution of greatest geometric means is greater in the preconstruction period relative to the during construction period. These data suggest compliance or non-compliance in parameters measured in the marine environment is not related to activities on the Ka Lae Mano project site.

There are ten samples collected on each of the five transects in the marine waters fronting the Ka Lae Mano project site. Seven samples are collected from the surface while the remaining three are taken at depth. Since freshwater is lighter than seawater, seaward flowing groundwater entering the sea will tend to "float" on the surface until wind, waves and currents mix this water, thus losing the lower salinity signature. Examining the mean salinity data for each marine sample site, only one site of all fifty routinely sampled has a small depression in salinity and this is site 1 (shoreline station) on transect KL-A (see Figure 1). Mean salinity of KL-A-1 is 34.100 ppt and at KL-A-2 (10 m seaward) is 34.211 ppt (means determined by using all data). Grand mean salinity all other surface sample sites on all transects = 34.552 ppt. In short, the only groundwater signature seen to date at the marine sample sites is located at the shoreline and 10 m offshore stations (nos. 1 and 2) on transect KL-A, otherwise all salinities measured in surface waters since the inception of this program show very little evidence of groundwater input. The presence of groundwater as manifested through lower measured salinities at stations 1 and 2 on transect KL-A is small relative to many other areas along the West Hawai'i coast (e.g., Kukio, Waikoloa, etc.) but the groundwater at Ka Lae Mano as evidenced from the mauka well data (Well sites 4 and 5, see Table 9) has extremely high natural concentrations of nitrogen and phosphorus. Since groundwater often has nitrogen and phosphorus naturally occurring in relatively high concentrations relative to seawater, the universal occurrence of high geometric means at transect KL-A is not unexpected and the high variability in non-compliance is probably related to the degree to which groundwater is or is not present at the time of sampling. To further complicate matters, groundwater may be entering the sea fronting the Ka Lae Mano project site but if winds, waves or currents are active at that time of sampling, elevation in nitrogen and phosphorus in the marine samples may not be strongly evident. Sampling at periods of calm and when the tide is falling (thus drawing groundwater in a seaward direction) will enhance the probability that groundwater signature will be present and nutrient concentrations will be elevated. Thus the physical conditions of the ocean and tide state probably play the largest role in compliance or the lack of it at Ka Lae Mano.

Finally if phosphorus and nitrogen from the use of fertilizers applied to landscaping at Ka Lae Mano were leaching to the groundwater below and traveling to the ocean thus being the source of the changes in nitrogen and phosphorus encountered in the marine samples, examination of the parameters that allow leaching to occur need to be discussed. Nitrogen in fertilizers is often applied in the ammonium form that will rapidly convert to the nitrate form (NO_3 - the form readily utilized by plants), which does not bind to the soil and readily moves down through soil horizons with water. Because of this lability, fertilizers could potentially be a source for the changes in concentrations of nitrogen measured in the ocean. However a different picture emerges with phosphorus. Once applied to soils, phosphorus is very immobile and this is related to the adsorptive capacity of soils (Taylor 1967) and the latosol soils of Hawai'i have a high fixing capacity for phosphorus (Fox 1972). In some areas, the soil competes with plants for available phosphorus and very little movement of phosphorus occurs with studies conducted on the order of years (Chang and Young 1977). More recent studies also show that leaching of applied phosphorus is unlikely because of its low solubility and high reactivity (sorption) in soils (Green 1991, Soicher and Peterson 1997) suggesting that phosphorus encountered in groundwater at Ka Lae Mano is probably not from a fertilizer source but from completely natural sources upland of the project site.

In closing, the baseline dataset spans an eleven-year period (1993 through September 2004) while the during construction period only covers a eight-year period. The baseline rate of noncompliance is a mean (here 50%) spread over eleven years but the overall during construction rate of noncompliance is 43% as given above. Thus compliance - noncompliance in parameters measured in this study does not appear to be influenced by the activities occurring on the project site.

2. Well and Anchialine Pool Data

Five wells were drilled for the monitoring of groundwater at the Ka Lae Mano project site. Three wells are located along the makai portion of the project site (nos. 1 - 3) to monitor the quality of water as it leaves the project site and two wells (nos. 4 and 5) are situated along the inland (mauka) boundary of the project area (Figure 2). The two mauka wells monitor the quality of the groundwater as it enters beneath the project site. These wells were completed and first sampled in the final baseline survey period (September 2004) and have been sampled on all subsequent during construction surveys. However in the March 2008 survey Well 1 (south makai well, see Figure 2) was removed due to its first placement in a roadway. It was redrilled moving it about seven meters away to the north and it has been sampled on all subsequent surveys.

Right after the commencement of grading, a dust control well was drilled (Well 6, Figure 2). This well was sampled on all surveys since its construction except in December 2005, August and November 2009 when the pump was not operational and it was subsequently closed in 2010 because it was no longer needed. However, a new well (Well 7) was recently drilled as a source of irrigation water and was first sampled in September 2011. Well 7 is now routinely sampled on the quarterly surveys commencing in 2012.

While hand clearing vegetation (kiawe) in 2005, an anchialine pool was discovered. This pool is situated close to the shoreline mauka of a sand/coral rubble berm near the northern boundary of the project site. The pool is in an advanced state of senescence having been filled in by sand, coral rubble and plant debris, thus only having water present on the highest of high tides. When water is present, native anchialine shrimp are present in high abundance. Water was present only during the December 2005 and the 9 November 2006 surveys. In early 2007, permission was obtained from kupuna whose families cared for this land in the past to place a plastic bucket with no bottom and a removable top into the mud of the pond bottom during a low tide period. The removable lid keeps leaf litter out of the bucket and water enters through the bottom of the bucket. The bucket extends about 30 cm into the mud thus has water present during all tide stages allowing the collection of a water samples at any time thus the pond has been sampled during each survey commencing in 2007.

The water quality data from these seven wells and the single anchialine pool sample are summarized in Table 10 for wells and Table 11 for the anchialine pool. The well data are presented as means for each parameter by survey date. The 2012 well and anchialine pool data are given in their entirety in Appendices 1 - 4. As noted above, there are six active wells present on the project site. Three of these wells are located inland and upgradient of the ongoing development (Well nos. 4, 5 and 7, Figure 2) and sample water as it enters the project site. The remaining three wells are either in the middle of the development (Well no. 6 which is not used at present was a source of water for dust control) or along the makai (seaward) edge of the development (Well nos. 1, 2 and 3). These latter wells sample the water as it is either beneath (Well 6) or is leaving the project site (Well nos. 1, 2, and 3, Figure 2).

A. Analysis of Well Data

The locations of the six active wells allows for comparative analysis of the concentrations of nutrients between sites and over time. Table 14 presents the results of these analyses using the nonparametric Wilcoxon Two-Sample Test to address questions which are given below. The first question, "Are there significant differences between the mean parameter concentrations comparing the inland (mauka) to the seaward or makai wells in the preconstruction period?" These results are given in Table 14 (Section A - top) where the analysis found no statistically significant differences in mean parameter concentrations between the mauka and makai wells in the preconstruction period. Asking the same question, "Are there significant differences in the mean concentrations of parameters in the mauka wells relative to the makai wells in the during construction period?" is addressed in Part B (Table 14) where mean nitrate nitrogen, total nitrogen and salinity are significantly greater in the makai wells over the mauka wells in the during construction period. However, mean orthophosphorous and silica are significantly greater in the mauka wells over the makai wells in the during construction period and total phosphorus along with ammonia nitrogen showed no significant differences among the mauka wells to makai wells in the during construction period. If data from all dates (preconstruction and during construction) are considered together asking the same question, i.e., "Are there significant differences in mean parameter concentrations between mauka to makai wells?" we find the same result as seen in Part B, namely that mean orthophosphorous and silica are significantly greater in the mauka wells over the makai wells, mean nitrate nitrogen, total nitrogen and salinity are significantly greater in the makai wells over the mauka wells (Table 12, Part C) and again total phosphorus and salinity showed no significant differences. Examining the data from the mauka (inland) wells only and addressing the question, "Are there significant differences between preconstruction to during construction means in mauka wells?" finds only one statistically significant difference with the parameter total nitrogen where total nitrogen is significantly greater in the preconstruction period otherwise there are no statistically significant differences between these two time periods (Table 12, Part D). Again, asking the same question, "Are there significant differences in mean parameter concentrations in makai wells comparing the preconstruction period to the during construction period?" finds that the preconstruction mean of total nitrogen is significantly greater than the during construction mean, otherwise there are no significant differences in the other parameter means (Table 12, Part E).

Summarizing the analysis of well data, there are no significant differences in parameter concentrations in the preconstruction period between mauka and makai wells (Table 11, Part A) probably because of the small sample size (only one sample period with two mauka and three makai wells). The during construction period only (Part B) as well as the all dates (Part C) analyses comparing mauka to makai wells (Table 12, Parts B and C) finds greater mean orthophosphorous and silica in mauka wells over makai wells and in the makai wells salinity, total nitrogen and nitrate nitrogen are significantly greater. Being closer to shore salinity should be higher in the makai wells over the mauka wells and silica concentrations should be greater in the mauka wells because groundwater has silica naturally occurring in high concentration and in seawater these concentrations are low. Thus mauka wells being situated further inland should have greater silica concentrations. However, significantly greater nitrate nitrogen and total nitrogen in the makai wells over the mauka wells could suggest that a anthropogenic input of nitrogen to the groundwater is occurring somewhere on the project site.

The source of nitrogen could be from the fertilization of the limited landscaping present at Ka Lae Mano. However, irrigation rates are low and the downward movement of nitrogen to the seaward flowing groundwater requires sufficient irrigation which is not likely given that much of the landscaping at Ka Lae Mano is comprised of xerophytic plant species (i.e., those that use less water).

Both nitrate nitrogen and orthophosphorous are used in fertilizing landscaping. Other than fertilizers, the only other possible source of nitrate emanating from the project site could be from explosives used in site grading. However if this were the source, a means of conveying the residues from the explosives left on the surface to the underlying groundwater which lies more than 10 m below would be needed. The only obvious transport mechanism is water but the only water used on the project site has been for dust control (where only enough is spread on the surface to prevent airborne dust) and limited irrigation. Furthermore annual rainfall totals are very low (less than 10 inches/year) for the Ka Lae Mano makai lands. Lacking an identified transport mechanism (here sufficient water), the significantly greater mean nitrogen concentration in the makai wells in the during construction period may from completely natural (unidentified) source(s) as would be the elevated orthophosphorous in mauka wells.

Further support for small groundwater efflux to the ocean in the during construction period at Ka Lae Mano may be found with the results of the statistical analysis of changes in marine water quality parameters (see next section). Albeit the differences in salinity are small, the statistical analysis found that the mean salinity was significantly greater in the during construction period relative to the preconstruction period which suggests that less groundwater is escaping to the sea in the during construction period. These data suggest that less groundwater is entering the ocean fronting the Ka Lae Mano project site now than previously.

The results from Part C (Table 14) follow those of directly above (Part B) simply because the during construction data set is significantly greater (n=171) than the preconstruction data set (n=5). The examination of mauka wells finds only one significant differences between the preconstruction means from the during construction means (Part D) which was with the parameter total nitrogen where total nitrogen is significantly greater in the preconstruction period. The same analysis applied to the makai wells finds that the preconstruction mean for total nitrogen is significantly greater than the during construction mean in the makai wells (Part E). With no anthropogenic source present on the project site in the preconstruction period, the only logical explanation for the significantly greater mean concentration of total nitrogen is that it was from natural source(s) which supports the contention that there is considerable variability in the concentrations of nutrients in undisturbed West Hawai'i groundwater and the concentrations found in Ka Lae Mano wells despite significant changes are probably from natural sources.

3. Analysis of Marine Data

Five baseline period surveys were completed over a 121-month period prior to the commencement of construction at Ka Lae Mano. These baseline water quality data represent the natural conditions for the marine waters fronting the Ka Lae Mano project site. On-site construction commenced in earnest following the September 2004 survey and the quarterly water quality monitoring program began in 2005. This quarterly program has sampled in March, July, September and December 2005, March, June, August and November 2006, April, July, October and November 2007, March, May, August and October 2008, March, August and November 2009, again in April, June and November 2010, in April, May, September and November 2011 as well as in March, June, September and November 2012. The question, "Has there been any significant change in water quality in the ocean since the commencement of construction?" can be addressed by statistically comparing the means of parameters in the preconstruction to the during construction periods using the nonparametric Wilcoxon 2-Sample Test. The results of the Wilcoxon 2-Sample Test are given in Table 15 where the means for nitrate nitrogen, silica, orthophosphorous, turbidity, temperature and pH were found to be significantly greater in the preconstruction period relative to the during construction period. During construction means that were significantly greater include ammonia nitrogen and salinity. No statistically significant differences were found for the means of total nitrogen, total phosphorus, chlorophyll-*a*, and the percent saturation of dissolved oxygen. The concentrations of many parameters from the preconstruction period have higher mean values relative to those from the during construction period. The statistically significant differences in some parameters may be easily explained such as that for silica and salinity; groundwater usually has high silica concentrations whereas dissolved silica in seawater occurs at low concentrations. Thus higher salinity waters usually have lower silica concentrations. The significantly greater mean silica concentration in the preconstruction period is probably related to the significantly lower salinity in that period. These statistically significant changes may be related to changes in groundwater discharge to the ocean fronting the Ka Lae Mano project site. These could be due to past seasonal changes in input (mauka rainfall) or possibly to the withdrawal of low salinity groundwater on the project site used for dust control since the start of construction. However, if latter use was the reason for the significant change in salinity offshore, it should be reflected in the salinities found in the groundwater monitoring wells and it is not. The mean groundwater salinity in the coastal monitoring wells prior to the commencement of construction was 2.662 ppt and the mean salinity in these wells since the start of construction is 2.607 ppt.

Another way to statistically view the preconstruction to during construction marine water quality data is to examine the means of parameters from each sampling event, looking for chronological change. In this case the question addressed is, "Has there been any statistically significant change in the means of the parameters measuring marine water quality over 230-month period of this study encompassing five baseline field surveys and thirty during construction surveys?" To address this question two non-parametric tests were used; the Kruskal-Wallis analysis of variance (ANOVA) determined if significant differences did exist among the means of parameters comparing means by date and the Student-Newman-Keuls Test was used to separate which means differed significantly from others. Nonparametric statistical tests were used to avoid some of the assumptions that are requisite with use of parametric statistics (i.e., normality, homogeneity of variances, etc).

The results of the nonparametric tests are summarized in Table 16. The Kruskal-Wallis ANOVA found statistical differences among the thirty-five sample dates for all parameters. The SNK test also found significant differences among the thirty-five surveys for all parameters. The greatest means are found in the preconstruction (baseline) period for nitrate nitrogen and total nitrogen in April 1998, silica in April 2002 and turbidity in January 1994. All other parameters had the greatest means in the during construction period; most notable were the greatest orthophosphorous and total phosphorus means occurred in the March 2009 survey but by the end of the year (November 2009) the phosphorus means were near the bottom of the range. With respect to the parameter means found in the four most recent 2012 surveys, most were spread through the upper third to the lower third of their respective ranges. The lack of any chronological order to the increases or decreases in mean concentrations for all parameters suggest no relationship with the passage of time. The only parameter showing any relationship to time are the seasonally driven changes in mean temperatures which have nothing to do with development.

Thus there is no evidence of a trend of increasing concentrations with time; indeed the during construction means (2005 through 2012) are spread with no order through the range for most parameters. In the case of ammonia nitrogen, the statistically greater mean concentration found in the October 2008 and November 2011 surveys are not particularly elevated. Ammonia nitrogen is a product of organism metabolism (excretion) and can be an indicator of sewage input if concurrent measurements of nitrate nitrogen, silica and orthophosphorous are likewise high and salinity significantly less which has not been the case at Ka Lae Mano. Ammonia nitrogen is frequently out of compliance with state water quality standards along undeveloped coastlines and this may be due to excretion by locally abundant fish (Brock and Kam 2000) as has been encountered over the last twenty years along much of the undeveloped coastline of Lana'i Island (Brock 2007b).

Finally, it should be noted for many of the parameters having their greatest mean concentrations occurring in the during construction period, that these mean concentrations are typical of Hawaiian coastal waters and at these concentrations are biologically insignificant. Examples are found with temperature, pH, salinity and percent saturation of dissolved oxygen. Thus the data do not support the contention that the ongoing grading, landscaping and limited residential construction activities at Ka Lae Mano are having an impact on the quality of the ground- and/or nearshore marine waters. At a minimum, the fact that there is statistically significant separation among the means for all parameters in the marine waters fronting this project site over the preconstruction and during construction periods supports the contention that variability in the concentrations of these water quality parameters is the norm and this variability is natural and must be considered in any analysis of data, particularly during the construction phase of the project. Furthermore, despite statistical separation by the ANOVA, the SNK Test noted considerable overlap among sample dates for all parameters with just a few instances of clear statistical separation being evident; this is a further indication that there are no clear trends in these data with time which would be expected if parameter concentrations were increasing due to the development.

Finally, change to the quality of the marine waters fronting the Ka Lae Mano project site due to the development is not expected at this early point in the development process. As noted above, the project site encompasses approximately 1,071 acres, 876.6 acres of which could be developed and ~200 acres are to be preserved. This first phase of the development includes roadways, about 75 house lots situated in the makai portion of the project site and limited infrastructure including a cultural center with a landscaped buffer. Some landscaping has been developed in the buffers along some of the roadways. In the context of the entire project site, the landscaping and construction activities comprise an extremely small part of the total project site. Thus at this juncture, preliminary grading of raw lava has comprised the majority of the activities. The landscaping that has been planted is made up of a palette of hardy largely native xerophytic species. This landscaping has been developed in the makai portions of the project site alongside of some roadways and has been watered by drip irrigation. Once the vegetation is established, the irrigation schedules have been greatly reduced or terminated because water is a precious commodity and is not wasted which leaves little chance for its escapement to the underlying watertable (Kauhane Morton, personal communication). Some low-salinity groundwater has been withdrawn and used for the purpose of dust control, however the method of application (surface spray to control dust) does not allow much, if any escapement of water to the underlying groundwater because volumes used per unit area are small and evaporation is high. Furthermore over the last two years, much of the dust control activities have ceased. The only activity occurring during grading that could result in a change to ground- and/or near shore marine waters would be an increase in nitrate due to the use of explosives. Nitrate may occur as a residue following the use of dynamite. However, the usual mechanism to transport materials from the surface to the groundwater table is sufficient water to cause the leaching of materials from the surface to down to the underlying seaward-flowing groundwater. In the absence of high rainfall on the project site, the opportunity for sufficient water to be available is remote if just dust-control applications and limited drip irrigation (which has been largely reduced or terminated) are the only identified sources. As noted above, annual rainfall at Ka Lae Mano is less than 10 inches per year. If they are to occur, possible changes to ground- and near shore marine water chemistry due to the development would not manifest themselves until landscaping has encumbered a much larger portion of the project site than it presently occupies and only if the use of plant palettes change to less drought-tolerant species requiring much greater use of irrigation water. Since the Ka Lae Mano development fosters a sustainable focus, greater use of irrigation water would probably not occur. Thus it is unlikely that the activities occurring on the Ka Lae Mano project site will result in changes to the ground and near shore marine water chemistry in the foreseeable future.

CONCLUSIONS

The concentration of many nutrient parameters is usually much greater in groundwater relative to oceanic waters which establishes a concentration gradient in marine waters where groundwater enters the sea. Thus the presence of groundwater in the near shore marine environment appears to have a major influence on the quality of these near shore waters. When groundwater is present, the geometric means of many parameters do not meet the state Department of Health regional water quality standards and when absent, most parameters other than turbidity, total nitrogen and sometimes ammonia nitrogen are in compliance. Hence the presence or absence of groundwater in the marine environment may play a pivotal role in meeting or exceeding state water quality standards. Usually along the relatively porous lavas of the Kona coast, groundwater is more evident in the coastal marine environment on falling tides due to its increased seaward flow and conversely, this flow is impeded by rising tides. However, local surf and wind conditions may serve to mask the presence of groundwater by increasing the mixing and dilution of effluxing groundwater in the near shore marine environment. The waters fronting Ka Lae Mano have high exposure to wind and surf relative to many other parts of the West Hawai'i coast thus compliance of these waters to state water quality standards may be affected by the local weather at the time of sample collection.

There have been thirty-five water quality surveys carried out in the marine environment fronting Ka Lae Mano over the last nineteen years; the tide state and local weather/surf conditions are unknown for the first four surveys (29 August 1993, 16 January 1994, 8 April 1998 and 15 April 2002) but are known for the last thirty-one surveys (20 September 2004 through 16 November 2012). The ocean conditions during the time of the first five surveys (20 September 2004, 31 March, 19 July, 27 September and 6 December 2005 were generally rough, with winds blowing from the NNW from 15 to 30 mph and the seas very choppy. These conditions serve to rapidly mix effluxing groundwater in the near shore area. The salinity data as given in the 2005 annual survey (Brock 2006) also support the hypothesis that mixing was high (i.e., having high salinities) despite favorable tide states (sampling has been carried out on falling, near zero, weakly rising tides). In the 2006 surveys, the tides were either dropping or were showing little change during the time that samples were collected. Winds were somewhat less during all four surveys and only in the November 2006 survey was there any surge. Again the salinity data suggest little evidence of groundwater (Brock 2007a) along the shoreline. On all four of the 2007 surveys, there was some surge present but almost no surf. On the first three 2007 surveys the tide was at or near ebb and on the last (November) 2007 survey the tide was falling. Because of generally low tides and little to no surf present (but some surge), conditions for all of the 2007 surveys would be expected to show some reasonable salinity depression close to shore but again did not. In the four 2008 surveys there was some surge in the March, August and October surveys but the May survey was carried out during a period of calm and clear ocean conditions. The tide state in the 2008 surveys ranged from being favorable (i.e., relatively low or falling for the March and May surveys) but was rising steeply in the August survey and much less so in the October 2008 survey and once again the shoreline salinity data show little evidence of groundwater efflux.

Brisk northerly winds were present during the March and November 2009 surveys which resulted in choppy seas that would tend to mix and mask any effluxing groundwater. In the August 2009 survey, the seas were calm which would assist in identifying any groundwater entering the sea. Tide states in 2009 rising slightly in the March survey, ebbing slightly in the August survey and steeply falling in the November survey. In general the weather conditions in 2009 were not favorable for encountering groundwater offshore of Ka Lae Mano. On the 20 April 2010 survey there was a small tradewind swell present but the water conditions adjacent to shore were relatively calm. Tide at the time of sampling was gently rising which would impede groundwater flow to the sea. In the 29 June 2010 survey the water was calm and the tide was gently falling which should assist in detecting groundwater flow. On the 12 November 2010 survey some surge was present along the shoreline and the tide was strongly rising at the time of sampling which, again, serve to impede the flow of groundwater to the ocean.

In 2011 tides were rising in the first two surveys; on 13 April, the tide was rising from the ebb moving from +0.0 to +0.2 feet over the period of water sample collection and the seas were relatively calm. On 26 May 2011 the tide was rising from the ebb (occurring about one hour earlier) and rose from +0.2 to +0.4 feet and again the sea was relatively calm and winds were light. On the 15 September 2011 survey the tide was high and was beginning to ebb, moving from +1.6 to +1.2 feet and again seas were relatively calm and the wind was light. On the 8 November survey tides were decreasing from +0.8 to +0.6 feet and tradewinds were light.

In 2012 the tide was falling on three of the four surveys (22 March, 18 September and 16 November). In the September and November surveys, the tide was steeply declining and the seas were relatively calm but on the 22 March survey the decrease was small and there was a long-period west swell present which created considerable white water. In the 25 June survey the tide was relatively high (+1.0 feet) and continued to rise during the period of sampling but the ocean was calm.

Despite little salinity depression along the shoreline in many of the surveys, groundwater is effluxing along the Ka Lae Mano coastline is the probable sole source of the often elevated measured nutrient concentrations. Examination of the nutrient chemistry of the Ka Lae Mano groundwater as given in the well data shows that the natural nutrient concentrations are among the highest found anywhere along the West Hawai'i coast. Thus, in the case of Ka Lae Mano, the amount of groundwater entering the ocean does not need to be a high volume flow because its signature is readily identifiable by the natural elevation of inorganic nutrients.

It is surmised that when mixing is high in the coastal waters as occurs during period of surf, winds and in particular on rising tides, the effluxing groundwater is rapidly mixed and diluted such that its signature is quickly "lost"resulting in a lower rate of non-compliance in water quality parameters. However, when the tide is rapidly falling, winds are light and surf is near absent, the effluxing groundwater is less rapidly mixed and the resulting rate of non-compliance is greater. The Ka Lae Mano environmental monitoring program attempts to focus sampling during periods when surf, wind and tides favor the sampling of effluxing groundwater but the exposed nature of the Ka Lae Mano coastline often results in less than perfect sampling conditions. These weather conditions are reflected in the rate of non-compliance with state water quality standards; in the preconstruction period (1993 through September 2004), the overall rate of noncompliance was 50%; in 2005 it was 17% (a year with poor or rough weather conditions), in 2006 the rate of noncompliance increased to 35% (slightly better weather conditions during most surveys), in 2007 the rate of noncompliance was 50% which is equal to the overall noncompliance found during the eleven-year baseline period and the weather conditions were better for water quality sampling than in 2006. In 2008 the annual rate of noncompliance had increased to 65% and the weather and tides were generally favorable suggesting a better sampling of effluxing groundwater because mixing was less. In 2009 the rate of non-compliance was 39% and in 2010 the overall rate of non-compliance was 32% suggesting that mixing was higher due to weather and tide states, thus the lower rate of non-compliance. In 2011 the rate of non-compliance was 49% and in 2012 it was 57% thus both years reflecting the generally calmer seas during most of the quarterly surveys. In summary, besides tide state which is the usual driver for groundwater flow, the local wind and surf conditions play a large role in the detecting compliance/noncompliance in many water quality parameters at Ka Lae Mano. Furthermore, when the conditions are absolutely calm coupled with a strongly falling tide, effluxing groundwater will be greatest and most obvious at the surface along the shoreline and under these conditions, more parameters will not meet state regional water quality standards.

Groundwater sampled in the five Ka Lae Mano coastal monitoring wells, the now-closed dust control well and the new irrigation water well shows this water to be high in inorganic nutrients and relatively low salinity when considering the proximity of these sample sites to the coast. The high nutrient signature of this groundwater is very similar to that sampled at Kukio about 3.9 km to the southeast which suggests that the source of the high nutrient Kukio groundwater may be from the lands mauka of Ka Lae Mano. Examination of the groundwater sampled in these wells found many of the parameters at higher concentrations in the makai wells relative to the mauka wells. One might infer that these higher concentrations are due to activities occurring on the construction site, however they are present in the baseline data suggesting that other natural factors are responsible for the differences in measured concentrations. Secondly, examination of well data over time shows considerable variability at given sites, a finding that has been encountered at many other well sites in West Hawai'i. As a consequence of these two findings, the few statistically significant differences seen in parameters measured in mauka and makai wells are probably not related to inputs coming from the construction site but are related to the high natural variability.

Nutrient concentrations are often naturally elevated in groundwater relative to marine waters. Thus effluxing groundwater may be a source for some nutrient species in near shore marine settings. Statistical analyses addressing the question, "Has there been any significant change in quality of marine waters fronting the Ka Lae Mano project site since the commencement of construction relative to the preconstruction period?" found that the means for nitrate nitrogen, orthophosphorous, silica, turbidity, temperature and pH were significantly greater in the preconstruction period relative to the during construction period. During construction means that were significantly greater include ammonia nitrogen and salinity. The ammonia nitrogen means are not particularly elevated (preconstruction = 1.67 ug/l and during construction = 2.28 ug/l; both being within state regional standards) and the presence of well-developed fish communities (i.e., via community metabolism) may be responsible for these differences.

Another statistical approach is to examine the means of marine water quality parameters from each sampling event, looking for chronological change. In this case the question addressed is, "has there been any significant change in the means of parameters over the 230-month period of this study?" The Kruskal-Wallis ANOVA found statistical differences among the thirty-five sample dates for all water quality parameters. It should be noted that for many of the parameters that have their greatest mean concentrations occurring in the during construction period, their mean concentrations are typical of Hawaiian coastal waters and at these concentrations are biologically insignificant despite their being statistically greater.

Furthermore examination of marine survey means by date in the during construction period finds no evidence of a trend of increasing concentrations with time; indeed, the during construction means (2005 through 2012) are spread with no order through the range for most parameters. The highest marine survey means for orthophosphorous and total phosphorus were encountered in the March 2009 survey but by the next survey (August 2009) these means were both considerably reduced. The November 2009 survey mean for salinity was the highest to date but the difference between this mean (35.192 ppt) relative to the lowest survey mean (August 1993 = 33.894 ppt) is trivial and has no biological significance.

In the case of ammonia nitrogen, the statistically greatest mean concentration occurred in the October 2008 during construction sample period (mean = 6.03 ug/l) and followed by November

2011 mean (4.94 ug/l); these means are not particularly elevated. Furthermore, the SNK Test failed to find any further statistical separation among the ammonia nitrogen means from all other sample dates due to strong overlap. Ammonia nitrogen is a product of organism metabolism (excretion) and can be an indicator of sewage input if concurrent measurements of nitrate nitrogen, silica and orthophosphorous are likewise high and salinity significantly less which has not been the case at Ka Lae Mano. Ammonia nitrogen is frequently out of compliance with state water quality standards along undeveloped coastlines and this may be due to excretion by locally abundant fish (Brock and Kam 2000) as has been encountered over the last twenty years along much of the undeveloped coastline of Lana'i Island. (Brock 2007b).

It is virtually impossible that the development at Ka Lae Mano is having impact to ground or near shore water chemistry at this point in time. For impact to occur, two components are necessary; a source of pollutant materials applied in sufficient excess on the soil surfaces and a transport mechanism to carry these excess materials to the underlying groundwater. A potential source of impact is the application of fertilizers applied to landscaping. Less than one percent of the total project site has been landscaped. Plant palettes used at Ka Lae Mano have focused on using xerophytic native species and efficient drip irrigation methods have been employed and only so until plants are established. With the groundwater lying from 10 to more than 25 m below the surface, a substantial near-continuous source of water would be necessary to transport any excess fertilizers to the underlying groundwater. Besides drip irrigation, the only other anthropogenic source of water has been for dust control purposes and only enough is used to settle dust during construction activities in a very arid, low rainfall (average = 10 inches/year) setting. Since the latter part of 2009, the use of water for dust control has largely ceased. Thus changes in water quality in ground and near shore marine waters measured in this study are from natural, highly variable sources.

In summary, the quality of the marine waters fronting Ka Lae Mano from the five baseline (1993-2004) and thirty (2005-2012) during construction surveys show them to be typical of well-flushed, West Hawai'i sites. The quarterly during construction monitoring surveys have not found any evidence of materials leaching to or otherwise entering the groundwater or near shore marine waters fronting the project site. The fact that some parameters are out of compliance with the West Hawai'i regional water quality standards is not unexpected in light of the lack of compliance noted at many other undeveloped (Kealakekua Bay - Brock 2000b, 2001) and formerly undeveloped sites (Hokuli'a - Brock 1999, Kukio - Brock 2000a) along the Kona coast. However, detecting the groundwater signature in the near shore marine environment fronting Ka Lae Mano is difficult due to the natural rapid mixing that occurs there via frequent local wind and waves.

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TABLE 1. Summary of the water quality parameters as geometric means from samples collected along four of 5 transects in the preconstruction period on 29 August 1993, 16 January 1994, and 8 April 1998 and 5 transects on 15 April 2002 and 20 September 2004 in the ocean fronting Ka Lae Mano for surface samples only; also given are the grand surface sample geometric means for each date. These data summarize the baseline water quality conditions of the Ka Lae Mano project site. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [°C]	Oxygen [%]	pH
29-Aug-93														
KL-A	48.62	3.24	142.88	4.95	11.32	720.74	74.64	5.70	33.165	0.16	0.159	27.3		8.24
KL-B	31.96	3.13	144.41	4.62	11.30	463.28	98.81	6.35	33.895	0.11	0.119	27.3		8.18
KL-C	36.89	1.91	141.99	6.82	13.20	542.80	86.64	5.61	33.642	0.12	0.138	27.3		8.18
KL-D	35.41	1.06	146.09	5.86	17.88	596.81	94.26	11.46	33.622	0.11	0.124	27.1		8.18
Geometric Mear	37.75	2.13	143.83	5.50	13.18	573.49	88.10	6.95	33.580	0.12	0.134	27.2		8.19
16-Jan-94														
KL-A	2.81	3.19	85.84	3.42	8.13	96.52	79.55	4.62	34.859	0.23	0.264	24.9		
KL-B	7.56	2.92	89.39	6.31	11.43	199.89	77.01	5.03	34.760	0.28	0.286	24.8		
KL-C	2.85	1.79	83.71	4.70	9.81	100.91	78.84	5.05	34.840	0.22	0.196	24.9		
KL-D	2.63	1.12	80.61	3.89	9.34	73.15	76.76	5.39	34.834	0.21	0.259	24.8		
Geometric Mear	3.55	2.08	84.83	4.46	9.61	109.24	78.03	5.02	34.823	0.23	0.249	24.8		
08-Apr-98														
KL-A	86.28	4.18	264.30	7.17	21.19	1183.90	163.82	14.34	33.430	0.13	0.384	24.8		8.18
KL-B	17.17	3.11	158.66	4.36	17.79	319.27	125.08	13.31	34.281	0.08	0.256	24.7		8.17
KL-C	49.52	2.16	213.41	7.41	20.76	760.66	145.76	12.96	33.682	0.10	0.305	24.8		8.17
KL-D	44.17	0.61	201.91	8.02	21.52	739.24	136.93	12.56	33.615	0.10	0.210	24.7		8.15
Geometric Mear	42.43	2.03	206.17	6.57	20.26	678.99	142.21	13.28	33.751	0.10	0.282	24.7		8.17
15-Apr-02														
KL-A	50.85	1.00	197.62	8.43	13.80	957.85	110.89	5.05	33.121	0.35	0.294	26.2		8.19
KL-B	6.81	0.41	131.89	3.75	8.44	267.62	119.64	4.13	34.314	0.14	0.282	26.1		8.15
KL-C	43.04	0.51	189.43	8.41	14.96	856.00	124.46	6.21	33.479	0.17	0.327	25.9		8.16
KL-D	21.18	0.29	174.83	5.77	11.45	513.05	145.51	5.55	34.046	0.13	0.240	26.2		8.18
KL-E	69.56	0.56	173.02	12.06	19.21	1087.76	93.66	6.72	33.172	0.13	0.236	26.1		8.15
Geometric Mear	29.40	0.51	171.73	7.14	13.08	657.05	117.61	5.46	33.623	0.17	0.274	26.1		8.17
20-Sep-04														
KL-A	1.74	0.35	118.62	2.09	7.78	91.16	115.56	5.41	34.707	0.11	0.164	28.8	100	8.15
KL-B	1.54	0.13	130.73	1.54	9.13	85.58	128.49	7.07	34.708	0.08	0.142	28.8	100	8.17
KL-C	1.27	1.36	118.98	0.91	8.43	82.80	117.37	7.38	34.719	0.07	0.169	28.5	99	8.20
KL-D	1.41	0.28	129.18	0.38	9.26	75.15	127.64	8.81	34.719	0.09	0.179	29.5	100	8.18
KL-E	1.62	1.29	139.72	1.21	10.97	80.29	136.08	9.68	34.701	0.10	0.179	29.5	100	8.12
Geometric Mear	1.51	0.47	127.20	1.06	9.05	82.82	124.80	7.52	34.711	0.09	0.166	29.0	100	8.17

TABLE 2. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2005 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [°C]	Oxygen [%]	pH
31-Mar-05														
KL-A	9.17	0.21	122.55	5.55	11.93	137.02	97.81	4.99	34.336	0.13	0.101	25.2	101	8.13
KL-B	2.64	0.25	114.52	4.87	12.39	110.23	107.82	7.48	34.504	0.08	0.113	24.9	101	8.16
KL-C	1.22	0.14	98.43	5.05	12.49	113.04	88.66	7.25	34.441	0.05	0.088	24.9	102	8.16
KL-D	0.36	0.16	92.22	4.46	10.77	75.61	91.08	6.25	34.582	0.08	0.077	24.7	102	8.16
KL-E	0.38	0.27	95.54	4.62	10.75	82.71	93.63	6.09	34.566	0.04	0.063	24.9	101	8.16
Geometric Mean	1.32	0.20	104.01	4.89	11.64	101.32	95.57	6.35	34.486	0.07	0.087	24.9	101	8.16
19-Jul-05														
KL-A	1.25	1.85	80.37	3.72	10.55	141.29	75.78	6.72	34.612	0.12	0.307	27.4	100	8.19
KL-B	1.16	1.40	81.98	3.19	10.32	127.81	78.77	7.11	34.620	0.09	0.264	27.5	101	8.20
KL-C	0.85	1.87	98.73	3.16	10.18	107.88	94.95	7.02	34.630	0.07	0.367	27.6	101	8.22
KL-D	0.86	0.62	82.64	2.71	9.87	109.63	80.26	7.12	34.631	0.07	0.301	28.0	101	8.21
KL-E	0.85	0.62	98.41	2.49	9.25	100.89	95.54	6.73	34.633	0.06	0.292	28.3	101	8.22
Geometric Mean	0.98	1.13	88.05	3.03	10.02	116.60	84.65	6.93	34.625	0.08	0.304	27.8	101	8.21
27-Sep-05														
KL-A	2.65	1.29	115.36	4.36	9.36	125.62	104.15	4.26	34.764	0.12	0.205	26.5	101	8.08
KL-B	1.18	1.07	117.21	3.34	9.24	106.37	111.89	5.74	34.824	0.12	0.174	27.0	102	8.09
KL-C	0.91	1.34	117.27	3.21	9.07	98.86	111.66	5.65	34.826	0.12	0.193	27.0	102	8.12
KL-D	0.55	1.69	98.03	3.11	8.70	89.54	94.03	5.47	34.855	0.10	0.185	27.2	102	8.11
KL-E	1.04	1.91	81.28	3.38	8.12	101.95	76.15	4.59	34.846	0.08	0.232	26.9	102	8.12
Geometric Mean	1.10	1.43	104.79	3.45	8.88	103.82	98.59	5.10	34.823	0.10	0.197	26.9	102	8.10
06-Dec-05														
KL-A	3.61	0.84	110.74	4.31	7.69	145.89	103.14	1.27	34.846	0.22	0.260	24.7	102	8.06
KL-B	3.42	0.67	113.56	3.61	8.23	116.51	107.61	4.36	34.862	0.14	0.187	24.6	102	8.09
KL-C	2.57	0.39	147.46	3.27	9.65	96.49	142.61	5.64	34.889	0.09	0.197	24.2	102	8.11
KL-D	3.10	0.51	93.37	3.37	6.43	88.59	88.45	2.75	34.860	0.11	0.230	24.0	102	8.09
KL-E	1.78	0.57	100.31	3.14	6.54	71.75	97.04	3.14	34.876	0.08	0.222	23.9	102	8.11
Geometric Mean	2.81	0.58	111.67	3.52	7.62	100.83	106.32	3.06	34.866	0.12	0.218	24.3	102	8.09

TABLE 3. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2006 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [°C]	Oxygen [%]	pH
08-Mar-06														
KL-A	9.81	1.88	88.89	6.35	11.20	458.09	56.47	4.20	34.441	0.23	0.321	25.2	101	8.15
KL-B	2.31	1.84	100.15	5.13	10.78	267.77	88.41	5.40	34.686	0.13	0.205	26.4	101	8.19
KL-C	4.24	1.50	133.44	5.93	12.03	259.65	110.92	5.94	34.466	0.13	0.228	25.8	101	8.20
KL-D	0.53	0.73	112.11	4.32	9.41	161.81	110.31	5.02	34.825	0.10	0.187	25.8	101	8.20
KL-E	0.89	0.91	126.29	4.37	8.69	171.04	121.78	4.25	34.781	0.11	0.233	25.5	101	8.19
Geometric Mean	2.14	1.28	110.96	5.16	10.35	244.93	94.26	4.92	34.639	0.13	0.231	25.7	101	8.19
01-Jun-06														
KL-A	1.25	1.85	80.37	3.72	10.55	141.29	75.78	6.72	34.612	0.12	0.307	27.4	100	8.19
KL-B	1.16	1.40	81.98	3.19	10.32	127.81	78.77	7.11	34.620	0.09	0.264	27.5	101	8.20
KL-C	0.85	1.87	98.73	3.16	10.18	107.88	94.95	7.02	34.630	0.07	0.367	27.6	101	8.22
KL-D	0.86	0.62	82.64	2.71	9.87	109.63	80.26	7.12	34.631	0.07	0.301	28.0	101	8.21
KL-E	0.85	0.62	98.41	2.49	9.25	100.89	95.54	6.73	34.633	0.06	0.292	28.3	101	8.22
Geometric Mean	0.98	1.13	88.05	3.03	10.02	116.60	84.65	6.93	34.625	0.08	0.304	27.8	101	8.21
25-Aug-06														
KL-A	7.06	2.92	153.00	7.80	15.20	241.69	120.40	7.24	34.300	0.16	0.345	27.7	100	8.00
KL-B	1.35	1.61	135.11	6.24	13.44	122.87	123.22	7.09	34.606	0.08	0.236	27.2	100	8.06
KL-C	6.21	1.26	110.20	6.41	14.13	191.66	86.84	7.40	34.521	0.08	0.173	27.1	100	8.09
KL-D	5.03	0.45	119.89	5.18	13.05	89.23	113.94	7.85	34.758	0.06	0.167	27.5	100	8.11
KL-E	9.67	1.07	122.85	5.39	14.23	97.58	111.49	8.81	34.737	0.07	0.188	27.3	100	8.10
Geometric Mean	4.92	1.23	127.39	6.14	13.99	137.73	110.36	7.66	34.584	0.09	0.213	27.4	100	8.07
09-Nov-06														
KL-A	1.71	2.27	133.33	5.08	8.71	156.94	127.47	3.26	34.762	0.13	0.295	26.7	100	8.12
KL-B	0.69	1.90	132.38	4.56	9.17	211.74	127.97	4.49	34.760	0.10	0.258	26.4	100	8.16
KL-C	0.41	1.00	128.50	4.56	8.75	117.92	126.56	4.09	34.804	0.09	0.208	26.4	100	8.16
KL-D	0.28	0.69	118.20	4.23	8.88	107.35	116.89	4.56	34.806	0.08	0.213	26.2	100	8.18
KL-E	1.05	0.86	107.32	4.18	8.39	98.72	104.58	4.11	34.817	0.08	0.216	25.9	100	8.18
Geometric Mean	0.68	1.21	123.54	4.51	8.77	132.94	120.34	4.08	34.790	0.10	0.236	26.3	100	8.16

TABLE 4. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2007 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [°C]	Oxygen [%]	pH
13-Apr-07														
KL-A	27.27	2.75	184.85	7.14	15.17	443.23	140.94	7.98	34.151	0.12	0.244	26.0	100	8.12
KL-B	13.77	0.87	188.56	5.41	14.18	182.88	162.30	8.38	34.490	0.07	0.199	26.0	100	8.13
KL-C	21.19	1.49	191.69	6.97	15.20	223.82	154.57	8.20	34.332	0.07	0.221	25.4	100	8.10
KL-D	10.66	1.18	169.25	6.76	13.83	173.37	155.09	7.03	34.560	0.06	0.173	25.1	100	8.08
KL-E	9.31	1.16	155.99	6.52	12.25	146.28	145.02	5.71	34.621	0.06	0.162	25.0	100	8.10
Geometric Mean	15.12	1.37	177.54	6.53	14.08	215.06	151.39	7.39	34.430	0.08	0.198	25.5	100	8.11
31-Jul-07														
KL-A	9.31	2.68	151.64	5.87	12.73	257.06	122.01	6.81	34.511	0.11	0.303	27.1	100	8.26
KL-B	2.14	2.55	158.70	4.97	11.92	161.40	134.76	6.83	34.637	0.10	0.306	26.8	100	8.27
KL-C	2.96	2.76	171.05	5.87	13.72	249.56	138.93	7.71	34.514	0.10	0.340	26.8	100	8.24
KL-D	0.76	1.31	130.72	3.73	10.23	92.39	126.83	6.47	34.891	0.09	0.237	26.4	100	8.23
KL-E	3.44	2.32	136.03	4.68	11.44	156.52	121.07	6.64	34.703	0.09	0.227	26.3	100	8.20
Geometric Mean	2.74	2.25	148.90	4.95	11.95	171.82	128.53	6.88	34.651	0.10	0.279	26.7	100	8.24
25-Oct-07														
KL-A	5.65	2.03	136.47	6.86	16.27	243.17	99.93	9.11	34.376	0.28	0.440	26.4	99	8.08
KL-B	1.96	1.28	129.06	5.05	13.52	113.15	114.17	8.28	34.819	0.15	0.322	27.0	100	8.12
KL-C	0.31	0.86	136.95	4.08	12.40	75.41	130.13	8.31	34.924	0.12	0.332	26.6	100	8.12
KL-D	0.14	0.97	123.32	3.58	10.96	77.64	121.30	7.28	35.002	0.13	0.270	27.0	100	8.11
KL-E	0.27	1.07	112.03	3.98	10.15	116.64	109.78	6.16	34.997	0.10	0.198	27.0	100	8.14
Geometric Mean	0.66	1.18	127.22	4.58	12.48	113.45	114.61	7.76	34.823	0.15	0.302	26.8	100	8.11
13-Nov-07														
KL-A	6.60	3.97	113.62	5.02	11.61	123.51	95.55	6.55	34.819	0.18	0.165	26.7	99	8.16
KL-B	3.69	2.18	113.34	4.08	11.15	81.76	103.36	7.00	34.904	0.12	0.142	26.1	100	8.12
KL-C	1.67	2.51	114.92	3.56	10.31	45.73	110.12	6.73	34.933	0.09	0.149	26.4	100	8.17
KL-D	1.78	2.32	106.96	3.75	11.01	53.84	102.29	7.21	34.967	0.09	0.132	25.9	100	8.18
KL-E	1.82	2.73	113.27	3.64	11.88	78.01	107.42	8.19	34.966	0.10	0.140	26.0	100	8.19
Geometric Mean	2.65	2.68	112.39	3.98	11.18	72.03	103.63	7.11	34.918	0.11	0.145	26.2	100	8.16

TABLE 5. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2008 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [°C]	Oxygen [%]	pH
13-Mar-08														
KL-A	13.39	3.44	133.64	5.70	14.27	352.73	113.53	8.44	34.634	0.21	0.312	25.5	100	8.09
KL-B	13.73	2.55	126.06	5.36	13.60	291.10	102.16	8.19	34.706	0.16	0.305	25.5	101	8.12
KL-C	3.12	2.32	112.49	3.73	11.83	117.35	105.30	8.05	34.896	0.10	0.230	24.9	100	8.13
KL-D	1.89	1.27	111.39	3.72	11.14	95.76	107.42	7.40	34.928	0.11	0.202	25.0	101	8.14
KL-E	1.44	3.26	111.93	4.15	11.37	110.77	106.22	7.16	34.915	0.10	0.211	24.5	101	8.14
Geometric Mean	4.35	2.43	118.76	4.46	12.38	166.46	106.86	7.83	34.815	0.13	0.248	25.1	101	8.13
08-May-08														
KL-A	11.37	0.75	124.29	6.27	14.02	338.30	92.76	7.40	34.377	0.14	0.215	25.8	99	8.06
KL-B	7.42	1.40	110.83	5.64	14.77	219.37	92.58	8.70	34.596	0.15	0.229	25.3	100	8.09
KL-C	12.98	1.39	124.76	6.37	12.83	271.98	93.52	6.07	34.421	0.09	0.213	25.7	100	8.09
KL-D	4.85	1.31	102.91	5.26	10.70	147.57	95.03	5.18	34.710	0.10	0.173	25.5	100	8.09
KL-E	8.10	1.42	117.14	5.99	12.04	208.99	102.69	5.69	34.479	0.10	0.182	25.1	100	8.11
Geometric Mean	8.45	1.22	115.68	5.89	12.79	228.47	95.24	6.49	34.516	0.11	0.201	25.5	100	8.09
26-Aug-08														
KL-A	20.73	2.12	132.01	5.16	13.06	280.90	107.20	7.83	34.603	0.16	0.251	26.5	100	8.10
KL-B	14.63	1.38	131.60	4.00	13.80	193.22	110.49	9.56	34.646	0.13	0.254	26.7	100	8.14
KL-C	14.97	0.78	133.88	6.28	14.24	224.37	111.52	7.93	34.616	0.09	0.219	26.4	100	8.14
KL-D	10.08	1.86	129.16	6.45	13.92	210.14	116.99	7.45	34.748	0.11	0.237	26.8	100	8.13
KL-E	12.84	1.71	144.68	6.94	14.53	222.71	128.62	7.55	34.636	0.11	0.290	26.1	100	8.13
Geometric Mean	14.25	1.49	134.16	5.66	13.90	224.47	114.72	8.03	34.650	0.12	0.249	26.5	100	8.13
24-Oct-08														
KL-A	8.46	5.66	165.58	7.34	15.47	182.85	138.21	7.91	34.551	0.14	0.239	25.5	101	8.11
KL-B	5.90	3.40	145.25	6.26	13.98	141.13	130.77	7.64	34.774	0.10	0.203	25.7	101	8.14
KL-C	6.06	3.65	137.89	6.07	13.68	159.49	114.76	7.41	34.750	0.09	0.218	25.2	100	8.16
KL-D	4.03	3.30	144.89	5.43	13.06	74.01	136.24	7.60	34.861	0.10	0.160	25.3	101	8.15
KL-E	1.82	2.73	113.27	3.64	11.88	78.01	107.42	8.19	34.966	0.10	0.140	26.0	100	8.19
Geometric Mean	4.67	3.63	140.33	5.60	13.57	118.90	124.87	7.75	34.780	0.10	0.188	25.5	101	8.15

TABLE 6. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2009 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [°C]	Oxygen [%]	pH
05-Mar-09														
KL-A	10.52	1.60	108.64	14.30	30.73	343.09	82.69	14.99	34.738	0.13	0.259	21.4	101	8.18
KL-B	6.28	0.57	106.13	8.93	20.91	216.41	93.62	11.94	35.013	0.07	0.188	20.9	101	8.22
KL-C	2.77	0.81	145.89	3.56	12.42	145.95	137.57	8.70	35.013	0.06	0.183	20.9	101	8.22
KL-D	1.98	0.86	148.14	4.31	16.39	140.50	143.13	11.80	35.244	0.05	0.180	20.7	101	8.22
KL-E	1.28	1.02	126.04	2.22	10.19	119.51	118.59	7.68	34.990	0.06	0.180	20.6	101	8.23
Geometric Mean	3.41	0.92	125.72	5.35	16.79	178.65	112.57	10.71	34.999	0.07	0.196	20.9	101	8.21
07-Aug-09														
KL-A	12.02	3.42	114.14	7.73	16.35	600.54	90.55	8.40	34.674	0.10	0.162	26.2	100	8.10
KL-B	7.77	2.46	121.37	7.05	16.04	262.19	102.91	8.90	34.765	0.09	0.186	26.2	100	8.13
KL-C	7.71	1.92	118.14	6.78	14.74	203.69	100.82	7.88	34.742	0.07	0.200	26.4	100	8.12
KL-D	3.19	1.72	115.37	5.99	13.85	109.33	109.95	7.85	34.905	0.08	0.197	26.4	101	8.14
KL-E	4.01	2.17	112.56	6.30	13.48	159.34	105.16	7.12	34.900	0.08	0.171	25.7	101	8.13
Geometric Mean	6.21	2.27	116.28	6.75	14.85	223.58	101.67	8.01	34.797	0.08	0.183	26.2	100	8.12
17-Nov-09														
KL-A	6.76	1.06	145.86	4.76	10.26	222.79	117.99	5.02	34.888	0.11	0.204	25.9	100	8.12
KL-B	1.39	0.64	118.91	2.73	8.53	111.31	115.23	5.65	35.238	0.09	0.179	25.3	101	8.15
KL-C	1.36	0.56	126.35	3.13	9.56	130.20	119.75	6.18	35.174	0.09	0.190	25.7	101	8.12
KL-D	0.42	1.05	115.08	1.98	8.61	100.00	112.83	6.57	35.268	0.09	0.158	25.4	101	8.15
KL-E	0.37	0.47	107.97	1.93	8.08	87.84	107.02	6.11	35.270	0.11	0.192	25.6	101	8.15
Geometric Mean	1.14	0.71	122.18	2.74	8.97	123.18	114.48	5.88	35.167	0.10	0.184	25.6	101	8.14

TABLE 7. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2010 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [˚C]	Oxygen [%]	pH
20-Apr-10														
KL-A	21.00	2.48	176.27	9.42	16.99	363.63	136.24	5.39	34.543	0.15	0.219	23.3	99	8.07
KL-B	8.19	1.27	162.93	5.20	11.82	168.84	152.43	6.59	34.902	0.08	0.185	23.2	100	8.11
KL-C	6.37	2.27	179.12	6.00	13.50	170.12	163.90	7.41	34.826	0.08	0.228	23.3	100	8.13
KL-D	2.12	1.06	154.25	4.63	11.42	93.89	150.05	6.77	34.975	0.08	0.145	23.5	100	8.13
KL-E	2.15	1.29	137.99	5.11	11.06	100.61	132.46	5.92	34.946	0.09	0.138	22.9	100	8.14
Geometric Mean	5.49	1.58	161.39	5.87	12.79	158.07	146.57	6.38	34.838	0.09	0.179	23.2	100	8.12
29-Jun-10														
KL-A	12.11	1.03	161.57	6.37	12.15	516.17	127.55	5.29	34.410	0.12	0.209	25.3	99	8.05
KL-B	3.00	0.79	133.45	4.95	11.47	191.91	120.94	6.37	34.818	0.10	0.186	25.3	100	8.09
KL-C	3.30	0.87	136.18	5.05	9.71	211.40	123.34	4.55	34.783	0.09	0.263	25.6	100	8.10
KL-D	2.17	0.64	118.43	4.24	7.64	175.37	115.18	3.38	34.988	0.09	0.244	25.0	100	8.11
KL-E	2.55	0.61	117.10	3.35	7.64	119.91	113.51	3.60	34.986	0.10	0.240	24.9	100	8.11
Geometric Mean	3.67	0.77	132.42	4.69	9.54	213.19	119.99	4.51	34.796	0.10	0.227	25.2	100	8.09
12-Nov-10														
KL-A	3.14	2.44	91.73	2.85	9.87	104.58	84.44	6.88	34.967	0.19	0.180	25.6	100	8.06
KL-B	1.05	1.84	92.26	2.16	8.76	64.14	89.01	6.55	35.042	0.17	0.149	25.7	100	8.12
KL-C	0.57	2.07	107.14	2.30	9.60	55.34	104.13	7.19	35.051	0.12	0.170	25.3	100	8.13
KL-D	0.37	2.11	100.74	2.25	9.63	47.29	98.31	7.34	35.056	0.10	0.119	25.0	100	8.15
KL-E	0.39	2.71	127.49	2.89	9.99	53.80	123.75	6.94	35.047	0.09	0.143	24.9	100	8.14
Geometric Mean	0.77	2.21	103.09	2.47	9.56	62.38	99.02	6.98	35.033	0.13	0.150	25.3	100	8.12

TABLE 8. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2011 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [°C]	Oxygen [%]	pH
13-Apr-11														
KL-A	26.49	2.04	169.67	6.77	15.02	512.73	122.61	7.92	34.265	0.16	0.164	24.8	99	8.09
KL-B	15.61	1.04	204.56	6.01	15.59	280.08	179.73	9.39	34.612	0.09	0.152	25.1	100	8.06
KL-C	14.90	1.23	175.09	6.52	15.55	265.50	147.07	8.64	34.473	0.09	0.177	24.6	100	8.09
KL-D	8.11	1.06	153.75	5.26	14.10	173.92	142.86	8.79	34.749	0.09	0.143	24.7	100	8.09
KL-E	14.22	1.45	146.83	6.19	14.94	262.47	124.69	8.53	34.556	0.10	0.168	24.5	100	8.10
Geometric Mean	14.80	1.32	168.83	6.13	15.03	280.63	142.00	8.64	34.531	0.10	0.160	24.7	100	8.09
26-May-11														
KL-A	38.99	3.76	128.88	7.57	12.46	504.49	82.67	4.18	34.186	0.18	0.340	24.8	100	8.06
KL-B	13.02	2.49	94.49	5.08	10.56	200.47	73.68	5.40	34.521	0.11	0.257	25.1	100	8.07
KL-C	21.88	1.68	99.17	6.01	11.20	302.63	74.57	5.16	34.422	0.12	0.246	24.9	100	8.09
KL-D	9.87	1.17	85.69	4.87	9.87	139.95	74.22	4.99	34.651	0.11	0.215	24.7	100	8.08
KL-E	10.45	1.90	98.06	5.82	10.25	185.39	84.38	4.42	34.590	0.13	0.227	25.1	100	8.09
Geometric Mean	16.29	2.03	100.29	5.80	10.83	239.87	77.77	4.81	34.473	0.13	0.253	24.9	100	8.08
15-Sep-11														
KL-A	8.91	2.02	154.79	5.56	12.30	264.83	134.86	6.51	34.720	0.22	0.246	25.5	100	8.00
KL-B	5.01	2.41	143.42	4.99	12.31	181.77	133.16	7.25	34.882	0.17	0.271	25.6	100	8.04
KL-C	2.78	1.14	153.52	4.52	12.56	118.61	148.55	7.98	34.953	0.13	0.307	25.3	72	8.05
KL-D	3.35	1.98	120.69	4.28	11.84	133.43	115.00	7.48	34.954	0.12	0.247	25.0	100	8.07
KL-E	4.73	2.81	125.18	4.63	10.78	131.63	117.57	6.14	34.937	0.12	0.185	25.7	100	8.05
Geometric Mean	4.56	1.98	138.79	4.78	11.94	158.58	129.25	7.04	34.889	0.15	0.248	25.4	94	8.04
08-Nov-11														
KL-A	5.50	4.52	115.93	4.37	12.35	292.39	88.87	7.72	34.710	0.15	0.215	25.3	99	8.06
KL-B	2.74	2.83	99.46	4.06	11.92	155.13	84.63	7.60	34.920	0.12	0.193	25.0	100	8.08
KL-C	2.79	2.79	93.54	3.72	11.37	149.86	81.82	7.34	34.882	0.11	0.207	24.3	100	8.09
KL-D	2.61	3.72	118.42	3.25	10.74	98.94	108.80	7.41	35.036	0.13	0.202	24.2	100	8.08
KL-E	4.25	5.29	130.70	3.09	10.99	116.02	116.05	7.61	34.964	0.14	0.188	23.9	100	8.08
Geometric Mean	3.42	3.71	110.79	3.67	11.46	150.82	95.08	7.54	34.902	0.13	0.200	24.5	100	8.08

TABLE 9. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2012 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [˚C]	Oxygen [%]	pH
22-Mar-12														
KL-A	16.71	2.16	161.86	13.91	22.61	625.23	125.58	7.43	34.304	0.30	0.302	23.6	100	8.09
KL-B	3.08	0.98	134.19	7.22	14.89	231.92	126.25	7.59	34.777	0.20	0.300	23.1	100	8.13
KL-C	1.38	0.99	108.65	5.88	13.79	133.28	100.92	7.74	34.783	0.14	0.260	22.6	100	8.15
KL-D	0.57	0.53	104.87	5.57	13.23	89.02	103.45	7.60	34.954	0.13	0.252	23.5	100	8.14
KL-E	0.55	1.10	117.96	5.72	12.92	100.17	116.36	7.16	34.954	0.12	0.225	23.1	100	8.14
Geometric Mean	1.86	1.04	123.89	7.16	15.13	176.71	114.01	7.50	34.754	0.17	0.266	23.2	100	8.13
25-Jun-12														
KL-A	2.85	2.09	126.59	5.92	17.88	243.61	103.69	11.56	34.747	0.19	0.204	24.6	100	8.09
KL-B	2.19	2.56	155.21	5.64	16.02	159.59	147.85	10.17	34.883	0.16	0.164	24.4	100	8.12
KL-C	2.51	2.12	136.45	5.27	15.10	126.98	130.90	9.77	34.925	0.13	0.150	24.6	100	8.13
KL-D	3.07	0.95	141.84	5.04	14.68	133.36	137.33	9.61	34.956	0.12	0.140	24.7	100	8.13
KL-E	2.47	1.08	182.55	5.06	14.91	106.29	178.52	9.82	34.971	0.13	0.127	25.3	100	8.14
Geometric Mean	2.60	1.63	147.33	5.37	15.68	147.57	137.53	10.16	34.896	0.14	0.155	24.7	100	8.12
18-Sep-12														
KL-A	4.20	1.48	179.52	6.25	15.70	238.89	165.44	9.32	34.951	0.15	0.191	26.1	99	8.09
KL-B	2.43	1.62	167.79	5.48	14.60	143.21	161.28	9.06	35.045	0.12	0.182	25.5	100	8.13
KL-C	2.61	1.08	157.14	5.31	13.85	123.74	153.03	8.53	35.089	0.10	0.177	25.5	99	8.13
KL-D	2.54	1.38	158.85	5.39	13.81	102.01	154.73	8.40	35.084	0.10	0.180	25.3	100	8.14
KL-E	3.52	2.16	162.42	5.47	14.10	132.38	156.40	8.59	35.074	0.10	0.174	25.5	100	8.12
Geometric Mean	2.99	1.50	164.95	5.57	14.40	141.72	158.11	8.77	35.049	0.11	0.181	25.5	100	8.12
16-Nov-12														
KL-A	2.41	3.92	171.16	6.10	13.14	133.64	160.36	6.95	35.096	0.23	0.249	24.2	99	8.11
KL-B	0.64	1.90	158.63	5.16	12.51	86.30	154.32	7.30	35.190	0.14	0.189	24.1	99	8.15
KL-C	1.34	1.35	121.62	5.93	11.82	77.69	118.24	5.81	35.194	0.14	0.206	24.0	99	8.16
KL-D	0.67	0.57	110.62	6.50	11.07	74.15	108.22	4.47	35.208	0.12	0.190	23.7	100	8.14
KL-E	0.66	0.78	102.52	6.33	10.91	74.74	99.46	4.53	35.212	0.12	0.179	24.3	100	8.17
Geometric Mean	0.98	1.35	130.22	5.99	11.86	86.93	125.79	5.69	35.180	0.14	0.201	24.1	99	8.15

TABLE 10. Parameter means by date from the five monitoring wells drilled at Ka Lae Mano sampled once during the baseline period and on each of the 2005 - 2012 quarterly surveys. Note that a dust control well (Well 6) was developed at the start of construction but was not sampled in December 2005, August and November 2009, April and June 2010 (pump off). Well 6 was terminated following the November 2010 sampling to be replaced by a new dust control well (Well 7) on 15 September 2011. All values in ug/l unless otherwise noted.

DATE	NITRATE	AMMONIA	TOTALN	ORTHO-P	TOTALP	SILICA	SALINITY [ppt]	URBIDITY [NTU]	TEMP [°C]	OXYGEN [%]	pH
Baseline											
20-Sep-04	2372.30	4.88	5455.13	200.94	243.16	26751.56	2.662	4.87	20.7	62	8.07
During Construction											
31-Mar-05	2495.06	3.03	4602.71	194.73	329.53	28420.37	2.526	1.55	22.5		7.93
19-Jul-05	2441.89	4.03	3451.00	180.67	286.80	27291.80	4.530	0.91	22.5	38	7.65
27-Sep-05	2499.44	1.38	3621.73	178.82	229.97	26915.56	2.559	0.75	24.6	44	7.87
06-Dec-05	2504.95	1.11	3609.82	193.36	254.14	29754.13	2.720	0.85	24.9	48	7.87
08-Mar-06	2279.01	1.31	5169.73	163.99	236.32	28679.42	2.642	0.39	23.5	65	8.01
01-Jun-06	2466.81	0.68	3763.60	184.48	222.74	27184.32	2.529	0.62	25.6	50	7.86
25-Aug-06	2506.52	0.88	3685.66	179.14	238.70	26337.72	2.711	0.21	25.6	52	7.89
09-Nov-06	2544.42	125.41	3978.19	194.52	291.40	26619.77	2.719	1.46	24.0	59	7.94
13-Apr-07	2469.16	0.23	6741.98	166.35	503.29	26588.96	2.603	0.43	23.2	62	7.89
31-Jul-07	882.66	1.04	4957.77	69.21	308.45	10350.52	2.696	0.50	24.8	79	8.29
25-Oct-07	2415.79	1.04	3204.39	195.22	266.55	27060.19	2.665	0.56	23.7	76	7.92
13-Nov-07	2479.85	0.24	3222.15	223.96	327.57	26856.07	2.717	0.28	23.7	77	7.93
13-Mar-08	2723.85	4.35	3964.55	239.92	352.16	25633.26	2.201	0.28	23.3	67	7.87
08-May-08	2625.12	2.60	3356.73	217.44	278.28	26361.74	2.394	0.90	24.4	74	7.91
26-Aug-08	2672.21	7.04	3841.02	209.04	250.27	26714.57	2.538	2.19	24.1	76	7.98
24-Oct-08	2593.06	13.82	5085.13	211.27	282.51	23315.79	2.527	3.20	25.0	72	8.20
05-Mar-09	2323.28	7.25	4340.72	204.98	284.99	27445.98	2.509	2.89	22.0	73	8.01
07-Aug-09	2688.17	0.25	2915.02	205.84	224.44	27346.22	2.699	1.34	24.9	76	8.08
17-Nov-09	2600.43	0.32	2920.79	199.54	205.32	26912.54	2.673	0.35	23.2	64	7.92
20-Apr-10	2459.91	3.42	4335.30	224.94	254.26	26989.09	2.489	0.56	22.8	62	7.95
29-Jun-10	2448.88	2.02	3862.29	178.87	290.84	20101.20	2.600	0.72	23.6	59	7.71
12-Nov-10	2572.15	93.68	3221.00	161.72	229.14	27365.47	2.677	0.38	23.1	71	8.11
13-Apr-11	2675.09	0.08	3971.94	187.36	279.43	27189.12	2.500	0.30	22.8	72	7.85
26-May-11	2432.36	0.36	3501.96	180.05	229.28	26816.33	2.628	0.49	23.5	67	7.88
15-Sep-11	2478.28	2.26	3378.06	190.55	289.64	26069.07	2.708	0.44	24.0	62	8.00
08-Nov-11	2443.06	7.76	3386.40	183.58	277.82	25977.73	2.692	0.32	22.9	68	7.88
22-Mar-12	2396.73	5.53	3153.45	127.31	230.23	28592.34	2.707	0.98	22.4	68	7.97
25-Jun-12	1527.68	0.00	2714.74	122.92	193.29	18948.95	2.738	0.32	23.2	73	7.95
18-Sep-12	2436.02	21.86	3340.96	200.57	261.69	25238.50	2.738	0.44	24.0	72	8.02
16-Nov-12	2430.35	5.74	2702.54	178.41	215.66	26109.02	2.768	0.49	22.1	64	7.96

TABLE 11. Water quality data and dates of collection for the single anchialine pond present at Ka Lae Mano. All data in ug/l unless otherwise noted.

DATE	NITRATE	AMMONIA	TOTALN	ORTHO-P	TOTALP	SILICA	SALINITY [ppt]	URBIDITY [NTU]	TEMP [°C]	OXYGEN [%]	CHL-a	pH
06-Dec-05	1423.95	27.74	2947.56	147.93	221.96	29558.81	2.941	0.34	0.177	24.9	62	7.36
09-Nov-06	1657.00	175.23	3333.33	181.54	282.88	25932.35	2.942	0.43	0.171	24.1	91	7.55
13-Apr-07	739.73	47.74	4086.74	185.82	544.67	27613.06	3.311	0.25	0.025	24.1	78	7.40
31-Jul-07	483.71	180.45	3268.86	206.57	338.83	28346.80	3.247	0.26	0.082	25.5	70	7.77
25-Oct-07	640.36	193.99	1341.48	204.75	284.58	28007.50	2.991	0.45	0.369	24.3	86	7.44
13-Nov-07	1392.32	6.99	1913.66	179.68	272.18	26995.36	2.985	0.28	0.252	24.9	85	7.71
13-Mar-08	628.75	108.68	1664.46	300.65	421.29	26764.68	3.049	0.30	0.117	24.1	76	7.53
08-May-08	846.61	53.17	1835.54	191.38	240.87	28290.51	3.194	0.41	0.429	25.3	81	7.48
26-Aug-08	437.94	46.54	3060.12	228.46	524.21	13201.29	3.095	0.31	1.690	25.2	80	7.65
24-Oct-08	335.88	52.20	2817.36	264.18	312.79	27580.09	2.992	0.35	0.232	26.2	81	7.77
05-Mar-09	878.55	67.96	2265.62	294.07	364.56	28462.09	3.304	0.30	0.116	22.0	88	7.61
07-Aug-09	397.46	23.24	782.88	178.51	199.02	29175.47	3.273	0.36	0.182	25.6	77	7.68
17-Nov-09	455.10	36.48	1282.68	248.77	269.70	28725.05	3.293	0.55	0.684	24.9	82	7.57
20-Apr-10	187.74	66.08	1955.94	198.40	319.30	29315.44	3.323	0.53	4.207	23.1	54	7.30
29-Jun-10	1317.96	16.10	2212.28	147.87	230.02	17364.20	3.240	0.47	0.014	24.9	71	7.60
12-Nov-10	209.30	307.16	1664.18	438.34	510.26	29219.40	3.197	1.55	2.209	23.6	65	7.45
13-Apr-11	443.38	28.00	2170.98	345.65	439.89	28881.72	3.282	1.09	0.016	23.6	69	7.34
26-May-11	518.28	7.42	1611.54	294.19	341.62	28092.96	3.291	0.31	0.034	24.5	65	7.50
15-Sep-11	689.08	11.34	1227.10	200.26	224.75	26526.08	3.114	0.2	0.038	24.8	79	7.76
08-Nov-11	414.12	35.42	1171.52	231.57	297.91	26820.36	3.168	0.32	0.152	23.7	80	7.34
22-Mar-12	909.44	8.26	1473.50	153.14	191.27	27494.32	3.154	0.15	*	23.3	75	7.79
25-Jun-12	915.88	13.16	1394.96	248.00	282.10	20113.80	3.146	0.92	0.209	23.9	66	7.62
18-Sep-12	610.68	20.44	968.66	215.14	282.10	23888.76	3.181	0.22	0.194	24.7	77	7.82
16-Nov-12	1889.58	5.60	2357.60	195.92	236.84	25358.20	3.164	0.22	0.387	23.1	80	7.86

* Missing Data

TABLE 12. Three tiers of water quality criteria developed by the Department of Health for the Kona or West Hawaii coast. Also included are the regional criteria for three parameters under all salinity regimes as well as those for sites with no significant groundwater discharge as has been the case with all samples collected since the 20 September 2004 survey of marine sites fronting the Ka Lae Mano project site.

All Salinity Regimes:	Single Value "Not To Exceed" Criterion For: Ammonia Nitrogen - Criterion = 2.5 ug/l Chlorophyll-*a* - Criterion = 0.3 ug/l Turbidity - Criterion = 0.1 N.T.U.
No Salinity Gradient Observed:	Single Value "Not To Exceed" Criterion For: Total Nitrogen - Criterion = 100.0 ug/l Total Phosphorus - Criterion = 12.5 ug/l Nitrate+Nitrite Nitrogen - Criterion = 4.5 ug/l Orthophosphorous - Criterion = 5.0 ug/l
Salinity Gradient Observed:	Regression Coefficient (Slope) Criterion For: Total Nitrogen Total Phosphorus Nitrate+Nitrite Nitrogen Orthophosphorous

NOTE: Salinities measured in the marine waters fronting the Ka Lae Mano project site in September 2004 and over all 26 during construction surveys (through November 2011) were all above 32 ppt, so no regression analysis was required to determine compliance with the regional water quality standards.

TABLE 13. Summary of the geometric means for water quality parameters (ug/l unless otherwise noted) as measured at marine stations fronting the Kukio development during the 111-month baseline study period (August 1990 through November 1999). Underlined values exceed the Department of Health regional standards.

Site No.	No. of Samples	Nitrate N	Ammonia N	TDN	Ortho P	TDP	Si	DON	DOP
3	17	31.13	9.08	147.99	7.77	16.31	592.05	70.02	7.42
4	17	9.98	3.67	92.06	4.04	12.01	195.05	70.32	7.79
5	17	6.55	3.92	98.68	3.70	12.24	182.42	84.15	8.36
6	17	4.25	3.71	93.39	3.64	10.66	108.82	82.34	6.84
14	35	68.23	12.69	170.11	8.46	14.50	1214.79	84.76	5.67
15	34	19.27	7.36	114.40	5.61	12.09	395.32	77.50	6.02
16	20	8.05	5.53	101.32	4.11	11.23	211.43	77.80	6.48
17	17	3.86	3.69	86.75	3.31	10.70	127.38	76.15	6.96
18	17	236.11	25.49	399.33	15.47	22.57	3254.21	77.29	4.76
19	11	66.50	11.36	223.43	7.45	15.51	959.04	104.22	7.07
Grand Geometric Means		17.14	7.03	132.68	5.32	14.18	372.39	79.15	7.38

Site No.	Turbidity (NTU)	Chl-*a*	Salinity (°/oo)	Oxygen (%)	Temp. (°C)	pH
3	0.16	0.365	32.947	103	26.0	8.03
4	0.10	0.172	34.144	102	26.0	8.11
5	0.11	0.140	34.197	103	26.0	8.11
6	0.10	0.144	34.261	102	26.0	8.13
14	0.17	0.325	32.733	103	26.3	8.16
15	0.13	0.180	33.867	102	26.3	8.14
16	0.11	0.135	34.126	102	26.6	8.13
17	0.10	0.136	34.258	102	26.5	8.15
18	0.44	0.670	29.017	102	27.0	8.09
19	0.17	0.415	31.578	103	26.4	8.09
Grand Geometric Means	0.14	0.220	33.120	102	26.2	8.11

TABLE 14. Statistical summary of seven parameters from well data collected to date using the nonparametric Wilcoxon Two Sample Test. Wells are examined in two groups: Makai Wells are numbers 1, 2, 3 and 6 and Mauka Wells are numbers 4, 5 and 7; data are also examined in the preconstruction period only, during construction period as well as all dates together. Means and sample sizes (n) are given for each group. All data in ug/l except salinity which is in ppt.

A. Preconstruction Period Only: Are there significant differences between mauka and makai wells?

Analyte	Mauka Wells Means	(n)	Makai Wells Means	(n)	Significantly Different?
Nitrate-N	2190.02	(2)	2493.82	(3)	No
Ammonia-N	1.66		7.02		No
Total-N	4888.03		5833.19		No
Ortho-P	208.49		195.91		No
Total-P	239.01		245.93		No
Silica	27127.93		26500.65		No
Salinity	2.131		3.017		No

B. During Construction Period Only: Are there significant differences between mauka and makai wells?

Analyte	Mauka Wells Means	(n)	Makai Wells Means	(n)	Significantly Different?
Nitrate-N	2248.37	(65)	2508.99	(106)	YES (P<0.0001)
Interpretation: Nitrate is significantly greater in makai wells.					
Ammonia-N	10.78		11.25		No
Total-N	3564.33		3960.93		YES (P<0.001)
Interpretation: Total nitrogen is significantly greater in makai wells.					
Ortho-P	191.37		179.81		YES (P<0.0005)
Interpretation: Ortho-P is significantly greater in mauka wells.					
Total-P	273.22		270.01		No
Silica	26476.01		25409.94		YES (P<0.005)
Interpretation: Silica is significantly greater in the mauka wells.					
Salinity	2.329		2.904		YES (P<0.0001)
Interpretation: Salinity is significantly greater in makai wells.					

TABLE 14. Continued

C. All Dates: Are there significant differences between mauka to makai wells?

Analyte	Mauka Wells Means	(n)	Makai Wells Means	(n)	Significantly Different?
Nitrate-N	2246.62	(67)	2508.57	(109)	YES (P<0.0001)
Interpretation: Nitrate is significantly greater in makai wells.					
Ammonia-N	10.51		11.13		No
Total-N	3603.84		4012.46		YES (P<0.002)
Interpretation: Total nitrogen is significantly greater in makai wells.					
Ortho-P	191.88		180.25		YES (P<0.0003)
Interpretation: Ortho-P is significantly greater in mauka wells.					
Total-P	272.20		269.35		No
Silica	26495.47		25439.96		YES (P<0.004)
Interpretation: Silica is significantly greater in mauka wells.					
Salinity	2.323		2.907		YES (P<0.0001)
Interpretation: Salinity is significantly greater in the makai wells.					

D. Mauka Wells Only: Are there significant differences between preconstruction to during construction means?

Analyte	Preconstruction Means	(n)	During Construction Means	(n)	Significantly Different?
Nitrate-N	2190.02	(2)	2248.37	(65)	No
Ammonia-N	1.66		10.78		No
Total-N	4888.03		3564.33		YES (P<0.04)
Interpretation: Total-N is significantly greater in the preconstruction period.					
Ortho-P	208.49		191.37		No
Total-P	239.01		273.22		No
Silica	27127.93		26476.01		No
Salinity	2.131		2.329		No

TABLE 14. Continued

E. Makai Wells Only: Are there significant differences between preconstruction to during construction means?

Analyte	Preconstruction Means	(n)	During Construction Means	(n)	Significantly Different?
Nitrate-N	2493.82	(3)	2508.99	(106)	No
Ammonia-N	7.02		11.25		No
Total-N	5833.19		3960.93		YES (P<0.008)
Interpretation: Preconstruction mean is significantly greater.					
Ortho-P	195.91		179.81		No
Total-P	245.93		270.01		No
Silica	26500.65		25409.94		No
Salinity	3.017		2.904		No

TABLE 15. Results of the Wilcoxon 2-Sample Test applied to the means of parameters from the preconstruction (n= 215 samples) and during construction (n= 1498 samples) period a Ka Lae Mano addressing the question. "Has there been any significant change in the means of marine water quality parameters since the commencement of construction?" All means in the body of the table are ug/l unless otherwise noted.

Parameter	Preconstruction Mean	During construction Mean	Significantly Different?	
Nitrate N	26.33	9.67	YES	P < 0.0001
	Preconstruction mean significantly greater			
Ammonia N	1.67	2.28	YES	P > 0.0002
	During construction is significantly greater			
Total N	142.36	129.47	NO	
Ortho P	4.91	5.40	YES	P > 0.0001
	Preconstruction mean significantly greater			
Total P	12.59	12.52	NO	
Silica	425.45	208.47	YES	P < 0.0003
	Preconstruction mean significantly greater			
Salinity (o/oo)	34.299	34.805	YES	P < 0.0001
	During construction mean is significantly greater			
Turbidity (NTU)	0.14	0.12	YES	P < 0.0001
	Preconstruction mean significantly greater			
Chlorophyll-a	0.216	0.221	NO	
Temp (`C)	26.4	25.3	YES	P < 0.0001
	Preconstruction mean significantly greater			
Oxygen (% Sat)	99.9	99.8	NO	
pH (Units)	8.17	8.13	YES	P < 0.0001
	Preconstruction mean significantly greater			

TABLE 16. Summary of statistical comparisons of parameters by date using the Kruskal-Wallis Anova and the Student-Neuman-Keuls (SNK) Test addressing the question "Has there been any statistically significant changes in parameters through time at stations in the ocean fronting the Ka Lae Mano project site?" In the body of the table are given the SNK results which the sample date and arithematic mean for a given parameter on that date. Means are expressed in ug/l unless otherwise noted. In the SNK Test, letters with the same designation show means and sample dates are related; changes in letter designation show where significant differences exist. Overlaps in letters indicate a lack of significant differences. In such cases, only the extremes may be significantly different.

Nitrate Nitrogen (P<0.0001)

Date	Mean			
Apr-98	43.83	A		
Aug-93	41.45	A		
Apr-02	39.97	A		
Apr-07	20.87		B	
Apr-11	20.43		B	
Jun-06	17.22		B	C
May-08	17.18		B	C
May-11	16.94		B	C
Jul-07	15.71		B	C
Aug-08	14.51		B	C
Aug-06	13.28		B	C
Oct-07	12.06		B	C
Jun-10	10.95		B	C
Nov-11	10.93		B	C
Mar-09	10.45		B	C
Oct-08	10.34		B	C
Aug-09	10.22		B	C
Apr-10	10.16		B	C
Mar-06	10.07		B	C
Mar-12	9.15		B	C
Mar-08	8.36		B	C
Mar-05	7.18		B	C
Nov-09	7.15		B	C
Sep-11	6.88		B	C
Sep-12	5.03			C
Jun-12	4.91			C
Nov-07	4.53			C
Sep-05	4.06			C
Dec-05	3.93			C
Jan-94	3.86			C
Nov-12	2.85			C
Sep-04	2.15			C
Jul-05	1.82			C
Nov-06	1.50			C
Nov-10	1.46			C

Interpretation: Mean nitate at marine stations is significantly greater on 3 preconstruction surveys relative to all other surveys.

Ammonia Nitrogen (P<0.0001)

Date	Mean					
Oct-08	6.03	A				
Nov-11	4.94		B			
Nov-07	3.72			C		
Mar-08	3.52			C	D	
Jul-07	3.44			C	D	
Jun-06	3.36			C	D	E
May-11	3.00	F		C	D	E
Apr-98	2.63	F	G	C	D	E
Aug-09	2.60	F	G	CH	D	E
Sep-11	2.59	F	G	CH	D	E
Aug-93	2.46	F	G	H	D	E
Nov-10	2.44	F	G	H	D	E
Jan-94	2.39	F	G	H	D	E
Nov-12	2.34	F	G	H	D	E
Jun-12	2.27	F	G	H	DI	E
Sep-12	2.11	F	G	H	I	EJ
Jul-05	1.92	FK	G	H	I	J
Aug-08	1.88	FK	GL	H	I	J
Aug-06	1.88	FK	GL	H	I	J
Apr-10	1.83	FK	GL	H	I	J
Mar-09	1.77	FK	GL	H	I	J
Sep-05	1.77	FK	GL	H	I	J
Apr-07	1.76	FK	GL	H	I	J
Nov-06	1.72	FK	GL	H	I	J
May-08	1.68	FK	GL	H	I	J
Oct-07	1.64	FK	GL	H	I	J
Mar-06	1.57	K	GL	H	I	J
Apr-11	1.51	K	GL	H	I	J
Mar-12	1.42	K	GL	H	I	J
Dec-05	1.19	K	L	H	I	J
Nov-09	0.93	K	L		I	J
Jun-10	0.82	K	L			J
Apr-02	0.72	K	L			
Mar-05	0.63	K	L			
Sep-04	0.52		L			

Interpretation: Ammonia nitrogen is significantly greater in the Oct 2008 and Nov 11 periods over all others whose means show considerable overlap.

TABLE 16. Continued.

Total Nitrogen (P<0.0001)

Date	Mean					
Apr-98	191.81	A				
Apr-07	174.86		B			
Sep-12	167.08		B	C		
Apr-11	166.78		B	C		
Apr-10	162.93		B	C		
Apr-02	162.54		B	C		
Jun-12	159.33		B	C		
Oct-08	150.58			C	D	
Jul-07	148.30			C	D	E
Sep-11	141.70		F		D	E
Sep-04	137.27		F	G	D	E
Oct-07	134.23		F	G	DH	E
Aug-08	133.98		F	G	DH	E
Nov-12	133.70		F	G	DH	E
Jun-10	132.80		F	G	DH	E
Aug-93	131.06		F	G	DH	E
Aug-06	130.58	I	F	G	DH	E
Mar-09	129.08	I	FJ	G	H	E
Mar-12	126.92	I	FJ	G	H	
Nov-06	126.40	I	FJ	G	H	
Nov-09	125.19	I	FJ	G	H	
Mar-08	118.50	I	J	GK	H	
Aug-09	116.23	I	J	GK	H	
May-08	115.85	I	J	GK	H	
Dec-05	115.68	I	J	GK	H	
Mar-06	115.18	I	J	GK	H	
Nov-07	115.12	I	J	GK	H	
Jun-06	112.69	I	J	K	H	
Nov-11	112.02	I	J	K	H	
Nov-10	108.76	I	J	K	L	
Sep-05	107.80		J	K	L	
Mar-05	107.36		J	K	L	
May-11	101.67			K	L	
Jul-05	92.85				L	M
Jan-94	84.69					M

Interpretation: Significantly greater mean TN found in one baseline period. No evidence of chronological order.

Orthophosphorus (P<0.0001)

Date	Mean					
Mar-09	13.06	A				
Mar-12	8.07		B			
Apr-02	7.10		B	C		
Aug-09	6.69		B	C		
Apr-07	6.51		B	C	D	
Apr-10	6.49		B	C	D	
Aug-06	6.28		B	C	D	
Oct-08	6.21		B	C	D	
Nov-12	6.11		B	C	D	
Apr-11	5.99		B	C	D	E
May-08	5.97		B	C	D	E
Apr-98	5.85		B	C	D	E
Sep-12	5.71		B	C	D	E
Jun-12	5.60		B	C	D	E
Aug-08	5.59		B	C	D	E
May-11	5.49		B	C	D	E
Mar-06	5.26		B	C	D	E
Aug-93	5.25		B	C	D	E
Jul-07	5.16		B	C	D	E
Mar-05	5.02		B	C	D	E
Oct-07	4.93		B	C	D	E
Sep-11	4.89		B	C	D	E
Jun-10	4.81		B	C	D	E
Jan-94	4.60	F		C	D	E
Jun-06	4.59	F		C	D	E
Nov-06	4.56	F		C	D	E
Mar-08	4.53	F		C	D	E
Nov-07	4.12	F		C	D	E
Nov-11	3.89	F		C	D	E
Dec-05	3.72	F		C	D	E
Sep-05	3.69	F		C	D	E
Nov-09	3.14	F			D	E
Jul-05	3.13	F			D	E
Nov-10	2.63	F				E
Sep-04	1.55	F				

Interpretation: No evidence of increasing concentration due to construction activities on the project site.

Total Phosphorus (P<0.0001)

Date	Mean					
Mar-09	30.27	A				
Apr-98	18.93		B			
Jun-12	15.75		B	C		
Mar-12	15.51		B	C	D	
Apr-11	14.81		B	C	D	E
Aug-09	14.72		B	C	D	E
Sep-12	14.45		B	C	D	E
Aug-06	14.11	F	B	C	D	E
Oct-08	13.86	F	B	C	D	E
Apr-07	13.74	F	B	C	D	E
Aug-08	13.65	F	B	C	D	E
Apr-10	13.06	F		C	D	E
Apr-02	12.94	F		C	D	E
May-08	12.92	F		C	D	E
Oct-07	12.80	F		C	D	E
Aug-93	12.54	F		C	D	E
Mar-08	12.41	F		C	D	E
Nov-12	11.95	F		C	D	E
Sep-11	11.94	F		C	D	E
Jul-07	11.88	F		C	D	E
Mar-05	11.57	F		C	D	E
Nov-11	11.40	F		C	D	E
Nov-07	11.20	F		C	D	E
May-11	10.61	F		C	D	E
Mar-06	10.46	F		C	D	E
Jul-05	10.11	F		C	D	E
Nov-10	9.69	F		C	D	E
Jan-94	9.61	F		C	D	E
Jun-10	9.56	F		C	D	E
Sep-04	9.19	F			D	E
Nov-09	9.07	F				E
Sep-05	8.92	F				E
Nov-06	8.66	F				E
Jun-06	8.57	F				E
Dec-05	7.78	F				

Interpretation: No evidence of increasing concentration due to construction activities on the project site.

Silicate (P<0.0001)

Date	Mean			
Apr-02	686.98	A		
Apr-98	632.15	A		
Aug-93	582.72	A		
Apr-11	351.21		B	
Jun-06	350.38		B	
Apr-07	289.73		B	C
Mar-06	287.39		B	C
May-08	285.20		B	C
Aug-09	279.92		B	C
Mar-12	279.92		B	C
Jun-10	271.01		B	C
Mar-09	263.22		B	C
Jul-07	249.05		B	C
May-11	238.38		B	C
Oct-07	223.57		B	C
Nov-11	217.96		B	C
Aug-08	214.99		B	C
Aug-06	210.78		B	C
Mar-08	204.67		B	C
Apr-10	193.29		B	C
Jun-12	193.29		B	C
Sep-11	179.22		B	C
Oct-08	176.52		B	C
Sep-12	176.52		B	C
Nov-09	172.64		B	C
Mar-05	150.79		B	C
Nov-06	147.27		B	C
Jul-05	134.56			C
Sep-05	133.91			C
Dec-05	112.63			C
Jan-94	112.50			C
Nov-12	112.50			C
Nov-07	96.23			C
Sep-04	89.52			C
Nov-10	75.10			C

Interpretation: Significantly greater concentration in baseline period. No evidence of increasing concentration due to construction activities on the project site. Slilica shows an inverse relatonship with salinity.

TABLE 16. Continued.

Salinity (P<0.0001)

Date	Mean					
Nov-09	35.192	A				
Nov-12	35.180	A				
Sep-12	35.054	A	B			
Nov-10	35.034	A	B	C		
Mar-09	35.011		B	C	D	
Nov-11	34.939		B	C	D	E
Nov-07	34.931	F	B	C	D	E
Jan-94	34.909	F	BG	C	D	E
Jun-12	34.906	F	BG	C	D	E
Sep-11	34.906	F	BG	C	D	E
Jun-10	34.881	F	BG	C	D	E
Dec-05	34.872	F	G	C	D	E
Oct-07	34.867	F	G	C	D	E
Apr-10	34.859	F	G	CH	D	E
Sep-05	34.839	F	G	CH	DI	E
Mar-08	34.834	F	G	CH	DI	E
Aug-09	34.827	F	G	CH	DI	E
Mar-12	34.796	F	G	H	DI	E
Nov-06	34.792	F	G	H	I	E
Oct-08	34.773	F	G	H	I	EJ
Jul-07	34.714	FK	G	H	I	J
Sep-04	34.708	K	GL	H	I	J
Aug-08	34.698	K	GL	H	I	J
Mar-06	34.673	K	L	H	I	J
Apr-11	34.634	K	L		I	J
Jul-05	34.631	K	L		I	J
Aug-06	34.626	K	L		I	J
May-08	34.586	K	L			J
May-11	34.546	K	L			
Jun-06	34.523	K	L			
Mar-05	34.517	K	L			
Apr-07	34.502		L			
Apr-98	34.106			M		
Apr-02	33.922				N	
Aug-93	33.894				N	

Interpretation: Salinity is related to groundwater input both fronting the project site as well as away from it. There is no evidence of changes in salinity related to the development.

Chlorophyll-a (P<0.0001)

Date	Mean					
Oct-07	0.315	A				
Jul-05	0.315	A				
Jul-07	0.296	A	B			
Mar-12	0.296	A	B	C		
May-11	0.275	A	B	C		
Apr-98	0.271	A	B	C		
Mar-08	0.262	A	B	C	D	
Sep-11	0.260	A	B	C	D	E
Apr-02	0.259	A	B	C	D	E
Nov-06	0.250	AF	B	C	D	E
Jan-94	0.246	AF	B	C	D	E
Aug-06	0.245	AF	B	C	D	E
Aug-08	0.245	AF	B	C	D	E
Mar-06	0.239	F	B	C	D	E
Jun-10	0.235	F	B	C	D	E
Dec-05	0.230	F	B	C	D	E
Oct-08	0.215	F	G	C	D	E
Nov-12	0.215	F	G	C	D	E
Jun-06	0.212	F	G	C	D	E
Mar-09	0.212	F	G	C	D	E
Apr-07	0.207	F	G	C	D	E
May-08	0.204	F	G	C	D	E
Nov-11	0.201	F	G	CH	D	E
Sep-05	0.201	F	G	CH	D	E
Nov-09	0.186	F	G	H	D	E
Sep-12	0.186	F	G	H	D	E
Apr-10	0.186	F	G	H	D	E
Nov-10	0.179	F	G	H		E
Jun-12	0.179	F	G	H		E
Aug-09	0.184	F	G	H		
Sep-04	0.169	F	G	H		
Apr-11	0.169	F	G	H		
Nov-07	0.148		G	H	I	
Aug-93	0.128			H	I	
Mar-05	0.107				I	

Interpretation: No evidence of increase in chlorophyll-a with time and considerable overlap masks any real significant changes.

Turbidity (NTU) P<0.0001

Date	Mean					
Jan-94	0.23	A				
Mar-12	0.23	A	B			
Apr-02	0.18		B	C		
Oct-07	0.17		B	C	D	
Nov-12	0.17		B	C	D	
Dec-05	0.17		B	C	D	
Sep-11	0.16		B	C	D	
Jun-12	0.16		B	C	D	E
Nov-10	0.15	F		C	D	E
Nov-11	0.14	F	G	C	D	E
Mar-08	0.14	F	G	C	D	E
Mar-06	0.14	F	G	C	D	E
May-11	0.13	F	G	CH	D	E
Oct-08	0.13	F	G	CH	D	E
Nov-07	0.12	F	G	H	D	E
Aug-93	0.12	F	G	H	D	E
Aug-08	0.12	F	G	H	D	E
May-08	0.12	F	G	H	D	E
Sep-05	0.12	F	G	H	D	E
Sep-12	0.12	F	G	H	D	E
Nov-06	0.11	F	G	H		E
Apr-11	0.11	F	G	H		E
Jun-10	0.11	F	G	H		E
Nov-09	0.10	F	G	H		E
Jul-07	0.10	F	G	H		E
Apr-10	0.10	F	G	H		E
Jun-06	0.10	F	G	H		E
Apr-98	0.10	F	G	H		E
Aug-06	0.10	F	G	H		
Jul-05	0.10	F	G	H		
Mar-05	0.10	F	G	H		
Sep-04	0.10	F	G	H		
Aug-09	0.09		G	H		
Apr-07	0.08			H		
Mar-09	0.08			H		

Interpretation: Turbidity shows no relationship with the during construction period; highest turbidity value is during the baseline period. Turbidity is probably related to surf causing resuspension of materials in situ.

% Oxygen Saturation (P<0.0001)

Date	Mean					
Dec-05	101.3	A				
Sep-05	101.1	A	B			
Mar-05	100.8	A	B	C		
Oct-08	100.5	A	B	C		
Mar-06	100.5	A	B	C	D	
Mar-09	100.4	A	B	C	D	
Jul-05	100.2	A	B	C	D	
Nov-09	100.2	A	B	C	D	
Mar-08	100.1	A	B	C	D	
Aug-08	100.1	A	B	C	D	
Aug-06	100.0	A	B	C	D	
Jul-07	99.9	A	B	C	D	
Apr-07	99.9	A	B	C	D	
Jun-06	99.9	A	B	C	D	
Sep-04	99.9	A	B	C	D	
Aug-09	99.9	A	B	C	D	
May-08	99.8	A	B	C	D	
Nov-06	99.8	A	B	C	D	
Jun-12	99.7	A	B	C	D	
Nov-07	99.7	A	B	C	D	
May-11	99.5	A	B	C	D	
Nov-10	99.4		B	C	D	
Mar-12	99.4		B	C	D	
Nov-11	99.4		B	C	D	
Apr-10	99.4		B	C	D	
Oct-07	99.4		B	C	D	
Jun-10	99.3		B	C	D	
Apr-11	99.3		B	C	D	
Sep-12	99.1			C	D	
Nov-12	98.8				D	
Sep-11	97.7					E

Interpretation: Note that dissolved oxygen was not measured in most preconstruction surveys. Dissolved oxygen concentrations are probably related to time of day of sampling and to local surf.

TABLE 16. Continued.

Temperature ('C) P<0.0001

Date	Mean					
Sep-04	29.0	A				
Jul-05	27.8		B			
Aug-06	27.4			C		
Aug-93	27.3			C		
Sep-05	26.9				D	
Oct-07	26.8				D	
Jul-07	26.6					E
Aug-08	26.5					E
Nov-06	26.3	F				
Nov-07	26.2	F	G			
Aug-09	26.2	F	G			
Apr-02	26.0		G			
Jun-06	25.7			H		
Mar-06	25.7			H	I	
Nov-09	25.6			H	I	J
Sep-12	25.6	K		H	I	J
Apr-07	25.5	K	L		I	J
May-08	25.5	K	L		I	J
Sep-11	25.4	K	L	M		J
Oct-08	25.3	K	L	M		
Nov-10	25.1		L	M		
Jun-10	25.1			M	N	
Mar-08	25.1				N	O
May-11	24.9	P				O
Mar-05	24.9	P	Q			O
Jan-94	24.8	P	Q			
Apr-98	24.8	P	Q			
Jun-12	24.7	P	Q			
Apr-11	24.7		Q			
Nov-11	24.5			R		
Dec-05	24.2				S	
Nov-12	24.0					T
Apr-10	24.2			U		
Mar-12	23.1			U		
Mar-09	24.2				V	

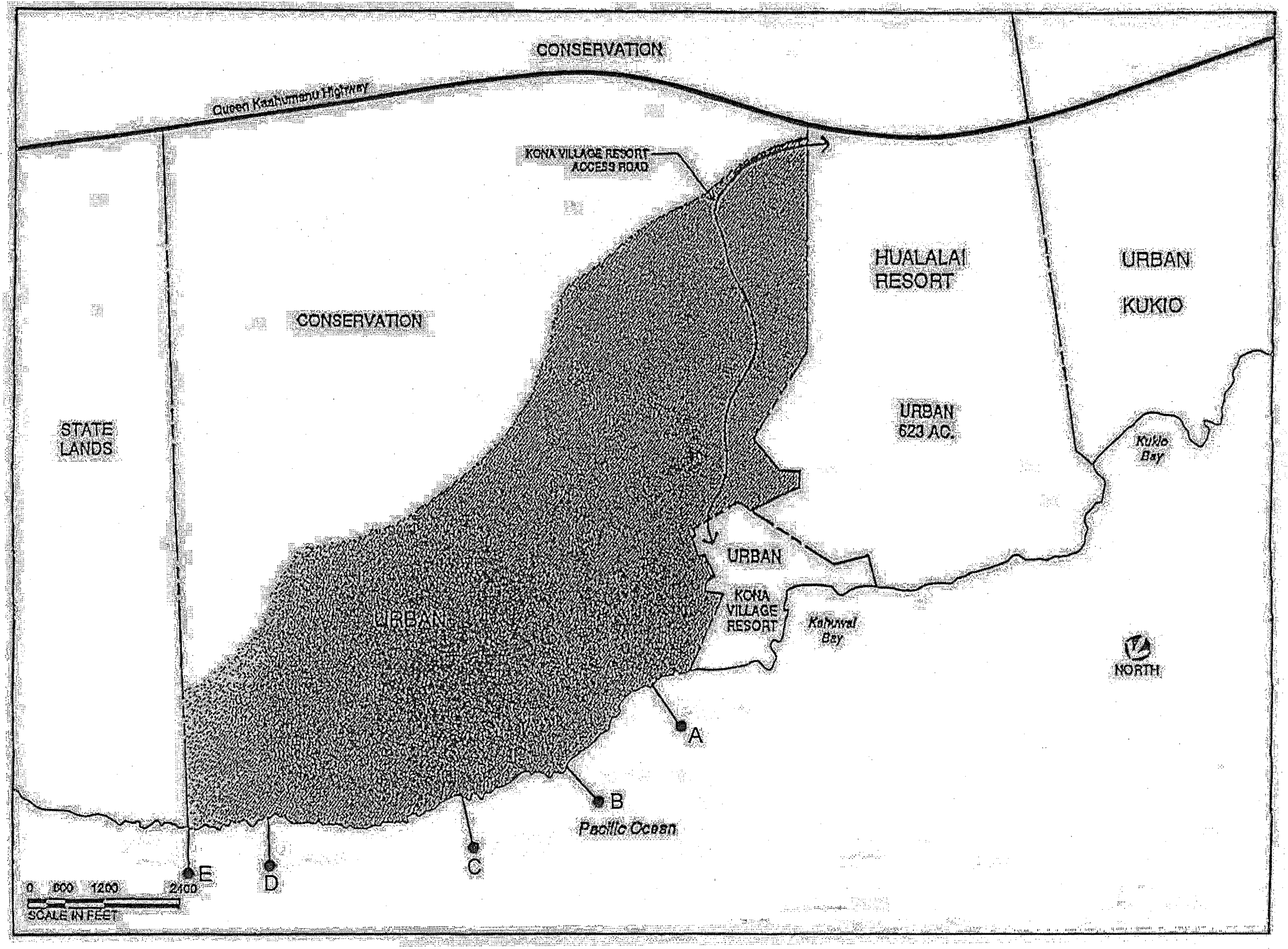
pH (units) P<0.0001

Date	Mean					
Jul-07	8.24	A				
Mar-09	8.21		B			
Jul-05	8.20		B	C		
Aug-93	8.19			C	D	
Mar-06	8.19				D	
Apr-98	8.17					E
Sep-04	8.16	F				E
Apr-02	8.16	F				E
Nov-07	8.16	F				E
Mar-05	8.16	F	G			E
Nov-06	8.16	F	G			E
Jun-06	8.15	F	G	H		
Nov-12	8.15		G	H		
Oct-08	8.14		G	H	I	
Nov-09	8.14		G	H	I	
Aug-08	8.13			H	I	J
Mar-12	8.13				I	J
Mar-08	8.13				I	J
Aug-09	8.12	K				J
Sep-12	8.12	K				J
Nov-10	8.12	K	L			J
Apr-10	8.12	K	L			J
Jun-12	8.12	K	L			J
Oct-07	8.11	K	L			J
Apr-07	8.11	K	L	M		
Sep-05	8.10		L	M	N	
Jun-10	8.09			M	N	O
Dec-05	8.09			M	N	O
May-08	8.09				N	O
Apr-11	8.09				N	O
May-11	8.08					O
Nov-11	8.07	P				O
Aug-06	8.07	P				
Sep-11	8.04		Q			

Interpretation: Significant differences in means are related to seasonal influences.

Interpretation: Significant differences in means are not related to the development, the differences are small, in the normal range and are biologically insignificant.

FIGURE 1. Outline map of the coastal portion of the Ka Lae Mano project site showing the approximate locations of the five water quality monitoring transects (A through E) with ten sampling stations on each (adopted from Marine Research Consultants 1993).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URBAN
KUKIO
CONSERVATION
STATE LANDS
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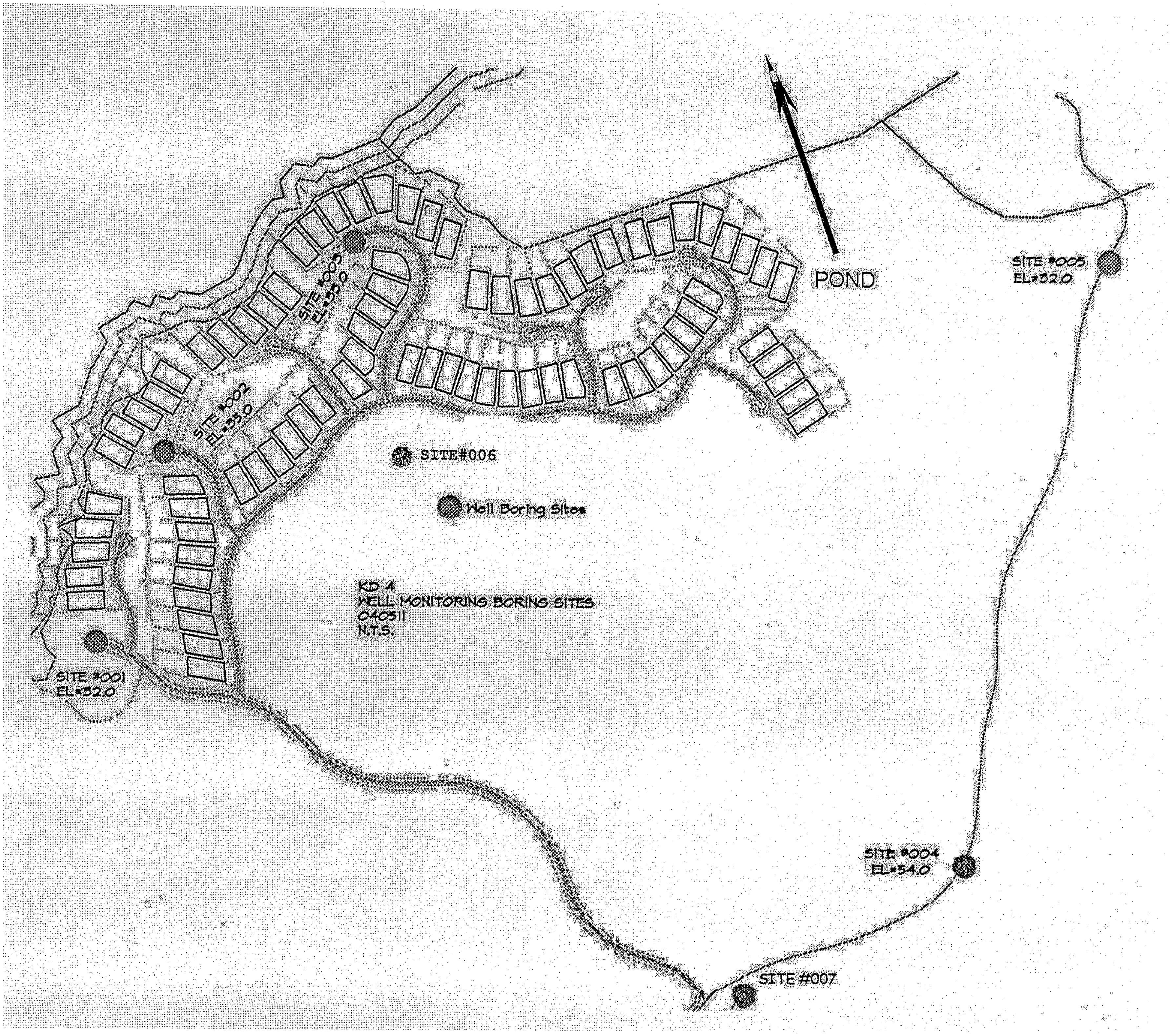
Kukio Bay
URBAN
KONA VILLAGE RESORT
Kahuwai Bay
URBAN
NORTH
A
B
Pacific Ocean
C
D
E
0 600 1200 2400
SCALE IN FEET

FIGURE 2. Map showing the first phase of the development at Ka Lae Mano with roads and residential lots (under construction). Also shown are the five coastal monitoring wells (1 through 5) along with a dust control well (site 6), the new irrigation well (Well 7) and anchialine pool. Map courtesy of W.B. Kukio, LLC.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WELL MONITORING BORING SITES
040511
N.T.S.
SITE #001
EL=52.0
SITE #004
EL=54.0
SITE #007

APPENDIX 1. Summary of the water quality parameters as measured at 57 sites for the KaLaeMano project on 22 March 2012. One sample is from an anchialine pool, five from a mauka wells, and 50 from the adjacent ocean. For ocean samples the underlined geometric mean exceed the regional Kona coast Department of Health water quality standards applied to nitrate nitrogen, ammonia nitrogen, total nitrogen, orthophosphorus, total phosphorus, chlorphyll-a and turbidity for surface samples. All values are in ug/l unless indicated; ND = below limits of detection.

Transect	Site No.	DFS [m]	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [o/oo]	Turbidity [NTU]	CHL-a	Temp. [°C]	Oxygen [%]	pH
KL-A	1-S	0	50.82	4.48	193.62	58.28	63.24	1119.16	138.32	4.96	33.964	0.63	0.441	23.2	99	8.06
	2-S	10	77.14	3.78	209.86	15.81	24.80	1445.92	128.94	8.99	33.649	0.80	0.504	22.8	99	8.07
	3-B	10	60.48	3.78	206.36	13.95	22.32	1219.68	142.10	8.37	33.897	0.52	0.504	23.1	98	8.07
	4-S	50	30.24	3.50	161.42	13.64	21.08	717.36	127.68	7.44	34.399	0.29	0.290	23.5	99	8.08
	5-B	50	2.10	1.54	120.26	6.82	14.26	142.80	116.62	7.44	34.955	0.20	0.317	23.4	97	8.09
	6-S	100	45.50	2.80	166.74	11.16	18.91	991.20	118.44	7.75	34.126	0.22	0.264	24.0	100	8.09
	7-B	100	1.82	0.98	113.26	5.89	13.02	113.40	110.46	7.13	34.968	0.19	0.282	23.2	98	8.11
	8-S	200	31.92	2.24	160.86	9.61	17.36	760.76	126.70	7.75	34.406	0.23	0.251	23.5	100	8.10
	9-S	300	15.12	2.10	136.92	11.47	19.53	417.48	119.70	8.06	34.640	0.24	0.218	24.0	100	8.09
	10-S	500	0.14	0.28	120.82	6.51	14.26	102.20	120.40	7.75	34.960	0.13	0.247	23.9	100	8.11
KL-B	11-S	0	12.32	2.10	145.18	8.68	16.43	475.72	130.76	7.75	34.656	0.24	0.356	22.8	100	8.12
	12-S	10	22.54	1.54	301.84	10.23	19.22	693.84	277.76	8.99	34.480	0.34	0.509	23.1	100	8.11
	13-B	10	2.52	1.26	130.06	7.44	15.50	163.52	126.28	8.06	34.951	0.26	0.290	22.8	99	8.11
	14-S	50	12.04	1.40	118.02	8.68	15.81	431.48	104.58	7.13	34.691	0.32	0.326	23.3	99	8.11
	15-B	50	2.24	1.12	114.52	8.68	15.50	114.24	111.16	6.82	35.002	0.20	0.243	22.7	97	8.12
	16-S	100	10.50	1.54	126.28	8.06	15.81	379.68	114.24	7.75	34.731	0.25	0.253	22.8	100	8.12
	17-B	100	1.54	1.12	107.38	6.20	12.71	97.72	104.72	6.51	34.984	0.18	0.222	22.7	98	8.12
	18-S	200	0.42	0.70	114.10	5.58	12.71	92.96	112.98	7.13	34.961	0.12	0.206	22.9	100	8.13
	19-S	300	ND	0.42	101.50	5.58	12.71	78.40	101.08	7.13	34.969	0.13	0.270	23.2	100	8.14
	20-S	500	ND	0.42	103.60	5.27	12.71	91.56	103.18	7.44	34.956	0.13	0.266	23.3	101	8.15
KL-C	21-S	0	58.38	3.50	186.90	12.40	20.46	1137.08	125.02	8.06	33.793	0.27	0.338	22.2	100	8.14
	22-S	10	2.66	1.26	102.06	5.89	13.64	172.20	98.14	7.75	34.891	0.15	0.299	22.3	100	8.13
	23-B	10	2.24	1.54	116.62	5.89	12.71	137.48	112.84	6.82	34.927	0.17	0.255	22.6	99	8.14
	24-S	50	1.12	0.70	97.16	5.58	13.33	100.52	95.34	7.75	34.944	0.12	0.231	22.7	100	8.14
	25-B	50	0.70	0.70	97.58	5.58	12.71	93.52	96.18	7.13	34.991	0.13	0.227	22.4	99	8.15
	26-S	100	0.84	0.56	93.52	5.58	12.71	91.56	92.12	7.13	34.950	0.12	0.229	22.7	100	8.15
	27-B	100	ND	0.84	108.22	5.58	12.40	91.84	107.38	6.82	34.959	0.11	0.231	22.8	98	8.15
	28-S	200	0.56	1.68	95.62	4.96	12.40	72.52	93.38	7.44	34.977	0.13	0.238	22.6	100	8.15
	29-S	300	0.28	0.56	106.82	4.65	12.71	75.32	105.98	8.06	34.971	0.10	0.253	22.7	100	8.16
	30-S	500	0.42	0.56	100.94	4.65	12.71	75.88	99.96	8.06	34.975	0.11	0.251	23.1	100	8.16
KL-D	31-S	0	2.24	1.82	111.72	6.20	13.33	150.64	107.66	7.13	34.902	0.18	0.255	23.0	100	8.14
	32-S	10	1.96	1.68	100.80	6.20	13.33	156.24	97.16	7.13	34.904	0.20	0.208	22.5	100	8.12
	33-B	10	1.26	2.66	125.02	6.82	14.57	134.12	121.10	7.75	34.906	0.26	0.827	22.9	99	8.11
	34-S	50	0.42	0.84	90.86	5.58	12.71	84.84	89.60	7.13	34.958	0.13	0.196	24.1	100	8.12
	35-B	50	0.56	0.98	113.40	5.89	13.02	82.88	111.86	7.13	34.966	0.13	0.179	23.7	98	8.13
	36-S	100	0.14	ND	100.24	4.96	12.71	73.36	100.10	7.75	34.970	0.14	0.364	23.7	100	8.14
	37-B	100	0.28	0.56	118.30	5.27	12.09	73.92	117.46	6.82	34.969	0.10	0.230	24.6	98	8.15
	38-S	200	ND	0.28	111.30	4.96	13.02	69.16	111.02	8.06	34.979	0.09	0.257	24.0	100	8.16
	39-S	300	ND	0.14	111.16	4.65	13.02	69.72	111.02	8.37	34.976	0.10	0.257	23.7	100	8.16
	40-S	500	ND	0.28	109.90	6.82	14.57	62.72	109.62	7.75	34.986	0.11	0.261	23.8	101	8.17
KL-E	41-S	0	0.84	3.92	163.24	6.82	13.33	115.08	158.48	6.51	34.927	0.18	0.264	22.6	99	8.14
	42-S	10	0.56	1.68	112.00	6.51	13.64	130.48	109.76	7.13	34.912	0.16	0.195	22.3	99	8.12
	43-B	10	0.98	1.68	128.24	6.51	13.33	128.24	125.58	6.82	34.923	0.21	0.214	22.3	98	8.12
	44-S	50	0.98	1.12	105.42	6.20	13.02	123.76	103.32	6.82	34.913	0.15	0.176	22.4	100	8.12
	45-B	50	0.70	1.12	116.06	5.89	13.02	94.64	114.24	7.13	34.971	0.18	0.180	22.7	98	8.12
	46-S	100	ND	0.56	109.76	5.27	13.02	75.04	109.20	7.75	34.978	0.12	0.294	22.8	100	8.13
	47-B	100	ND	0.56	116.48	5.27	12.71	82.88	115.92	7.44	34.975	0.11	0.227	22.4	99	8.15
	48-S	200	ND	0.56	111.72	5.27	12.71	73.64	111.16	7.44	34.977	0.09	0.242	23.5	100	8.16
	49-S	300	ND	0.98	120.68	5.27	13.02	165.20	119.70	7.75	34.975	0.10	0.227	24.2	101	8.16
	50-S	500	ND	0.84	111.44	4.96	11.78	59.64	110.60	6.82	34.993	0.08	0.198	23.9	101	8.16
Geometric Means			1.86	1.04	123.89	7.16	15.13	176.71	114.01	7.50	34.754	0.17	0.266	23.2	100	8.13
Anchialine Pool and Well Samples																
Well 1	W		2499.42	7.14	3241.56	108.81	224.75	27957.72	735.00	115.94	3.576	4.30	*	22.4	64	7.90
Well 2	W		2497.18	5.32	3258.78	119.04	223.20	28355.32	756.28	104.16	2.950	0.45	*	22.8	66	7.97
Well 3	W		2375.24	5.32	3175.90	137.64	241.80	28196.28	795.34	104.16	2.924	0.49	*	22.6	70	8.00
Well 4	W		2386.86	5.32	3165.82	142.29	249.55	29237.88	773.64	107.26	1.919	0.26	*	21.9	69	8.01
Well 5	W		1988.42	5.04	2737.56	141.98	238.70	28225.96	744.10	96.72	2.481	0.23	*	22.4	71	8.00
Well 7	W		2633.26	5.04	3341.10	114.08	203.36	29580.88	702.80	89.28	2.390	0.14	*	22.4	70	7.96
Pond 1	A		909.44	8.26	1473.50	153.14	191.27	27494.32	555.80	38.13	3.154	0.15	*	23.3	75	7.79

APPENDIX 2. Summary of the water quality parameters as measured at 56 sites for the KaLaeMano project on 25 June 2012. One sample is from an anchialine pool, five from a mauka wells, and 50 from the adjacent ocean. For ocean samples the underlined geometric mean exceed the regional Kona coast Department of Health water quality standards applied to nitrate nitrogen, ammonia nitrogen, total nitrogen, orthophosphorus, total phosphorus, chlorphyll-a and turbidity for surface samples. All values are in ug/l unless indicated; ND = below limits of detection.

Transect	Site No.	DFS [m]	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [o/oo]	Turbidity [NTU]	CHL-a	Temp. [°C]	Oxygen [%]	pH
KL-A	1-S	0	25.34	4.62	173.18	9.61	18.60	711.48	143.22	8.99	34.408	0.48	0.405	24.5	99	8.04
	2-S	10	14.42	3.50	176.68	7.75	17.67	498.12	158.76	9.92	34.663	0.37	0.284	24.4	99	8.06
	3-B	10	12.46	5.74	200.06	7.13	17.05	453.04	181.86	9.92	34.669	0.27	0.337	24.6	98	8.07
	4-S	50	1.68	1.26	229.74	4.96	20.15	150.92	226.80	15.19	34.271	0.31	0.320	24.3	100	8.07
	5-B	50	34.30	4.06	194.46	8.99	17.05	803.04	156.10	8.06	34.863	0.20	0.236	25.7	99	8.08
	6-S	100	6.44	3.08	196.98	6.20	17.05	255.36	187.46	10.85	34.818	0.16	0.154	24.7	100	8.09
	7-B	100	2.10	2.66	199.36	5.58	17.36	145.32	194.60	11.78	34.981	0.13	0.834	25.2	98	8.10
	8-S	200	0.70	0.70	196.56	4.34	19.53	109.20	195.16	15.19	35.023	0.09	0.131	24.5	100	8.12
	9-S	300	3.92	2.80	10.50	4.34	16.43	205.24	3.78	12.09	35.033	0.11	0.149	24.3	101	8.13
	10-S	500	0.14	1.40	182.28	5.89	16.12	166.32	180.74	10.23	35.020	0.09	0.134	25.4	101	8.13
KL-B	11-S	0	0.14	0.70	172.48	4.34	17.98	106.68	171.64	13.64	34.579	0.26	0.345	24.1	100	8.13
	12-S	10	19.74	4.76	207.48	8.06	18.60	495.60	182.98	10.54	34.688	0.24	0.236	24.3	100	8.10
	13-B	10	12.60	3.92	154.70	6.82	19.53	400.40	138.18	12.71	34.756	0.19	0.192	24.3	99	8.00
	14-S	50	5.04	7.70	174.02	7.75	15.50	210.84	161.28	7.75	34.942	0.14	0.138	24.4	100	8.09
	15-B	50	3.64	2.24	132.86	5.58	15.50	151.20	126.98	9.92	34.936	0.14	0.147	24.7	99	8.09
	16-S	100	3.64	2.52	183.40	5.89	17.67	236.04	177.24	11.78	34.954	0.15	0.130	24.7	100	8.11
	17-B	100	2.66	1.82	200.34	5.58	17.05	179.48	195.86	11.47	34.989	0.13	0.213	24.5	98	8.12
	18-S	200	1.68	2.24	119.28	5.27	14.26	110.88	115.36	8.99	35.006	0.13	0.123	24.4	101	8.13
	19-S	300	1.68	1.54	132.16	4.65	14.57	95.48	128.94	9.92	35.006	0.11	0.132	24.5	101	8.14
	20-S	500	1.68	3.22	120.54	4.65	14.26	94.64	115.64	9.61	35.012	0.14	0.134	24.6	101	8.14
KL-C	21-S	0	6.44	4.20	149.24	6.20	15.19	224.00	138.60	8.99	34.813	0.19	0.181	24.9	99	8.11
	22-S	10	6.44	3.78	138.88	6.20	15.50	238.00	128.66	9.30	34.797	0.16	0.219	25.2	99	8.09
	23-B	10	3.22	4.90	131.46	5.89	14.88	140.00	123.34	8.99	34.922	0.14	0.178	24.8	98	8.10
	24-S	50	5.60	2.94	186.06	5.89	15.81	192.36	177.52	9.92	34.848	0.13	0.161	24.2	100	8.10
	25-B	50	2.24	2.94	130.48	5.58	14.26	112.00	125.30	8.68	34.962	0.11	0.132	24.3	99	8.11
	26-S	100	1.82	1.68	116.06	4.96	14.26	102.48	112.56	9.30	34.979	0.10	0.124	24.2	100	8.13
	27-B	100	1.82	2.24	127.12	5.27	14.88	128.52	123.06	9.61	34.984	0.08	0.108	24.1	99	8.13
	28-S	200	1.82	1.54	121.52	4.96	13.95	86.52	118.16	8.99	35.004	0.14	0.168	25.1	100	8.14
	29-S	300	0.98	1.26	147.14	4.65	17.36	79.80	144.90	12.71	35.017	0.10	0.115	24.3	100	8.16
	30-S	500	0.84	1.26	110.04	4.34	13.95	73.36	107.94	9.61	35.015	0.10	0.113	24.6	101	8.16
KL-D	31-S	0	4.06	2.24	135.10	5.27	14.57	178.64	128.80	9.30	34.924	0.13	0.180	24.5	99	8.13
	32-S	10	3.64	1.54	139.30	5.27	14.26	158.20	134.12	8.99	34.942	0.14	0.135	24.9	99	8.11
	33-B	10	2.66	1.82	141.12	5.27	14.88	143.64	136.64	9.61	34.955	0.11	0.125	24.6	99	8.12
	34-S	50	2.24	0.70	127.82	4.96	14.26	120.40	124.88	9.30	34.971	0.12	0.137	24.6	100	8.13
	35-B	50	2.10	1.26	130.20	4.96	14.26	120.68	126.84	9.30	34.974	0.11	0.117	25.0	99	8.13
	36-S	100	4.06	1.26	125.16	5.27	14.26	144.20	119.84	8.99	34.933	0.12	0.144	24.6	101	8.13
	37-B	100	2.10	0.70	134.54	4.96	14.26	106.12	131.74	9.30	34.995	0.11	0.111	24.9	98	8.13
	38-S	200	4.48	0.98	128.24	5.27	14.26	153.44	122.78	8.99	34.921	0.14	0.117	24.6	101	8.14
	39-S	300	2.52	0.84	204.26	4.96	16.74	112.28	200.90	11.78	34.984	0.09	0.145	24.5	101	8.14
	40-S	500	1.68	0.28	146.44	4.34	14.57	88.76	144.48	10.23	35.014	0.10	0.132	24.9	101	8.15
KL-E	41-S	0	4.48	5.60	273.00	6.20	15.81	174.72	262.92	9.61	34.882	0.21	0.215	25.1	99	8.13
	42-S	10	4.06	1.40	192.36	5.27	15.19	139.44	186.90	9.92	34.940	0.18	0.167	25.3	99	8.12
	43-B	10	4.06	1.96	213.92	5.89	15.81	121.80	207.90	9.92	34.957	0.17	0.163	24.5	99	8.12
	44-S	50	3.92	1.26	182.70	5.27	14.57	124.88	177.52	9.30	34.951	0.13	0.112	24.9	100	8.12
	45-B	50	3.92	1.26	159.60	5.58	14.57	113.12	154.42	8.99	34.971	0.12	0.125	24.6	99	8.13
	46-S	100	2.94	0.70	157.92	4.96	14.26	92.40	154.28	9.30	34.990	0.10	0.114	25.6	100	8.14
	47-B	100	2.52	1.12	166.18	4.96	14.57	92.40	162.54	9.61	34.997	0.15	0.113	25.1	99	8.14
	48-S	200	1.96	0.84	167.44	4.96	15.50	95.48	164.64	10.54	35.002	0.13	0.109	25.2	100	8.15
	49-S	300	1.96	0.70	162.82	4.96	14.57	86.80	160.16	9.61	34.999	0.11	0.116	25.4	101	8.15
	50-S	500	0.70	ND	163.52	4.03	14.57	65.80	162.82	10.54	35.034	0.08	0.091	25.4	101	8.16
Geometric Means			2.60	1.63	147.33	5.37	15.68	147.57	137.53	10.16	34.896	0.14	0.155	24.7	100	8.12
Anchialine Pool and Well Samples																
Well 1	W		1579.90	ND	3050.46	112.22	177.01	17297.56	1470.56	64.79	3.623	0.91	*	23.0	70	7.92
Well 2	W		1646.96	ND	3004.54	125.24	184.76	19388.32	1357.58	59.52	2.989	0.23	*	23.4	73	8.02
Well 3	W		1490.30	ND	2568.16	126.48	206.46	19392.52	1077.86	79.98	2.998	0.33	*	23.3	77	8.02
Well 4	W		1508.92	ND	2606.66	130.51	212.04	18019.12	1097.74	81.53	1.917	0.18	*	22.7	75	7.89
Well 5	W		1306.20	ND	2174.62	130.51	207.70	20025.88	868.42	77.19	2.499	0.20	*	23.3	75	7.93
Well 7	W		1633.80	ND	2884.00	112.53	171.74	19570.32	1250.20	59.21	2.403	0.08	*	23.5	65	7.90
Pond 1	A		915.88	13.16	1394.96	248.00	282.10	20113.80	465.92	34.10	3.146	0.92	0.209	23.9	66	7.62

APPENDIX 3. Summary of the water quality parameters as measured at 55 sites for the KaLaeMano project on 18 September 2012. One sample is from an anchialine pool, six from a mauka wells, and 50 from the adjacent ocean. For ocean samples the underlined geometric mean exceed the regional Kona coast Department of Health water quality standards applied to nitrate nitrogen, ammonia nitrogen, total nitrogen, orthophosphorus, total phosphorus, chlorphyll-a and turbidity for surface samples. All values are in ug/l unless indicated; ND = below limits of detection.

Transect	Site No.	DFS [m]	Nitrate N	Ammonia N	TDN	Ortho P	TDP	Si	TON	TOP	Salinity [o/oo]	Turbidity [NTU]	CHL-a	Temp. [°C]	Oxygen [%]	pH
KL-A	1-S	0	30.94	9.52	225.96	8.68	17.05	439.04	185.50	8.37	34.753	0.25	0.505	25.7	97	8.06
	2-S	10	43.96	4.76	218.12	9.61	19.84	1520.96	169.40	10.23	34.533	0.18	0.231	26.2	98	8.06
	3-B	10	10.78	3.78	175.98	6.82	15.19	273.00	161.42	8.37	34.968	0.19	0.266	26.0	96	8.06
	4-S	50	7.84	2.94	175.28	6.20	15.50	226.52	164.50	9.30	35.015	0.21	0.167	25.3	99	8.07
	5-B	50	6.02	2.66	170.38	5.89	14.88	190.96	161.70	8.99	35.025	0.17	0.196	25.8	98	8.09
	6-S	100	3.50	2.10	171.08	5.89	14.88	147.00	165.48	8.99	35.065	0.12	0.156	26.3	99	8.09
	7-B	100	2.10	1.40	165.34	5.27	13.64	135.52	161.84	8.37	35.101	0.11	0.149	26.5	99	8.11
	8-S	200	1.26	0.70	154.84	4.96	13.64	132.16	152.88	8.68	35.085	0.13	0.157	26.2	100	8.12
	9-S	300	0.70	0.28	155.54	4.96	15.19	131.60	154.56	10.23	35.103	0.11	0.133	26.1	100	8.13
	10-S	500	0.70	0.28	168.84	4.96	14.57	114.80	167.86	9.61	35.109	0.11	0.146	26.7	100	8.13
KL-B	11-S	0	16.66	4.76	191.94	7.13	15.50	321.72	170.52	8.37	34.851	0.14	0.308	25.0	99	8.13
	12-S	10	7.00	3.36	177.80	6.20	15.19	191.80	167.44	8.99	35.003	0.13	0.278	25.0	99	8.11
	13-B	10	7.42	3.36	172.20	6.20	14.57	193.76	161.42	8.37	34.998	0.14	0.235	25.0	98	8.10
	14-S	50	4.62	1.68	163.80	5.58	14.57	158.20	157.50	8.99	35.064	0.12	0.181	25.7	100	8.11
	15-B	50	2.24	1.12	149.66	5.27	13.64	117.04	146.30	8.37	35.084	0.12	0.175	25.8	98	8.12
	16-S	100	1.26	0.84	165.76	4.96	14.57	116.48	163.66	9.61	35.088	0.12	0.153	25.6	100	8.13
	17-B	100	1.26	1.26	173.46	4.96	14.88	115.64	170.94	9.92	35.097	0.14	0.159	25.4	97	8.14
	18-S	200	0.84	2.10	166.46	4.96	14.57	104.44	163.52	9.61	35.101	0.13	0.134	25.1	100	8.15
	19-S	300	0.70	2.24	157.92	4.96	13.33	98.28	154.98	8.37	35.108	0.11	0.147	25.9	100	8.15
	20-S	500	1.26	0.28	153.72	4.96	14.57	105.84	152.18	9.61	35.102	0.09	0.143	25.9	101	8.15
KL-C	21-S	0	3.64	2.66	158.62	5.58	14.57	113.12	152.32	8.99	35.085	0.13	0.218	25.4	98	8.14
	22-S	10	3.22	1.96	160.72	5.58	13.95	139.44	155.54	8.37	35.095	0.11	0.166	25.5	98	8.13
	23-B	10	3.64	3.08	176.12	7.75	17.05	184.52	169.40	9.30	35.099	0.13	0.170	25.4	97	8.13
	24-S	50	3.22	1.40	154.98	5.58	13.33	111.44	150.36	7.75	35.091	0.09	0.149	25.7	99	8.13
	25-B	50	3.78	2.10	168.28	5.58	15.19	110.60	162.40	9.61	35.090	0.12	0.165	25.5	97	8.13
	26-S	100	4.20	1.40	157.78	5.58	14.88	120.96	152.18	9.30	35.076	0.12	0.159	25.2	100	8.14
	27-B	100	3.78	1.54	161.28	5.27	14.26	120.12	155.96	8.99	35.083	0.11	0.153	25.4	98	8.14
	28-S	200	2.24	0.84	159.74	4.96	13.64	127.68	156.66	8.68	35.091	0.10	0.185	25.3	100	8.14
	29-S	300	1.82	0.70	154.84	4.96	13.33	124.32	152.32	8.37	35.082	0.10	0.173	25.4	100	8.10
	30-S	500	1.26	0.28	153.44	4.96	13.33	131.60	151.90	8.37	35.101	0.09	0.197	25.7	101	8.11
KL-D	31-S	0	4.20	2.66	173.74	6.20	13.64	115.08	166.88	7.44	35.081	0.11	0.194	25.9	99	8.14
	32-S	10	2.80	1.68	159.74	5.58	13.95	103.60	155.26	8.37	35.088	0.12	0.183	25.5	99	8.12
	33-B	10	3.36	2.24	168.84	5.58	13.64	100.24	163.24	8.06	35.090	0.10	0.180	25.3	98	8.11
	34-S	50	2.94	1.54	160.30	5.58	13.95	99.68	155.82	8.37	35.085	0.10	0.160	25.0	100	8.13
	35-B	50	2.94	1.82	172.90	5.58	13.64	96.32	168.14	8.06	35.087	0.10	0.173	24.9	98	8.14
	36-S	100	2.80	1.26	158.20	5.27	13.64	103.60	154.14	8.37	35.081	0.09	0.176	25.2	100	8.13
	37-B	100	2.94	1.40	166.60	5.27	13.64	103.04	162.26	8.37	35.084	0.09	0.170	25.2	98	8.14
	38-S	200	1.82	0.84	153.16	4.96	13.33	94.36	150.50	8.37	35.086	0.09	0.197	24.6	100	8.15
	39-S	300	2.80	1.54	153.16	5.27	13.95	112.56	148.82	8.68	35.064	0.11	0.171	25.1	101	8.15
	40-S	500	1.40	0.84	154.56	4.96	14.26	87.92	152.32	9.30	35.106	0.09	0.183	25.5	101	8.13
KL-E	41-S	0	5.88	3.92	190.26	6.51	15.19	119.28	180.46	8.68	35.048	0.15	0.200	25.3	99	8.14
	42-S	10	5.32	2.24	154.42	5.89	13.64	113.40	146.86	7.75	35.063	0.13	0.177	25.0	99	8.13
	43-B	10	6.30	3.08	174.02	6.51	14.88	118.16	164.64	8.37	35.058	0.11	0.195	25.6	98	8.12
	44-S	50	5.32	2.10	153.02	5.58	13.64	106.68	145.60	8.06	35.070	0.11	0.164	26.0	100	8.11
	45-B	50	5.88	3.36	192.22	6.51	13.95	111.44	182.98	7.44	35.067	0.16	0.170	26.1	99	8.11
	46-S	100	2.94	1.82	152.88	5.27	13.33	94.64	148.12	8.06	35.084	0.09	0.165	26.0	100	8.10
	47-B	100	2.94	2.10	166.88	5.58	13.95	110.32	161.84	8.37	35.087	0.10	0.157	25.3	98	8.13
	48-S	200	2.38	1.82	158.48	5.27	13.33	88.20	154.28	8.06	35.098	0.08	0.166	25.3	101	8.12
	49-S	300	1.96	1.96	163.38	4.65	13.95	108.92	159.46	9.30	35.079	0.08	0.178	25.2	101	8.14
	50-S	500	2.94	1.82	167.58	5.27	15.81	542.92	162.82	10.54	35.075	0.08	0.171	25.7	101	8.11
Geometric Means			2.99	1.50	164.95	5.57	14.40	141.72	158.11	8.77	35.049	0.11	0.181	25.5	100	8.12
Anchialine Pool and Well Samples																
Well 1	W		2632.70	16.94	3345.44	179.80	245.52	24834.32	695.80	65.72	3.620	1.47	*	24.0	65	7.86
Well 2	W		2567.18	29.40	3454.08	190.96	253.27	24892.84	857.50	62.31	2.991	0.22	*	23.7	77	7.99
Well 3	W		2410.80	19.88	3422.30	216.38	276.83	24863.44	991.62	60.45	3.011	0.38	*	23.9	80	8.04
Well 4	W		2415.84	23.38	3320.38	223.51	281.79	26003.04	881.16	58.28	1.919	0.25	*	24.1	77	8.11
Well 5	W		1810.62	27.02	2920.26	214.52	272.49	24659.04	1082.62	57.97	2.516	0.22	*	24.1	65	8.04
Well 7	W		2779.00	14.56	3583.30	178.25	240.25	26178.32	789.74	62.00	2.369	0.07	*	23.9	69	8.06
Pond 1	A		610.68	20.44	968.66	215.14	282.10	23888.76	337.54	66.96	3.181	0.22	0.194	24.7	77	7.82

APPENDIX 4. Summary of the water quality parameters as measured at 55 sites for the KaLaeMano project on 16 November 2012. One sample is from an anchialine pool, five from a mauka wells, and 50 from the adjacent ocean. For ocean samples the underlined geometric mean exceed the regional Kona coast Department of Health water quality standards applied to nitrate nitrogen, ammonia nitrogen, total nitrogen, orthophosphorus, total phosphorus, chlorphyll-a and turbidity for surface samples. All values are in ug/l unless indicated; ND = below limits of detection.

Transect	Site No.	DFS [m]	Nitrate N	Ammonia N	TDN	Ortho P	TDP	Si	TON	TOP	Salinity [o/oo]	Turbidity [NTU]	CHL-a	Temp. [°C]	Oxygen [%]	pH
KL-A	1-S	0	29.26	9.94	207.62	9.30	15.81	586.88	168.42	6.51	34.665	0.67	0.702	23.9	97	8.06
	2-S	10	6.86	7.00	182.98	6.82	13.95	239.12	169.12	7.13	35.039	0.51	0.272	23.8	98	8.07
	3-B	10	8.54	8.40	184.52	7.13	13.95	295.96	167.58	6.82	34.977	0.49	0.347	23.7	97	8.08
	4-S	50	5.60	4.06	159.88	6.51	13.33	161.84	150.22	6.82	35.118	0.35	0.235	24.0	99	8.09
	5-B	50	5.74	4.62	169.68	6.51	13.02	158.20	159.32	6.51	35.125	0.23	0.252	24.1	97	8.10
	6-S	100	3.64	3.36	156.94	5.89	12.71	116.48	149.94	6.82	35.171	0.17	0.199	24.2	99	8.11
	7-B	100	3.64	3.50	164.92	6.20	12.71	106.40	157.78	6.51	35.175	0.16	0.207	24.2	97	8.12
	8-S	200	1.96	2.66	167.02	5.27	12.09	74.20	162.40	6.82	35.217	0.12	0.195	24.8	99	8.14
	9-S	300	0.42	2.66	171.50	4.96	12.40	64.12	168.42	7.44	35.232	0.13	0.183	24.3	100	8.16
	10-S	500	0.14	2.10	157.64	4.96	12.09	60.48	155.40	7.13	35.234	0.12	0.186	24.1	100	8.17
KL-B	11-S	0	10.08	6.16	192.36	6.82	14.26	285.88	176.12	7.44	34.998	0.32	0.273	23.8	98	8.13
	12-S	10	2.94	4.06	164.78	6.20	13.33	120.12	157.78	7.13	35.168	0.17	0.210	24.1	99	8.13
	13-B	10	4.62	4.48	159.18	6.51	13.64	227.64	150.08	7.13	35.105	0.20	0.247	23.5	98	8.09
	14-S	50	1.26	2.24	162.40	4.96	12.09	68.32	158.90	7.13	35.230	0.14	0.186	24.0	99	8.14
	15-B	50	1.68	2.24	155.68	5.27	12.09	64.96	151.76	6.82	35.220	0.13	0.213	23.8	98	8.16
	16-S	100	0.42	2.10	142.94	4.96	12.09	67.48	140.42	7.13	35.224	0.12	0.182	24.2	99	8.15
	17-B	100	0.00	2.10	168.14	4.96	13.33	60.76	166.04	8.37	35.240	0.13	0.186	24.2	97	8.16
	18-S	200	0.14	1.12	145.32	4.65	11.78	57.12	144.06	7.13	35.237	0.09	0.177	24.3	100	8.17
	19-S	300	0.14	0.98	149.80	4.65	12.09	59.92	148.68	7.44	35.231	0.10	0.184	24.2	100	8.17
	20-S	500	0.14	0.70	157.78	4.34	12.09	65.80	156.94	7.75	35.240	0.12	0.138	24.0	100	8.18
KL-C	21-S	0	4.34	4.48	189.56	6.51	13.64	141.68	180.74	7.13	35.143	0.32	0.289	23.7	99	8.15
	22-S	10	4.34	2.94	178.50	6.51	13.02	160.16	171.22	6.51	35.133	0.16	0.250	23.6	99	8.12
	23-B	10	4.48	3.22	107.10	6.51	11.78	127.96	99.40	5.27	35.132	0.18	0.252	23.7	98	8.12
	24-S	50	2.80	3.78	106.82	5.89	11.78	80.08	100.24	5.89	35.196	0.15	0.173	24.1	99	8.13
	25-B	50	3.22	1.82	101.78	5.89	11.78	98.56	96.74	5.89	35.179	0.13	0.202	23.9	99	8.14
	26-S	100	1.96	0.84	112.14	5.27	11.78	66.64	109.34	6.51	35.224	0.12	0.260	23.9	99	8.16
	27-B	100	1.54	0.98	104.86	4.96	11.47	63.00	102.34	6.51	35.227	0.11	0.193	23.9	98	8.17
	28-S	200	ND	ND	98.56	4.65	10.85	53.20	98.56	6.20	35.232	0.13	0.186	24.2	100	8.18
	29-S	300	0.42	ND	94.22	6.20	10.54	59.92	93.80	4.34	35.244	0.10	0.183	24.2	100	8.18
	30-S	500	0.42	1.12	104.58	6.82	11.47	44.24	103.04	4.65	35.189	0.09	0.141	24.1	100	8.18
KL-D	31-S	0	4.90	2.66	109.62	8.06	11.47	146.44	102.06	3.41	35.128	0.16	0.263	23.7	99	7.96
	32-S	10	4.48	1.96	109.90	7.75	11.47	130.76	103.46	3.72	35.142	0.22	0.220	23.6	99	8.09
	33-B	10	3.64	1.26	104.86	7.44	11.47	105.56	99.96	4.03	35.189	0.13	0.223	24.1	98	8.13
	34-S	50	0.84	0.56	126.56	6.51	11.16	67.48	125.16	4.65	35.225	0.11	0.231	24.0	99	8.16
	35-B	50	0.84	0.70	114.38	6.51	11.16	67.76	112.84	4.65	35.228	0.12	0.194	23.9	97	8.17
	36-S	100	ND	0.14	98.14	5.89	10.54	58.24	98.00	4.65	35.235	0.09	0.177	23.7	100	8.18
	37-B	100	0.14	0.14	102.62	5.89	11.16	58.52	102.34	5.27	35.240	0.12	0.151	23.8	98	8.19
	38-S	200	ND	ND	105.84	5.89	10.85	58.80	105.84	4.96	35.244	0.11	0.161	23.5	100	8.19
	39-S	300	0.14	0.42	113.26	5.89	11.16	52.64	112.70	5.27	35.244	0.09	0.149	23.6	100	8.19
	40-S	500	0.14	0.28	112.98	5.89	10.85	52.92	112.56	4.96	35.241	0.09	0.160	23.9	100	8.19
KL-E	41-S	0	5.04	10.36	131.74	7.75	12.40	161.28	116.34	4.65	35.131	0.21	0.209	24.1	99	8.14
	42-S	10	3.78	1.82	111.86	7.44	11.47	94.64	106.26	4.03	35.186	0.17	0.195	24.5	99	8.14
	43-B	10	4.34	1.12	112.70	7.44	11.47	107.80	107.24	4.03	35.176	0.13	0.187	24.0	98	8.14
	44-S	50	0.98	0.56	96.46	6.20	11.16	69.72	94.92	4.96	35.221	0.11	0.177	24.0	99	8.17
	45-B	50	0.98	0.56	108.08	6.20	10.85	73.08	106.54	4.65	35.227	0.13	0.208	24.4	98	8.17
	46-S	100	0.56	0.14	88.76	6.20	10.85	70.28	88.06	4.65	35.227	0.10	0.205	24.3	100	8.18
	47-B	100	0.56	ND	122.36	5.89	10.54	70.56	121.80	4.65	35.235	0.13	0.191	24.5	97	8.18
	48-S	200	0.14	ND	88.20	5.89	9.61	57.96	88.06	3.72	35.236	0.09	0.167	24.6	100	8.19
	49-S	300	0.14	0.70	112.84	5.89	10.54	61.32	112.00	4.65	35.242	0.09	0.145	24.4	100	8.19
	50-S	500	0.28	ND	94.78	5.27	10.54	49.00	94.50	5.27	35.239	0.09	0.166	24.5	100	8.19
Geometric Means			0.98	1.35	130.22	5.92	11.86	86.93	125.79	5.69	35.180	0.14	0.201	24.1	99	8.15
Anchialine Pool and Well Samples																
Well 1	W		2559.76	4.62	2713.20	154.38	190.34	25180.96	148.82	35.96	3.862	0.41	*	22.2	65	7.94
Well 2	W		2547.58	7.56	2797.34	168.64	206.77	25701.20	242.20	38.13	3.002	0.32	*	22.4	71	8.02
Well 3	W		2413.88	5.18	2722.30	189.41	228.78	25733.12	303.24	39.37	2.976	0.39	*	22.1	65	8.03
Well 4	W		2458.12	6.16	2747.22	199.02	235.91	26915.00	282.94	36.89	1.910	0.32	*	21.5	61	8.00
Well 5	W		1926.68	5.32	2319.66	196.85	233.43	26041.12	387.66	36.58	2.495	0.28	*	22.1	60	7.88
Well 7	W		2676.10	5.60	2915.50	162.13	198.71	27082.72	233.80	36.58	2.361	1.24	*	22.5	60	7.86
Pond 1	A		1889.58	5.60	2357.60	195.92	236.84	25358.20	462.42	40.92	3.164	0.22	0.387	23.1	80	7.86

LAND USE COMMISSION
STATE OF HAWAII

2013 MAY 16 A 9:40

QUANTITATIVE ASSESSMENT OF THE MARINE COMMUNITIES FRONTING THE KA LAE MANO DEVELOPMENT - 2012 ANNUAL SURVEY

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EAC Report No. 2013-02

EXECUTIVE SUMMARY

The Ka Lae Mano development is taking land from a natural state and in the first phase developing about 75 residential lots with infrastructure. This development is situated along about 1.4 km of coastline at Ka Lae Mano in North Kona. The development is set back about 100 m of the shoreline leaving a substantial buffer between the development and the shoreline. A marine community monitoring program is in place to insure that this development does not impact the diverse coral reef communities offshore of Ka Lae Mano. The overall project site is comprised of 1,071 acres with 876.5 acres that could be developed and the remainder to be placed in preservation. Later phases may include more residential development and a golf course. The marine community monitoring program commenced in 1993 when the project was under previous ownership. Two baseline surveys were previously completed in 1993 and 2002. Under new ownership the final baseline survey was completed in April 2005 and construction grading, residential development is now underway along with limited landscaping. Six during construction annual surveys of the marine communities fronting this project site have been completed in October 2006, October 2007, May 2009 representing the 2008 annual survey and September 2009 representing the 2009 dataset. High surf over the last three months of 2010 precluded sampling; the 2011 field work was completed in December and the 2012 survey was done in November. This document presents the data from the 14-15 November 2012 "during construction" survey and comparatively examines these data to those collected previously.

Permanently marked marine quantitative sampling stations have been established at four locations offshore of the project site at depths from 5 to 20 m in each of the three biological zones present along this project site; these same zones also occur along much of the remaining West Hawai'i coastline. The three baseline surveys demonstrate that the marine communities are well-developed offshore of Ka Lae Mano. However, qualitative observations by this author on the fish communities present at Ka Lae Mano in 1972 found the area to have the "best developed coral reef fish communities of anywhere in the Hawaiian Islands" at that time. Although they continue to be well-developed, the Ka Lae Mano fish communities have declined significantly in the abundance and sizes of individual fishes of species normally targeted by fishermen. The baseline data suggest that this decline appears to have primarily occurred between 1972 and the first baseline survey in 1993 and is probably related to overuse of the resources by the public.

The 2006-2012 during construction surveys have noted increases in the diversity (number of species), abundance and biomass of fishes present over previous baseline period surveys. These increases are probably related to the mobility of the fish community which responds to local oceanographic conditions (currents, tides) and biological conditions (i.e., changes in food availability, greater success in spawning and recruitment, decreases in disease, predators, etc.). However, many of the fishes present in greater abundance and sizes in the more recent during construction surveys relative to the last baseline survey (carried out in 2005) are species often targeted by fishermen. The development of the Ka Lae Mano project site has curtailed entry by the public via the Queen Ka'ahumanū Highway to these resources. Thus a simple decrease in fishing pressure may be responsible for the changes in these communities noted in the recent surveys relative to 2005.

Coral communities at Ka Lae Mano have relatively high coverage by species commonly seen in West Hawai'i. The relatively large sizes of some colonies denotes considerable age and thus these colonies have probably been subjected to a relatively stable environmental history. No unusual marine species were encountered in any of the surveys; other marine invertebrates species at Ka Lae Mano are all commonly encountered elsewhere in the Hawaiian Islands. Threatened and endangered species encountered offshore of the project site include pods of spinner porpoises passing through the area, green sea turtles residing in the area and during the winter season and at a greater distance offshore, the humpback whale.

To insure that environmental degradation does not occur with this development, a two-part quantitative environmental monitoring program is in place. This program includes water quality monitoring as well as monitoring of the marine communities resident to the waters fronting the project site. Changes to marine communities in the Ka Lae Mano project site will probably be first mediated through changes in groundwater chemistry thus would first become evident in the groundwater passing beneath the project site. The implementation of the agency- and community-approved water quality monitoring program will insure that activities occurring in the Ka Lae Mano development do not impact the adjacent marine communities. This monitoring program not only samples groundwater (via wells drilled for this specific purpose) as it enters the project site on the mauka (inland) side, but also as it leaves the developed area on the makai or seaward side as well as in the ocean. Thus, changes in water chemistry are the first indication of a possible impact to marine communities offshore of the project site. The water quality monitoring program is designed to detect possible problems before they impact marine communities thus serves as a "early warning" mechanism to protect marine communities.

Similarly, the marine community monitoring program of which this report serves as the sixth "during construction" annual survey, is designed to quantify change that may occur in the future as the development proceeds through use of a statistical comparison of the condition of the marine communities prior to the development to the conditions at subsequent times. To this point in time the statistical analyses of the marine communities suggest that many changes in the measured parameters have occurred but all of these appear to be related to the natural movement of fishes and to differences in the methods used in the early baseline (1993 and 2002) studies relative to those now used. To date, none of the analyses suggest that there have been any declines in the marine communities that could be the result of the development; to the contrary, the development has impeded access to the shoreline resources by the fishing public and those resources appear to be in recovery from fishery use. Thus in summary, the programs in place should insure that the Ka Lae Mano marine communities are not degraded by the residential development and should remain for future generations.

INTRODUCTION

Purpose

The Ka Lae Mano project site is just north of Kona Village in the North Kona District. This project site extends for more than 2.7 km along the coastline at Ka Lae Mano, Kaupulehu. The first phase of the project is situated on a recent a'a lava flow (part of the Kaupulehu flow of 1800-1801, MacDonald *et al.* 1990) and the development is comprised of about 75 residential lots with supporting infrastructure (roads utilities, etc.). Unlike many of the coastal developments in North Kona which occur directly adjacent to the shoreline, the Ka Lae Mano development is set back approximately 100 m inland of the shoreline with the intervening land left in a natural state to serve as a buffer. Later phases of the development may include more residential development and a golf course which would be built in the more inland area.

A previous owner/developer had commenced on preliminary environmental work in accordance with conditions as specified in permits issued for the project site. These conditions included the need to institute a marine life monitoring program for the waters fronting the project site (Marine Research Consultants 1993a, 2002a). Following transfer of the property to the present developer, we developed a comprehensive environmental monitoring plan in April 2004. This plan included marine and groundwater monitoring program, marine life monitoring plan as well as a monitoring program for the ancient Hawaiian salt pans found on the project site that are slated for restoration and use in salt-making.

Under the previous owner and as indicated above, marine water quality monitoring was carried out on four occasions between 1993 through 2002 (see Marine Research Consultants 1993b, 1994, 1998, 2002b) and a preliminary assessment of the near shore marine communities was completed in 1993 and 2002 (Marine Research Consultants 1993a, 2002a). These reports provided guidance in developing the present monitoring protocol used in this study. To the degree possible, monitoring stations in the present program were located to duplicate those used in the earlier environmental surveys so that earlier data could be utilized in the environmental baseline. The marine biological monitoring protocol requires an annual survey so to update the status of marine communities in the waters fronting the project site prior to the commencement of construction, a final baseline survey was undertaken on 13-14 April 2005 with the final environmental baseline report completed in September 2005.

Preliminary grading for access roads was undertaken in mid-2004 on the project site allowing the development of the five coastal water quality monitoring wells to be drilled. Late in 2004 some preliminary grading commenced but at the time the first annual marine community baseline survey was undertaken in April 2005, the grading had not progressed much. Subsequently, grading began in earnest. Since an annual survey is required, the field work was carried out in October 2006 and October 2007. In 2008 the quarterly water quality monitoring for the project site remained on schedule but the annual marine life monitoring did not because the monitoring was left to end of the year at which time surf precluded field work. Other commitments as well as surf pushed the 2008 field survey work to May 2009. The 2009 field survey was carried out in September 2009. As with 2008, the 2010 field survey scheduled for the end of the year could not be carried out because of near-continuous poor weather conditions. Thus the 2010 biological field work was not undertaken. In the early morning hours of 11 March 2011, a tsunami caused considerable damage a number of West Hawai'i locations including Kona Village just south of the Ka Lae Mano project area. The 2011 biological survey was completed in December 2011 and the 2012 survey was undertaken on 14-15 November 2012. This document presents the results of the 2012 field survey and covers a comparative analysis of these data to those previously collected.

Strategy

Marine environmental surveys are usually performed to evaluate feasibility of and ecosystem response to specific proposed activities. Appropriate survey methodologies reflect the nature of the proposed action(s). An acute potential impact (such as channel dredging) demands a survey designed to determine the route of least harm and the projected rate and degree of ecosystem recovery. Impacts that are more chronic or progressive require different strategies for measurement. Management of chronic stress to a marine ecosystem demands identification of system perturbations which exceed boundaries of natural fluctuations. Thus a thorough understanding of normal ecosystem variability is required in order to separate the impact signal from background "noise".

The potential impacts confronting the Ka Lae Mano marine ecosystem are most probably those associated with chronic or progressive stresses. Because the Ka Lae Mano project site had received little or no previous anthropogenic impact (other than increased fishing pressure over the last 30 years), changes occurring with the development should be evident in both water quality and marine community structure if a quantitatively robust baseline is obtained. Environmental concerns include those related to residential development and possible later golf course construction bringing changes to ground and near shore marine water quality as well as continuing and increased direct human impacts on the marine ecosystem that could come from increased fishing pressure altering the structure (i.e., species composition, abundance and biomass) of the marine communities.

Monitoring strategies for assessing chronic stresses rely on comparative spatial and temporal evaluations of ecosystem structure and function in relation to ambient conditions. Usually in order to reliably detect system perturbations, detailed quantitative descriptions of the pre-development environment are necessary as a "benchmark" against which later studies may be comparatively analyzed. This is the strategy used in the present monitoring program for Ka Lae Mano development. Such a sampling strategy should allow the quantitative delineation of changes in Ka Lae Mano marine communities if they occur. Relating changes in marine communities to human activities elsewhere (as on land) may not always be a simple matter when the disturbance is of a chronic nature. However, water chemistry studies and quantitative measures of benthic and fish community structure should assist in early detection of problems and relating these to the causal factor(s). If statistically significant changes are noted in the measured parameters that may require corrective action, management and permit agencies, to the extent required, will be notified so that they may take corrective measures.

MATERIALS AND METHODS

As noted above, this monitoring program was designed to take advantage of work done on this project site previously (Marine Research Consultants 1993a, 1993b, 1994, 1998, 2002a, 2002b). Two of the earlier efforts (Marine Research Consultants 1993a, 2002a) sampled the marine communities offshore of Ka Lae Mano. These earlier studies had delineated four stations at each of which three transect sites located at different depths were sampled. The approximate locations of the four stations was duplicated in the present study (Figure 1).

This study was confined to area from the shoreline to about the 60-foot (20 m) isobath (the outer limit of this study) and covered the marine communities present from the common boundary shared with Kona Village Resort on the south, about 1.4 km north to the northern boundary of the project site at Mano Point. The area encompassed is about 99 acres (or 0.4 km^2) Since the earlier work (Marine Research Consultants 1993a, 2002a) had noted three major ecological zones or biotopes in this area, the present field survey reconfirmed this zonation by making in-water “spot checks” of the zonation through the entire study area.

Biotopes are qualitatively defined partially on the presence of large structural elements (e.g., amount of sand, hard substratum, fish abundance, coral coverage or dominant coral species). Within each of these a number of stations were established and quantitative studies were conducted, including visual enumeration of fish, counts along benthic transect lines and cover estimates in benthic quadrats. Besides these quantitative measures, a qualitative reconnaissance was made in the vicinity of each station by swimming and noting the presence of species not encountered in the transects. All assessments were carried out using SCUBA.

As noted above, the locations of the four stations were approximately placed at the same sites sampled earlier (Marine Research Consultants 1993a, 2002a). The coordinates of each of the three quantitative transects carried out in each of the three biotopes present at each of the four stations were marked in the present survey using a hand-held Ground Positioning System (GPS - Garmin 176-C). Underwater, the ends of each transect were marked using small subsurface floats tied to the substratum along with heavy-duty 32-inch long nylon cable ties such that each transect was permanently marked so that data can be collected again at these locations in the future. All transects were situated parallel to shore thus were carried out on approximately the same depth contours at each of the four locations.

The sampling protocol occurs in the following sequence: on arrival at a given station, a visual fish census was undertaken first to estimate the abundance of fishes. These censuses were conducted over a 25 x 4 m corridor and all fishes within this area to the water's surface were counted. Data collected included species, numbers of individuals and an estimate of their length; the length data were later converted to standing crop estimates using linear regression techniques. A single diver equipped with SCUBA, transect line, slate and pencil would enter the water, count and note all fishes in the prescribed area (method modified from Brock 1954). The 25 m transect line was paid out as the census progressed, thereby avoiding any previous underwater activity in the area which could frighten wary fishes.

Fish abundance and diversity is often related to small-scale topographical relief over short linear distances. A long transect may bisect a number of topographical features (e.g., cross coral mounds, sand flats, and algal beds), thus sampling more than one community and obscuring distinctive features of individual communities. To alleviate this problem, a short transect (25 m in length) has proven adequate in sampling many Hawaiian benthic communities (Brock and Norris 1989).

Besides frightening wary fishes, other problems with the visual census technique include the underestimation of cryptic species such as moray eels (family Muraenidae) and nocturnal species, e.g., squirrelfishes (family Holocentridae), aweoweos or bigeyes (family Priacanthidae), etc. This problem is compounded in areas of high relief and coral coverage affording numerous shelter sites. Species lists and abundance estimates are more accurate for areas of low relief, although some fishes with cryptic habits or protective coloration (e.g., the nohus, family Scorpaenidae; the flatfishes, family Bothidae) might still be missed. Obviously, the effectiveness of the visual census technique is reduced in turbid water and species of fishes which move quickly and/or are very numerous may be difficult to count and to estimate sizes. Additionally, bias related to the experience of the diver conducting counts should be considered in making any comparisons between surveys. In spite of these drawbacks, the visual census technique probably provides the most accurate nondestructive method available for the assessment of diurnally active fishes (Brock 1982).

After the assessment of fishes, the permanent nylon cable ties were tied to the substratum and subsurface floats placed nearby to assist in subsequent relocation of the station; typically these markers were placed at either end of the 25 m transect line. Once completed, an enumeration of epibenthic invertebrates (excluding corals) was undertaken using the same transect line as established for fishes. Exposed invertebrates usually greater than 2 cm in some dimension (without disturbing the substratum) were censused in a 4 x 25 m area. As with the fish census technique, this sampling methodology is quantitative for only a few invertebrate groups. e.g., some of the echinoderms (some echinoids and holothurians). Most coral reef invertebrates (other than corals) are cryptic or nocturnal in their habits making accurate assessment of them in areas of topographical complexity very difficult. This, coupled with the fact that the majority of these cryptic invertebrates are small, necessitates the use of methodologies that are beyond the scope of this survey (e.g., see Brock and Brock 1977). Recognizing constraints on time and the scope of this survey, the invertebrate censusing technique used here attempted only to assess those few macroinvertebrate species that are diurnally exposed.

Exposed sessile benthic forms such as corals and macrothalloid algae were quantitatively surveyed by use of quadrats and the point-intersect method. The point-intersect technique only notes the species of organism or substratum type directly under a point. Along the previously set fish transect line, 50 such points were assessed (once every 50 cm). These data have been converted to percentages. Quadrat sampling consisted of recording benthic organisms, algae and substratum type present as a percent cover in six, one-meter square frames placed at five meter intervals along the transect line established for fish censusing.

If macrothalloid algae were encountered in the 1 x 1 m quadrats or under one of the 50 points, they were quantitatively recorded as percent cover. Emphasis was placed on those species that are visually dominant and no attempt was made to quantitatively assess the multitude of microalgal species that constitute the "algal turf" so characteristic of many coral reef habitats.

During the course of the fieldwork, notes were taken on the number, size and location of green sea turtles and other threatened or endangered species seen within or near to the study area. Additionally, casual observations were made on recreational use patterns as observed within the study area while carrying out other field studies. Further information on threatened or endangered species and fishing use patterns has been obtained by questioning users familiar with the area.

RESULTS

The April 2005 qualitative reconnaissance reconfirmed the presence of four major biotopes or ecological zones in the waters fronting the Ka Lae Mano project site. These reconnaissance surveys were useful in making relative comparisons between areas, identifying any unique or unusual biological resources and providing a general picture of the physiographic structure and biological communities occurring throughout the study area. It should be noted that the boundaries of each zone are not sharp but rather grade from one to another; these are ecotones or zones of transition. Biotopes were delimited by physical characteristics including water depth, relative exposure to wave and current action, and the major structural components present in the benthic communities. The latter include the amount of sand, hard substratum, and vertical relief present as well as the biological attributes of relative coral coverage, fish abundance, and dominant species in the coral community.

Physiographic Setting

The most obvious feature of this 1.4 km section of shoreline is a basalt ledge of pahoehoe lava. Along the southern half of the project site, the Kaupulehu Lava Flow of 1801 extends to the shoreline. The shoreline is comprised of a series of small embayments bounded by outcrops of lava that extend seaward. Along the northern half of the project site, white sand dunes with scrub vegetation occur mauka (shoreward) of the pahoehoe shoreline. At the southern end of the property, small black sand beaches occur between the edge of the lava flow and the rocky shoreline.

The seaward edge of the lava shoreline is composed of either basaltic boulder fields or of vertical sea cliffs up to 5 m in height. Much of the shoreline is comprised of these cliffs which drop steeply away to depths of 4 to 6 m at which point the pahoehoe flattens out and is often overlain by basalt boulders, lava ridges and occasionally interspersed sand channels all of which slope away at about 10 to 15 degrees in a seaward direction. In the southern third of the property the subtidal pahoehoe bench is often overlain by basaltic sands interspersed with basalt ridges and boulders. In these areas the seaward slope of the bottom is less, thus the subtidal bench at depths less than 20 m is broader and is reflected in the bathymetry maps of the area. Moving seaward, the bottom slopes away and corals are encountered with greater frequency as depth increases and appropriate hard substratum is present. At the 15 to 18 m depth, there is an abrupt change in the slope of the bottom where it steeply slopes away at 25 to 45 degrees to depths of about 30 m where sand flats are encountered. Much of this steep slope is comprised of coral rubble and basalt rocks thus is in contrast to the shallower pahoehoe/basalt boulder dominated substratum or the sand plains found in deeper more offshore waters which constitutes a fourth biotope not sampled in this study due to depth.

Biotopes

The structure of the near shore environment along the Ka Lae Mano coast conforms to the pattern that has been documented as characterizing much of the West Hawaii coastline (Hobson 1974). There are three major ecological zones or biotopes offshore of Ka Lae Mano within diving depths. These are the biotope of boulders, the biotope of *Porites lobata* and the biotope of *Porites compressa*. The biotope of boulders is located just offshore of the shoreline and is comprised of a underlying subtidal lava (pahoehoe) bench usually covered by large basalt boulders. The most common coral seen in this zone is the cauliflower coral (*Pocillopora meandrina*) which is able to flourish in areas that are otherwise physically too harsh for most other coral species due to wave stress. This biotope is found from the shore to depths of about 3 to 8 m and occurs as a near-continuous band along the Ka Lae Mano project site.

The lava bench slopes seaward from the boulder zone into the biotope of *Porites lobata*. In some areas the lava bench in this zone is characterized by high relief and undercut ledges and pinnacles. Occasionally, sand channels are encountered but much of the bottom is covered by a number of coral species and sometimes along with large basalt boulders . The impact of wave stress decreases with increasing depth which allows a greater diversity of corals to occur in this biotope. As the name implies, the dominant coral species is the lobate or hemispherical coral, *Porites lobata*. Water depth in this zone ranges from 7 to 15 m or so.

At the 15-18 m isobath, the seaward edge of the reef platform is marked by an increased slope to an angle usually between 20 to 35 degrees. This sloping bottom changes from the solid basalt seen in more shoreward areas to a general aggregate of unconsolidated sand, rubble and rock. The predominant coral cover in this steeply sloped area are colonies of finger coral (*Porites compressa*) which gives this zone its name. *Porites compressa* grows laterally over unconsolidated substrata. This biotope of *Porites compressa* is found at depths between 12 to 25 m; these greater depths translate into an attenuation of wave forces. *Porites compressa* is very susceptible to breakage by occasional storm surf thus (1) it's occurrence is greater at greater depths and (2) when storm surf does occur, this relatively delicately branched coral species is frequently broken and is a source for much of the rubble found on these slopes.

At the base of the steep slope that makes up the biotope of *Porites compressa* the slope flattens out becoming the biotope of sand which continues seaward to below normal diving depths. Due to the paucity of many coral reef species and depths out of range for the quantitative monitoring of biological communities, the biotope of sand was not quantitatively surveyed in this study. Thus, the field work focused on sampling in the biotope of boulders, the biotope of *Porites lobata* and the biotope of *Porites compressa* fronting the Ka Lae Mano project site.

Structure of Marine Communities at Ka Lae Mano

The permanently marked transects were established during the 2005 survey in each of the three major biotopes present at Ka Lae Mano. Every effort was made to locate stations and transects in approximately the same areas as sampled in the earlier 1993 and 2002 studies so that data would be comparative. The zonation of benthic communities seen along much of the West Hawaii coastline is present at Ka Lae Mano but along the southern third of the project site the relatively large amount of sand reduces the exposed hard substratum which is necessary for coral growth and increases scouring when surf occurs resulting in less coral present in the shallow biotope of boulders. Quantitative studies were carried out at the 12 permanently marked transect sites; four transects were established in each of the three zones. Table 1 presents the latitude and longitude of the sampled transect sites; in some cases, transects were located in close proximity to one another so that positional information is only needed to locate the two extreme (shallowest and deepest) survey sites. The results of the November 2012 quantitative studies are given in Appendices 1 through 14; Appendix 1 present the results of the visual fish surveys carried out at each transect site and the quantitative benthic survey results from each of the twelve sites are given in Appendices 3 through 14 for November 2012survey. The data from the most recent survey are discussed by zone (biotope of boulders, biotope of *Porites lobata* and the biotope of *Porites compressa*) and are briefly discussed relative to the earlier surveys.

1. The Biotope of Boulders

Four transects (numbers 1, 4, 7 and 10, see Figure 1) sampled this biotope. The results of the benthic surveys of these four sites are given in Appendices 2, 5, 8 and 11 for the 14-15 November 2012 field effort. The November 2012 survey noted ten coral species (mean per transect = 7 species) having a mean coverage of 34.4 percent. The ten coral species included *Porites lobata, Porites lutea, Pavona varians, Pavona duerdeni, Montipora verrucosa, Montipora patula, Monitpora verrilli, Leptastrea purpurea* and *Leptastrea bewickensis*. In total fourteen species of diurnally-exposed macroinvertebrate species were encountered on the four transects (mean per transect = 8 species). The abundance of these macroinvertebrates ranged from 50 to 114 individuals on a transect (mean 86 individuals) in the biotope of boulders and the species seen included mollusks (*Spondylus tenebrosus, Drupa morum, Conus rattus, Conus lividus, Latirus nodatus*) hermit crabs (*Cilipagurus strigatus* and *Calcinus latens*), sea urchins (*Echinothrix diadema, Echinothrix calamaris, Echinometra mathaei, Echinostrephus aciculatum, Heterocentrotus mammillatus* and *Tripneustes gratilla*) and the black sea cucumber (*Holothuria atra*). In total, 46 species of fishes were censused on the four transects (range from 16 to 32 species; mean 26 species per transect). The most abundant species were goldring surgeonfish or kole (*Ctenochaetus strigosus*), the yellow tang or lau'ipala (*Zebrasoma flavescens*) and to a lesser extent, the damselfish (*Chromis vanderbilti*) and two uhu species, the bulletnose parrotfish (*Scarus sordidus*) and the palenose parrotfish (*Scarus psittacus*). The estimated number of individual fish censused on a transect ranged from 277 to 507 individuals (mean = 401 individual/transect). The estimated standing crop of fishes on a transect ranged from 173 to 594 g/m^2 and the mean standing crop was 346 g/m^2. Species contributing heavily to the biomass of fishes on a transect include the the orangebar surgeonfish or na'ena'e (*Acanthurus oliveaceus*) adding 14 to 49% and the uhu (*Scarus psittacus*) comprising 20 to 23% of the total on these transects. Other species making substantial contributions to the estimated standing crop at the four bould zone transects included the paletail unicornfish or kala lolo (*Naso breviostris*) on Transect 1, the convict tang or manini (*Acanthurus triostegus*) and the whitebar surgeonfish or maiko'iko (*Acanthurus leucoparieus*) on Transect 4, the bulletnose parrotfish or uhu (*Scarus sordidus*) on Transect 7 and brown surgeonfish or ma'i'i'i (*Acahturus nigrofuscus*) along with the redlip parrotfish or palukaluka (*Scarus rubroviolaceus*) on Transect 10.

The December 2011 survey noted eight coral species (mean per transect = 6 species) having a mean coverage of 28.5 percent and eleven species of diurnally-exposed macroinvertebrate species were encountered on the four transects (mean per transect = 7 species). The abundance of these macroinvertebrates ranged from 41 to 126 individuals on a transect (mean 70 individuals) in the biotope of boulders. In total, 44 species of fishes were censused on the four transects (range from 10 to 27 species; mean 21 species per transect). The most abundant species were the mai'i'i (*Acanthurus nigrofuscus*), the yellow tang or lau'ipala (*Zebrasoma flavescens*), the saddleback wrasse or hinalea lauwili (*Thalassoma duperrey*) and to a lesser extent, the damselfish (*Chromis vanderbilti*), the maiko'iko (*Acanthurus leucopareius*) and two uhu species *Scarus sordidus* and *Scarus psittacus*. The estimated number of individual fish censused on a transect ranged from 33 to 384 individuals (mean = 211 individual/transect). The estimated standing crop of fishes on a transect ranged from 9 to 208 g/m^2 and the mean standing crop was 129 g/m^2. Species contributing heavily to the biomass of fishes on a transect include the orangespine unicornfish or umaumalei (*Naso lituratus*) making up 9 to 65% of the total, the orangebar surgeonfish or na'ena'e (*Acanthurus oliveaceus*) adding 10 to 26%, the hinalea lauwili (*Thalassoma duperrey*) contributing 19 to 22% and the uhu (*Scarus psittacus*) comprising

17 to 20% of the total on these transects.

In the September 2009 survey, a total of nine coral species (mean per transect = 7 species) having a mean coverage of 25.4 percent and fifteen macroinvertebrate species (mean per transect = 9 species) were encountered in the four transects during the 2009 survey. In total, the number of individual macroinvertebrates counted on a transect line ranged from 54 to 99 individuals (mean per transect = 72 individuals) in the September 2009 survey of the biotope of boulders. Forty-six species of fishes were encountered in the four boulder zone transects in the 2009 survey (mean = 23 species/transect, range 12 to 27 species) . In 2009, a mean of 264 individual fishes per transect (range = 130 to 467 individuals) were found having a mean standing crop of 264 g/m^2 (range from 2 to 419 g/m^2).

The 2008 survey of the biotope of boulders was carried out on 4-5 May 2009. In this survey, nine coral species had a mean per transect of 7 species and also had a mean coverage of 24.3% (range = 19.4 to 31.6%). The census of macroinvertebrates noted thirteen species present among the four transects in the 2008 survey (range = 7 - 8 species, mean = 7 species per transect). In total, the number of individual macroinvertebrates counted on a transect line ranged from 49 to 65 individuals (mean per transect = 56 individuals) in the 2008 survey of the biotope of boulders. Forty-five species of fishes were encountered in the four boulder zone transects in the 2008 survey (mean = 20 species/transect) and a mean of 231 individual fishes per transect (range = 87 to 388 individuals) were found having a mean standing crop of 155 g/m^2 (range from 4 to 283 g/m^2).

The 2007 survey of the biotope of boulders noted a total of eight coral species (mean per transect = 5 species) having a mean coverage of 15.9 percent. There were seventeen macroinvertebrate species encountered in four boulder zone transects the 2007 survey (mean per transect = 9 species). In total, the number of individual macroinvertebrates counted on a transect line ranged from 63 to 111 individuals (mean per transect = 85 individuals) in the 2007 survey of the biotope of boulders. Forty-three species of fishes were encountered in the four transects (mean = 22 species per transect). In 2007, a mean of 256 individual fishes per transect (range = 104 to 438 individuals) were found haivng a mean standing crop of 254 g/m^2 (range from 18 to 431 g/m^2).

In 2006 there were 49 species of fishes found in the boulder zone transects having a mean of 271 individuals per transect and a mean standing crop of 224 g/m^2 (range 161 to 292 g/m^2). The 2006 survey noted nine coral species found (mean = 6 per transect) having a mean coverage of 16.8%. In 2005, there were ten coral species found (mean = 6 per transect) having a mean coverage of 16.6%. Also in 2005, there were 35 species of fishes in the biotope of boulders having a mean of 193 individuals censused per transect and the standing crop ranged from 5 to 226 g/m^2 (mean = 127 g/m^2).

On all surveys of the biotope of boulders, the most common coral species are the are the cauliflower coral (*Pocillopora meandrina*) and the lobate coral (*Porites lobata*) with the latter usually in encrusting forms. Other species that are present in the quadrat surveys at these four transect sites include *Porites lutea, Pavona varians, Pavona duerdeni,* rice corals (*Montipora patula, Montipora verrucosa, Montipora verrilli*) and *Leptastrea purpurea*. Other than *Pocillopora meandrina* and to a lesser extent, *Porites lobata* the other coral species do not comprise much coverage in this biotope. Because of their diurnally-exposed nature, sea urchins are common macroinvertebrate species seen in all transect areas. Species frequently encountered in the biotope of boulders include the black sea urchin (*Tripneustes gratilla*), the wana (*Echinothrix diadema*), the banded urchin (*Echinothrix calamaris*), the slate-pencil urchin (*Heterocentrotus mammillatus*), the green urchin (*Echinometra mathaei*) and the boring urchin (*Echinostrephus aciculatum*). A number of mollusks were seen including cone shells (*Conus distans, C. lividus, C. marmoreus, C. ebraeus, C. miles*), the drupe (*Drupa morum*) and the spindle shell (*Latirus nodatus*). More cryptic species encountered in the biotope of boulders include the rock oyster (*Spondylus tenebrosus*), the black-lipped pearl oyster or pa (*Pinctada margaritifera*), the spiny lobster or 'ula (*Panulirus penicillatus*), the christmas tree worm (*Spirobranchus gigantea*) which lives in association with the coral, *Porites lobata*, and the ghost shrimp (*Callianassa variabilis*). Away from the transects, the hermit crabs (*Dardanus deformis* and *Cilipagurus strigatus*), humpback cowry or leho (*Cypraea mauritana*), the leopard cone (*Conus leopardus*) and the shrimps (*Saron marmoratus* and *Stenopus hispidis*) have been encountered.

As noted above in the 15-16 September 2009 survey, 46 species of fishes were encountered in the biotope of boulders. The abundance of these fishes ranged from 130 to 467 individuals counted per transect (mean = 264 individuals). The most abundant fishes included the damselfish (*Chromis vanderbilti*), the ma'i'i'i (*Acanthurus nigrofuscus*), the lau'ipala (*Zebrasoma flavescens*), the hinalea lauwili (*Thalassoma duperrey*) and the uhu (*Scarus psittacus*). By weight, the most important contributors included the uhu (*Scarus psittacus*) making up from 13 to 24% of the total biomass present on a transect and the orangespine unicornfish or umaumalei (*Naso lituratus*) comprising from 13 to 27% of the standing crop present on a transect. Other important contributors to the estimated standing crop at the four boulder zone transects in 2009 included maiko'iko (*Acanthurus leucoparieus*), the na'ena'e (*Acanthurus oliveceus*), the black surgeonfish (*Ctenochaetus hawaiiensis*), palukaluka (*Scarus rubroviolaeus*) and the uhu (*Scarus sordidus*).

In the 2008 survey of the biotope of boulders carried out on 4-5 May 2009, there were 45 species of fishes noted among the four transects. The abundance of fishes ranged from 87 to 388 individuals encountered on a transect (mean = 231 individuals per transect).

The most abundant species encountered on these four transects included the damselfish (*Chromis vanderbilti*), the hinalea lauwili (*Thalassoma duperrey*), the ma'i'i'i (*Acanthurus nigrofuscus*) and the lau'ipala (*Zebrasoma flavescens*). The species contributing most heavily to the estimated standing crop in the 2008 survey of boulder zone transects include the ma'i'i'i (*Acanthurus nigrofuscus*) ranging from 9 to 10% of the total, na'ena'e (*Acanthurus oliveceus*) making up 8 to 10%, lau'ipala (*Zebrasoma flavescens*) adding 8 to 13% and the umaumalei (*Naso lituratus*) contributing from 20 to 38% of the estimated standing crop on these transects. Other major contributors to the 2008 standing crops at the four boulder zone stations include the hinalea lauwili (*Thalassoma duperrey*), the black surgeonfish (*Ctenochaetus hawaiiensis*), the palani (*Acanthurus dussumieri*), uhu (*Scarus psittacus*) and the palukaluka (*Scarus rubroviolaceus*).

In the 2007 survey, 43 species of fishes were encountered in the biotope of boulders. The abundance of fishes ranged from 104 to 438 individuals seen per transect (mean = 256 individuals per transect). The most abundant species on the four transects sampling this biotope were the damselfish (*Chromis vanderbilti*), the ma'i'i'i (*Acanthurus nigrofuscus*), the lau'ipala (*Zebrasoma flavescens*), the kole (*Ctenochaetus strigosus*), the two uhu species (*Scarus sordidus* and *Scarus psittacus*). By weight, the most important contributors to the standing crop estimates in the biotope of boulders were the umaumalei (*Naso lituratus*) comprising from 10% to 69% of the estimated standing crop at a station, the na'ena'e (*Acanthurus olivaceus*) making up from 15% to 51% of the weight present and to a lesser extent, the parrotfishes including the uhu (*Scarus sordidus*) and palukaluka (*Scarus rubroviolaceus*) as well as the black kole (*Ctenochaetus hawaiiensis*) contributed to the estimated standing crops at these stations in 2007. In past surveys (2005 and 2006) besides many of the above species, the blue-spotted grouper or roi (*Cephalopholis argus*), brick soldierfish or menpachi (*Myripristes amaenus*) and the ma'i'i'i (*Acanthurus nigrofuscus*) were also important contributors to the standing crop. Interestingly, on Transect 1, several large milkfish or awa (*Chanos chanos*) were encountered in 2006 which comprised 96 percent of the estimated standing crop at this station at that time.

2. *The Biotope of Porites lobata*

Just seaward of the biotope of boulders is the biotope of *Porites lobata*. This biotope occurs as a near-continuous feature offshore of the Ka Lae Mano project site. Because this biotope is situated at depths from about 7 to 15 m the forces of wave impact are less and a greater diversity of benthic (i.e., bottom-dwelling) species are present. The underlying substratum is basalt and often some of the boulders in the shallower biotope continue into this one. Four transects (nos 2, 5, 8 and 11, Figure 1) sampled the marine communities in this biotope. The results of this sampling are presented in Appendices 3, 6, 9 and 12 for the 2012 survey. Appendix 1 presents 2012 fish census results which are discussed below.

In the 2012 survey, seven coral species were found in the quadrats and the mean was six species per transect. Mean coral coverage was estimated to be 49.0% which is up 0.8% over the previous (2011) survey of this biotope. Coral coverage on the individual transects ranged from 40.4% to 55.2%. The greater coverage by corals in the biotope of *Porites lobata* relative to the biotope of boulders is probably related to the attenuation of wave impact with increasing depth. Coral species encountered in the quadrat survey include the dominant *Porites lobata*, and to a lesser extent, *Porites compressa, Pocillopora meandrina, Montipora patula, Montipora verrucosa, Pavona varians* and *Porites lutea*. Other coral species seen in this biotope but not in the transect areas include *Montipora flabellata, Pocillopora eydouxi Pavona duerdeni, Leptastrea purpurea, Leptastrea bewickensis, Fungia scuatria* and *Porites rus*.

The census of macroinvertebrates in the 2012 survey noted twelve diurnally-exposed species (mean = 8 species per transect) and a mean of 164 individual invertebrates censused in a transect (range from 93 to 242 individuals). Again, common species included the visually-prominent sea urchins (the wana *Echinothrix diadema*, the banded urchin *E. calamaris*, the green urchin *Echinometra mathaei*, the slate pencil urchin *Heterocentrotus mammillatus*, the black urchin *Tripneustes gratilla* and less commonly seen serrate urchin (*Chondrocidaris gigantea* as well as *Eucidaris metularia*). Other invertebrates encountered in the 2011 survey of this biotope include the boring bivalve (*Arca ventricosa*), rock oyster (*Spondylus tenebrosus*), cone shell (*Conus miles*), Christmas tree worm (*Spirobranchus giganteus*) and the coral-feeding starfish, *Acanthaster plancii*. Other macroinvertebrates seen in the biotope but away from the transects include the sea cucumber or loli (*Holothuria nobilis*), starfish (*Linckia multiflora*), octopus or he'e (*Octopus cyanea*) and textile cone (*Conus textile*) and marbled cone (*Conus marmoratus*).

The 2012 fish census of the four stations in the biotope of *Porites lobata* noted 48 species (Appendix 1) and the mean per station was 25 species (range from 19 to 29 species). The mean number of individual fish noted on a transect was 201 individuals (range = 145 to 270 individuals) and the mean standing crop was 160 g/m^2 (range from 93 to 245 g/m^2). The most common fishes found in the 2012 survey of the four transects carried out in the biotope of *Porites lobata* were the ma'i'i'i (*Acanthurus nigrofuscus*), the kole (*Ctenochaetus strigosus*) and the yellow tang or lau'ipala (*Zebrasoma flavescens*). Other common fishes included the damselfish (*Chromis vanderbilti*), the uhu (*Scarus psittacus*) and the hinalea lauwili (*Thalassoma duperrey*). Fishes contributing heavily to the 2012 standing crop estimates in the biotope of *Porites lobata* included the uhu (*Scarus sordidus*) making up 12% to 25% of the total, the kole (*Ctenochaetus strigosus*) adding 10 to 23%, the blue-spotted grouper or roi (*Cephalopholis argus*) contributing 12 to 32% and to a lesser extent, the lau'ipala (*Zebrasoma flavescens*) at Transect 11, the yellowmargin moray eel or puhi-paka (*Gymnothorax flavimarginatus*) on Transect 8, the black triggerfish or humuhumu 'ele'ele (*Melichthys niger*) on Transect 5 and on Transect 2, the ma'i'i'i (*Acanthurus nigrofuscus*) and the orangespine unicornfish or umaumalei (*Naso lituratus*).

The 2011 survey noted nine coral species in the quadrats havin a mean was six species per transect. Mean coral coverage was estimated to be 48.2%. Coral coverage on the individual transects ranged from 38.8% to 52.0%. Coral species encountered in the quadrat survey include the dominant *Porites lobata*, and to a lesser extent, *Porites compressa, Pocillopora meandrina, Montipora patula, Montipora verrucosa, Fungia scutaria, Pavona duerdeni, Pavona varians, Leptastrea purpurea* and *Porites evermanni.* The census of macroinvertebrates in the 2011 survey noted 10 diurnally-exposed species (mean = 8 species per transect) and a mean of 164 individual invertebrates censused in a transect (range from 136 to 209 individuals). Again, common species included the visually-prominent sea urchins (*Echinothrix diadema, E. calamaris, Echinostrephus aciculatum, Echinometra mathaei, Heterocentrotus mammillatus, Tripneustes gratilla* and *Chondrocidaris gigantea.* Other invertebrates encountered in the 2011 survey of this biotope include the boring bivalve (*Arca ventricosa*), rock oyster (*Spondylus tenebrosus*), Christmas tree worm (*Spirobranchus giganteus*), the black sea cucumber (*Holothuria atra*) and the coral-feeding starfish, *Acanthaster plancii.*

The 2011 fish census of the four stations in the biotope of *Porites lobata* noted 48 species (Appendix 1) and the mean per station was 23 species (range from 21 to 27 species). The mean number of individual fish noted on a transect was 237 individuals (range = 171 to 440 individuals) and the mean standing crop was 237 g/m^2 (range from 105 to 578 g/m^2). The most common fishes found in the 2011 survey of the biotope of *Porites lobata* were *Acanthurus nigrofuscus, Ctenochaetus strigosus* and *Zebrasoma flavescens*). Fishes contributing heavily to the 2011 standing crop estimates in the biotope of *Porites lobata* included *Scarus sordidus* making up 13% to 42% of the total, *Acanthurus olivaceus* adding 8 to 11%, *Zebrasoma flavescens* contributing 18 to 24%, *Scarus sordidus* adding 13 to 42% and *Ctenochaetus strigosus* comprising 11% to 32% on transects.

In the 2009 survey, nine coral species were found in the quadrats and the mean was seven species per transect. Mean coral coverage was estimated to be 41.9%. Coral coverage on the individual transects ranged from 26.0% to 47.9%. Coral species encountered in the quadrat survey include the dominant *Porites lobata*, and to a lesser extent, *Porites compressa, Pocillopora meandrina, Montipora patula, Montipora verrucosa, Pavona duerdeni, Pavona varians, Leptastrea purpurea* and *Porites evermanni.*

The census of macroinvertebrates in the 2009 survey noted 13 diurnally-exposed species (mean = 9 species per transect) and a mean of 125 individual invertebrates censused in a transect (range from 87 to 178 individuals). Again, common species included the visually-prominent sea urchins (*Echinothrix diadema, E. calamaris, Echinostrephus aciculatum, Echinometra mathaei, Heterocentrotus mammillatus, Tripneustes gratilla* and *Chondrocidaris gigantea*. Other invertebrates encountered in the 2009 survey of this biotope include *Arca ventricosa, Spondylus tenebrosus, Spirobranchus giganteus, Latirus nodatus, Pincada margaritifera, Holothuria atra*) and *Acanthaster plancii.*

The 2009 fish census of the four stations in the biotope of *Porites lobata* noted 47 species and the mean per station was 27 species (range from 21 to 30 species). The mean number of individual fish noted on a transect was 285 individuals (range = 205 to 397 individuals) and the mean standing crop was 255 g/m^2 (range from 130 to 470 g/m^2). The most common fishes found in the 2009 survey of the biotope of *Porites lobata* were *Acanthurus nigrofuscus, Ctenochaetus strigosus, Chromis vanderbilti, Zebrasoma flavescens* and *Scarus sordidus*. Fishes contributing heavily to the 2009 standing crop estimates in the biotope of *Porites lobata* included *Scarus sordidus* making up 13% to 24% of the total, *Naso lituratus* adding 10% to 25% and *Ctenochaetus strigosus* comprising 8% to 14% on transects. Besides these species, other species contributing substantially on individual transects were as follows in the 2009 survey: at Station 2: *Acanthurus leucoparieus* adding 34%; at Station 5: *Zebrasoma flavescens* adding 10%; at Station 8: *Scarus perspicillatus* making up 13%, *Scarus rubroviolaceus* adding 27% and at Station 11 *Cephalopholis argus* adding 13% to the total at this station.

In the 2008 survey of the biotope of *Porites lobata*, ten coral species were found in the quadrats having a mean number of eight species per transect. Mean coral coverage was estimated to be 40.9% which is up 2.5% over the previous (2007) survey of this biotope. Coral coverage on the individual transects ranged from 33.0% to 57.3% in 2009. As noted above, the greater coverage by corals in the biotope of *Porites lobata* relative to the biotope of boulders is probably related to the attenuation of wave impact with increasing depth. Coral species encountered in the quadrat survey include the dominant *Porites lobata*, and to a lesser extent, *Porites compressa, Pocillopora meandrina, Montipora patula, Montipora verrucosa, Montipora verrilli, Pavona duerdeni, Pavona varians, Porites rus* and *Porites evermanni*. Other coral species seen in this biotope but not in the transect areas include *Montipora flabellata, Pocillopora eydouxi* and *Fungia scutaria.*

The census of macroinvertebrates in the 2008 survey noted 16 diurnally-exposed species (mean = 10 species per transect) and a mean number of individual invertebrates censused in a transect was 134 (range from 110 to 159 individuals). Again, common species included the visually-prominent sea urchins (*Echinothrix diadema, E. calamaris,* *Echinometra mathaei*, *Heterocentrotus mammillatus*, *Tripneustes gratilla* and *Chondrocidaris gigantea*). Other invertebrates encountered in the 2008 survey of this biotope include *Arca ventricosa*, *Spondylus tenebrosus*, *Spirobranchus giganteus*, *Mitra assimilis*, *Latirus nodatus*, *Streptopinna saccata*, *Actinopyge maruitana*, *Holothuria atra*, *Dardanus deformis* and *Pinctada margaritifera*. Other macroinvertebrates seen in the biotope but away from the transects include the sea cucumber or loli (*Holothuria nobilis*), starfish (*Linckia diplax*), octopus or he'e (*Octopus cyanea*) and the cone (*Conus lividus*).

The 2008 fish census of the four stations in the biotope of *Porites lobata* noted a total of 40 species and the mean per station was 25 species (range from 16 to 32 species). The mean number of individual fish noted on a transect was 175 individuals (range = 108 to 208 individuals) and the mean standing crop was 140 g/m^2 (range from 77 to 202 g/m^2). The most common fishes found in the 2008 survey of the biotope of *Porites lobata* were *Acanthurus nigrofuscus*, *Ctenochaetus strigosus*, *Chromis vanderbilti*, *Zebrasoma flavescens* and *Thalassoma duperrey*. Fishes contributing heavily to the 2008 standing crop estimates in the biotope of *Porites lobata* included *Naso lituratus* making up from 7 to 16% of the total, *Zebrasoma flavescens* adding from 8 to 14%, *Myripristes amaenus* contributing 12 to 13% and *Ctenochaetus strigosus* adding 14 to 20% to the total seen in the biotope. Besides these species, other species contributing substantially on individual transects were as follows in the 2008 survey: at Station 2: *Acanthurus dussumieri* making up 7%, *Scarus rubroviolaceus* adding 31% and *Ctenochaetus hawaiiensis* contributing 6%; at Station 5, *Scarus sordidus* added 39% to the total and at Station 11, *Cephalopholis argus* contributed 15% to the total at this station.

In the 2007 survey, nine coral species were found in the quadrats and the mean was seven species per transect. Mean coral coverage was estimated to be 38.7% which is up 6.5% over the previous (2006) survey of this biotope. Coral coverage on the individual transects ranged from 31.2% to 52.2% in 2007. Coral species encountered in the quadrat survey include the dominant *Porites lobata*, and to a lesser extent, *Porites compressa, Pocillopora meandrina, Montipora patula, Montipora verrucosa, Pavona duerdeni, Pavona varians, Leptastrea purpurea* and *Porites evermanni*. Other coral species seen in this biotope but not in the transect areas include *Montipora flabellata, Pocillopora eydouxi, Porites rus* and *Fungia scutaria*.

The census of macroinvertebrates in the 2007 survey noted 17 diurnally-exposed species (mean = 10 species per transect) and a mean number of individual invertebrates censused in a transect of 136 (range from 80 to 189 individuals). Again, common species included the visually-prominent sea urchins (*Diadema setosum, Echinothrix diadema, E. calamaris, Echinostrephus aciculatum, Echinometra mathaei, Heterocentrotus mammillatus, Tripneustes gratilla* and *Chondrocidaris gigantea*. Other invertebrates encountered in the 2007 survey of this biotope include *Arca ventricosa, Spondylus* *tenebrosus*, *Spirobranchus giganteus*, *Conus vitulinus*, *C. striatus*, *Latirus nodatus*, *Callianassa variabilis* and *Acanthaster plancii*. Other macroinvertebrates seen in the biotope but away from the transects include *Holothuria nobilis*, *Linckia diplax*, *Octopus cyanea* and *Conus ebreus*.

The 2007 fish census of the four stations in the biotope of *Porites lobata* noted 51 species and the mean per station was 30 species (range from 28 to 33 species). The mean number of individual fish noted on a transect was 253 individuals (range = 217 to 326 individuals) and the mean standing crop was 237 g/m^2 (range from 146 to 353 g/m^2). The most common fishes found in the 2007 survey of the biotope of *Porites lobata* were *Acanthurus nigrofuscus*, *Ctenochaetus strigosus*, *Chromis vanderbilti*, *Zebrasoma flavescens*, *Myripristes amaenus*, *Naso hexacanthus*, *Scarus sordidus* and *S. psittacus*. Fishes contributing heavily to the 2007 standing crop estimates in the biotope of *Porites lobata* included *Scarus sordidus* making up 15% to 22% of the total, *Ctenochaetus hawaiiensis* adding 11% to 17%, *Cephalopholis argus* comprising 13% to 14% on transects. Besides these species, other species contributing substantially on individual transects were as follows in the 2007 survey: at Station 2: *Acanthurus dussumieri* making up 22% and *Acanthurus leucoparieus*; at Station 8: *Myripristes amaenus* adding 21% and *Ctenochaetus strigosus* making up 14%; at Station 11: *Naso hexacanthus* contributing 17% and *Naso lituratus* adding 10% to the total at this station.

In the 2006 survey, eight coral species were in the quadrats and the mean was 7 coral species per transect; mean coral coverage was estimated to be 32.2 percent. In the 2005 survey, again eight coral species were noted in the quadrat survey (mean per transect = 6 species) and coral coverage varied from 19.3 to 35.5% (mean per transect = 27.7%). In 2006, the census of diurnally-exposed macroinvertebrates found 15 species (mean per transect = 9 species). Species encountered in 2006 but not in 2007 included the yellow miter shell (*Mitra ferruginea*), spiny drupe shell (*Drupa speciosa*), polychaete (*Loimia medusa*), brown hermit crab (*Aniculus strigatus*) and starfish (*Linckia multiflora*). In the 2005 survey, six macroinvertebrate species were found in the biotope of *Porites lobata* having a mean of 6 species per transect.

The 2006 fish census of the four stations in the biotope of *Porites lobata* noted 50 species and the mean per station was 29 species. The mean number of individual fish noted on a transect was 256 individuals (range = 177 to 383 individuals) and the mean standing crop was 211 g/m^2. The most common fishes found in the 2006 survey of the biotope of *Porites lobata* were identical to those found in 2007 but not including *Naso hexacanthus* and *Scarus psittacus*. In 2006, the estimated standing crop of fishes ranged from 136 to 352 g/m^2 and the species making the greatest contribution to this biomass included *Acanthurus olivaceus*, *Acanthurus nigrofuscus*, *Acanthurus leucoparieus*, *Ctenochaetus striogsus*, *Acanthurus dussumieri*, *Ctenochaetus hawaiiensis*, *Naso* *lituratus, Cephalopholis argus, Myripristes amaenus, Scarus sordidus* and *Zebrasoma flavescens.*

The 2005 fish censuses carried out on the four transects noted 44 species having a mean per transect = 26 species. The abundance of censused fishes ranged from 221 to 243 individuals per transect (mean 236 individuals). The most common species were *Chromis vanderbilti, Acanthurus nigrofuscus, Ctenochaetus strigosus* and *Zebrasoma flavescens.* The estimated standing crop of fishes on a transect in the biotope of *Porites lobata* ranged from 134 to 218 g/m^2 with a mean of 160 g/m^2 per transect. Species contributing the most weight to the estimated biomass on these four transects included *Zebrasoma flavescens, Melichthys niger, Ctenochaetus strigosus, Scarus sordidus, Naso lituratus, Ctenochaetus hawaiiensis* and *Cephalopholis argus.*

3. Biotope of Porites compressa

The shelf break along the seaward edge of the biotope of *Porites lobata* that identifies the shoreward boundary of the biotope of *Porites compressa* commences at a depth from 15 to 18 m and ranges from about 60 to 200 m from the shoreline. The biotope of *Porites compressa* is situated on a relatively steep (20 to 35 degree) slope and is comprised of a mix of coral rubble, sand and basalt rocks. Basalt rock outcrops are occasionally encountered along the slope and serve as shelter for many reef species. The finger coral, *Porites compressa*, is the dominant coral species seen in this zone. Four transects (nos. 3, 6, 9 and 12, Figure 1) sampled the communities in this biotope; the results of these surveys are given in Appendices 4, 7, 10 and 13. The 2012 fish census data are given in Appendix 1.

The 2012 quadrat survey of the biotope of *Porites compressa* noted eight coral species (*Porites lobata, Porites compressa, Porites solida, Porites lutea, Pocillopora meandrina, Montipora verrucosa, Montipora patula* and *Pavona varians*). The number of coral species per transect ranged from 5 to 6 (mean = 6 species per transect). Coral coverage varied from 23.1% to 53.6% on the four transects and had a mean estimated coverage of 40.2% which is down 10.6% from the previous survey. Other coral species seen outside of the transect areas included *Porites rus, Pavona duerdeni, Montipora verrilli, Cycloseris vaughani,* and *Pocillopora eydouxi.*

In the 2011 quadrat survey of the biotope of *Porites compressa* seven coral species were noted: *Porites lobata, Porites compressa, Porites evermanni, Pocillopora meandrina, Montipora verrucosa, Montipora patula* and *Pavona varians*. The number of coral species per transect ranged from 4 to 7 (mean = 5 species per transect). Coral coverage varied from 38.8% to 72.6% on the four transects and had a mean estimated coverage of 50.8% which was up 11.4% from the previous survey. Other coral species seen outside of the transect areas included *Porites rus, Pavona duerdeni, Montipora verrilli, Cycloseris vaughani,* and *Pocillopora eydouxi.*

The 2009 quadrat survey of the biotope of *Porites compressa* noted six coral species (*Porites lobata, Porites compressa, Pocillopora meandrina, Montipora verrucosa, Montipora patula* and *Pavona varians*). The number of coral species per transect ranged from 5 to 6 (mean = 6 species per transect). Coral coverage varied from 29.9% to 54.4% on the four transects and had a mean estimated coverage of 39.4% which is down 2.3% from the previous survey. Other coral species seen outside of the transect areas included *Porites rus, Porites evermanni, Pavona duerdeni, Montipora verrilli, Cycloseris vaughani,* and *Pocillopora eydouxi.*

The 2008 quadrat survey of the biotope of *Porites compressa* carried out on 4-5 May 2009 noted six coral species (*Porites lobata, Porites compressa, Pocillopora meandrina, Montipora verrucosa, Montipora patula* and *Pavona varians*). The number of coral species per transect ranged from 5 to 6 (mean = 6 species per transect). Coral coverage varied from 32.9% to 49.9% on the four transects and had a mean estimated coverage of 41.7% which is up 5.6% from the previous year. Other coral species seen outside of the transect areas included *Porites rus, Fungia scutaria, Pavona duerdeni, Montipora verrilli, Cycloseris vaughani,* and *Pocillopora eydouxi.*

The 2007 quadrat survey of the biotope of *Porites compressa* noted eight coral species (*Porites lobata, Porites compressa, Porites evermanni, Pocillopora meandrina, Montipora verrucosa, Montipora patula, Pavona varians* and *Fungia scutaria*). The number of coral species per transect ranged from 5 to 7 (mean = 6 species per transect). Coral coverage varied from 20.9% to 58.2% on the four transects and had a mean estimated coverage of 36.1% which is up 7% from the previous year. Other coral species seen outside of the transect areas included *Porites rus, Pavona duerdeni, Montipora verrilli, Cycloseris vaughani,* and *Pocillopora eydouxi.*

The 2006 quadrat survey noted eight coral species (six of these in common with 2007 but not including *Porites evermanni* and *Fungia scutaria* which were replaced by *Montipora verrilli* and *Leptastrea purpurea*). The mean number of coral species was six per transect and the coverage varied from 16.8 percent to 39.5 percent (mean = 29.1 percent). The 2005 quadrat survey of the biotope of *Porites compressa* noted seven coral species (*Porites compressa, Porties lobata, Porites evermanni, Pocillopora meandrina, Pavona varians, Montipora verrucosa* and *Montipora patula*) with a mean of 6 species per transect. These corals had an overall estimated coverage of 26.3% (range from21.0 to 51.0%).

The 2012 survey of diurnally-exposed macroinvertebrates in the biotope of *Porites compressa* noted fifteen species (range from 8 to 10 species per transect). The species found included the rock oyster (*Spondylus tenebrosus*), boring bivalve (*Arca ventriosa*), the drupe shell (*Drupa morum*), reticulated cowry (*Cypraea reticulata*), tiger cowry (*Cypraea tigris*), pinna shell (*Streptopinna saccata*), black-lipped pearl oyster (*Pinctada margaritifera*), spindle shell (*Latirus nodatus*), christmas tree worm (*Spriobranchus giganteus*), serrate urchin (*Chondrocidaris gigantea*), small urchin (*Eucidaris metularia*), green urchin (*Echinometra mathaei*), black urchin (*Tripneustes gratilla*), wana (*Echinothrix diadema*) and the slate-pencil urchin (*Heterocentrotus mammillatus*). The number of individual invertebrates encountered per transect in 2012 ranged from 99 to 248 individuals (mean = 165 individuals). Other macroinvertebrates seen in the vicinity of the transects in 2012 included the imperial cone (*Conus imperialis*), banded shrimp (*Stenopus hispidus*), long-spined sea urchin (*Diadema setosum*), the polychaete (*Loimia medusa*), starfishes (*Linckia multiflora* and *L. diplax*), and sea cucumbers or loli (*Actinopyge obesa* and *Holothuria atra*).

In 2011, the survey of diurnally-exposed macroinvertebrates in the biotope of *Porites compressa* noted twelve species (range from 7 to 10 species per transect). The species found included the *Spondylus tenebrosus, Arca ventriosa, Spriobranchus giganteus, Sabellastarte sanctijosephi, Pinctada margaritifera, Chondrocidaris gigantea, Echinometra mathaei, Tripneustes gratilla, Echinothrix diadema, Heterocentrotus mammillatus, Culcita novaeguineae, Acanthaster plancii* and *Holothuria atra*. The number of individual invertebrates encountered per transect in 2011 ranged from 139 to 357 individuals (mean = 215 individuals). Other macroinvertebrates seen in the vicinity of the transects in 2011 included the leopard cone shell (*Conus leopardus*), imperial cone (*Conus imperialis*), cone shell (*Conus lividus*), banded shrimp (*Stenopus hispidus*), long-spined sea urchin (*Diadema setosum*), the polychaete (*Loimia medusa*), starfishes (*Linckia multiflora* and *L. diplax*), and sea cucumbers or loli (*Actinopyge obesa* and *Holothuria hilla*).

The 2009 survey of diurnally-exposed macroinvertebrates in the biotope of *Porites compressa* censused eleven species (range from 7 to 9 species per transect). The species found included *Spondylus tenebrosus, Arca ventriosa, Spriobranchus giganteus, Loimia medusa, Chondrocidaris gigantea, Echinometra mathaei, Tripneustes gratilla, Echinothrix diadema, Heterocentrotus mammillatus, Acanthaster plancii* and *Holothuria atra*. The number of individual invertebrates encountered per transect in 2009 ranged from 111 to 256 individuals (mean = 165 individuals).

The 2008 survey of diurnally-exposed macroinvertebrates in the biotope of *Porites compressa* carried out on 4-5 May 2009 censused nine species (range from 6 to 8 species per transect). The species found included *Spondylus tenebrosus, Arca ventriosa,* *Spriobranchus giganteus*, *Chondrocidaris gigantea*, *Echinometra mathaei*, *Tripneustes gratilla*, *Echinothrix diadema*, *Heterocentrotus mammillatus* and *Drupa morum*. The number of individual invertebrates encountered per transect in 2008 ranged from 142 to 293 individuals (mean = 214 individuals). Other macroinvertebrates seen in the vicinity of the transects in 2008 included *Conus leopardus*, *Conus imperialis*, *Stenopus hispidus*, *Saron marmoraeus, Diadema setosum, Culcita novaeguineae, Linckia multiflora* and *L. diplax*, and *Actinopyge obesa, Holothuria atra, Holothuria hilla*.

The 2007 survey of diurnally-exposed macroinvertebrates in the biotope of *Porites compressa* censused eleven species (range from 7 to 10 species per transect). The species found included *Spondylus tenebrosus*, *Arca ventriosa*, *Spriobranchus giganteus*, *Chondrocidaris gigantea*, *Echinometra mathaei*, *Tripneustes gratilla*, *Echinothrix diadema*, *Heterocentrotus mammillatus*, *Echinothrix calamaris*, *Streptopinna saccata* and *Actinopyge mauritana*. The number of individual invertebrates encountered per transect in 2007 ranged from 95 to 238 individuals (mean = 141 individuals). Other macroinvertebrates seen in the vicinity of the transects in 2007 included *Conus leopardus*, *Conus imperialis*, *Stenopus hispidus*, *Saron marmoraeus, Diadema setosum*, *Loimia medusa*, *Culcita novaeguineae*, *Linckia multiflora* and *L. diplax*, and *Actinopyge obesa, Holothuria atra, Holothuria hilla*.

The 2006 survey of macroinvertebrates also noted eleven species among the four transects which included all of the those seen in the 2007 survey except for *Streptopinna saccata* and the loli (*Actinopyge mauritana*) but present in the 2006 transects were *Loimia medusa* and *Culcita novaeguineae*. The 2005 census of macroinvertebrates noted eleven species including *Spondylus tenebrosus*, *Spriobranchus gigantea*, *Cypraea tigris*, *Pinctada margaritifera* and sea urchins (*Tripneustes gratilla, Echinothrix diadema, Echinothrix calamaris, Heterocentrotus mammillatus, Echinometra mathaei* and *Chondrocidaris gigantea*).

The results of the 2012 survey of fishes in the biotope of *Porites compressa* are presented below. Overall, 53 species were censused on the four transects; the number of species seen per transect ranged from 21 to 31 species (mean = 26 species). The number of individual fishes censused ranged from 145 to 497 per transect (mean = 312 fishes) and the standing crop estimates ranged from 179 to 399 g/m^2 having a mean of 252 g/m^2. The most common species encountered on the transects in 201 were the kole (*Ctenochaetus strigosus*), lau'ipala (*Zebrasoma flavescens*), ma'i'i'i (*Acanthurus nigrofuscus*) and the damselfish (*Chromis agilis*). Major contributors to the estimated standing crop included the palukaluka (*Scarus rubroviolaceus*) making up from 7 to 15% of the total and the kole (*Ctenochaetus strigosus*) adding 7 to 13%. Other species contributing to individual transects included the kala holo (*Naso hexacanthus* - 38%), kala lolo (*Naso brevirostris* - 24%) and humuhumu 'ele'ele (*Melichthys niger* - 10%) on Transect 3, mu (*Monotaxis* *grandoculis* - 18%) and the na'ena'e (*Acanthurus olivaceus* - 49%) on Transect 6, the opelu (*Decapterus macarellus* - 33%) and the uhu (*Scarus sordidus* - 15%) on Transect 9 and on Transect 12 the menpachi or u'u (*Myripristes amaenus* - 34%) and the 'ala'ihi (*Sargocentron spiniferum* - 26%).

The 2011 survey of fishes in the biotope of *Porites compressa* are given below. Overall, 46 species were censused on the four transects; the number of species seen per transect ranged from 22 to 25 species (mean = 24 species). The number of individual fishes censused ranged from 143 to 445 per transect (mean = 297 fishes) and the standing crop estimates ranged from 86 to 320 g/m^2 having a mean of 208 g/m^2. The most common species encountered on the transects in 2011 were *Ctenochaetus strigosus*, *Zebrasoma flavescens*, *Scarus sordidus*, *Acanthurus nigrofuscus* and *Chromis hanui*. Major contributors to the estimated standing crop included the *Scarus sordidus* making up from 5 to 38% of the total, *Acanthurus olivaceus* comprising from 14 to 27%, *Ctenochaetus strigosus* adding 7 to 13%, *Zebrasoma flavescens* contributing 6 to 12% and *Naso hexacanthus* contributing from 23 to 51% on these transects. Other species were important on individual transects; these included at station 3, *Naso brevirostris* (11%) and the kahala (*Seriola dumerili*) adding 14% to the total. At station 6 the po'ou (*Cheilinus rhodochrous*) added 8% and at station 9 the the palukaluka (*Scarus rubroviolaceus*) contributed 16% to the total for that station. At station 12 the uhu (*Scarus psittacus*) added 20% to the total, the umaumalei (*Naso lituratus*) made up 7% as did the menpachi (*Myripristes amaenus*).

The results of the 2009 survey of fishes in the biotope of *Porites compressa* are given below. Overall, 57 species were censused on the four transects; the number of species seen per transect ranged from 26 to 32 species (mean = 29 species). The number of individual fishes censused ranged from 232 to 510 per transect (mean = 338 fishes) and the standing crop estimates ranged from 182 to 660 g/m^2 having a mean of 411 g/m^2. The most common species encountered on the transects in 2009 were *Chromis agilis* and *C. vanderbilti*, *Abudefduf abdominalis*, *Acanthurus olivaceus*, *Ctenochaetus strigosus*, *Zebrasoma flavescens*, *Naso hexacanthus*, *Myripristes amaenus*, *Scarus psittacus*, *Acanthurus nigrofuscus*, *Naso brevirostris* and *Melichthys niger*. Major contributors to the estimated standing crop included the *Scarus sordidus* making up from 10 to 32% of the total, *Acanthurus olivaceus* comprising from 5 to 28%, *Ctenochaetus strigosus* adding 6 to 14% and *Monotaxis grandoculis* contributing from 19 to 30% on these transects. Other species were important on individual transects; these included at station 3 *Naso hexacanthus* (34%) and *Melichthys niger* adding 12% to the total. At station 6 *Scarus psittacus* added 14% and *Scarus rubroviolaceus* contributed 11% to the total and at station 9 *Cephalopholis argus* added 29% to the total for that station.

The results of the 2008 survey of fishes in the biotope of *Porites compressa* is given below. Overall, 55 species were censused on the four transects; the number of species seen per transect ranged from 24 to 35 species (mean = 29 species). The number of individual fishes censused ranged from 127 to 546 per transect (mean = 311 fishes) and the standing crop estimates ranged from 78 to 996 g/m^2 having a mean of 440 g/m^2. The most common species encountered on the transects in 2008 were *Chromis agilis*, *Acanthurus nigrofuscus*, *Ctenochaetus strigosus*, *Zebrasoma flavescens*, *Naso hexacanthus* and *Naso brevirostris*. Major contributors to the estimated standing crop included *Scarus sordidus* making up from 19 to 24% of the total, *Naso hexacanthus* comprising from 33 to 80% and *Cephalopholis argus* making up 3 to 22% on some of the transects. Other species contributed heavily to the estimated standing crops on individual transects; among these were at station 3, *Acanthurus olivaceus* added 13%, *Naso brevirostris* contributed 18%, at station 6 *Mulloides flavolineatus* added 10% and *Scarus rubroviolaceus* contributed 18% and finally at station 9 *Aprion virescens* contributed 14% to the station crop at that station.

The results of the 2007 survey of fishes in the biotope of *Porites compressa* found the following: overall, 63 species were censused on the four transects; the number of species seen per transect ranged from 24 to 41 species (mean = 33 species). The number of individual fishes censused ranged from 172 to 441 per transect (mean = 313 fishes) and the standing crop estimates ranged from 112 to 1,114 g/m^2 having a mean of 496 g/m^2. The most common species encountered on the transects in 2007 were *Chromis agilis* and *C. vanderbilti*, *Abudefduf abdominalis*, *Acanthurus olivaceus*, *Ctenochaetus strigosus*, *Zebrasoma flavescens*, *Naso hexacanthus*, *Myripristes amaenus*, *Scarus sordidus*, *Scarus rubroviolaceus*, *Naso hexacanthus* and *Melichthys niger*. Major contributors to the estimated standing crop included *Scarus sordidus* making up from 15 to 61% of the total, *Naso hexacanthus* comprising from 15 to 28% and on individual transects other species were important. These included at station 3 *Acanthurus olivaceus* (32%), *Scarus rubroviolaceus* (30%) and the milkfish or awa (*Chanos chanos*) adding 11% to the total. At station 9 *Zebrasoma flavescens* contributed 12% to the total and at station 12, *Myripristes amaenus* added 9% to the total at that stations.

The 2006 census of fishes at the four stations sampling the biotope of *Porites compressa* noted 60 species. The number of fish species per transect ranged from 26 to 40 species (mean = 33 species). Abundance of fishes varied from 136 to 640 individuals on a transect (mean = 417 individuals per transect). The most common fishes were *Chromis agilis*, *Acanthurus nigrofuscus*, *Acanthurus olivaceus*, *Ctenochaetus strigosus*, *Zebrasoma flavescens*, *Naso hexacanthus*, *Myripristes amaenus*, *Scarus sordidus*, and *Melichthys niger*. The standing crop of fishes was estimated to range from 61 to 984 g/m^2 (mean = 543 g/m^2). Species contributing most heavily to this standing crop in the biotope of *Porites compressa* included *Acanthurus olivaceus*, *Naso hexacanthus*, *Acanthurus leucoparieus*, *Cephalopholis argus*, *Myripristes amaenus*, *Scarus sordidus* and *S.*

psittacus, *Scarus rubroviolaceus*, *Zebrasoma flavescens* and *Ctenochaetus strigosus*.

The 2005 survey of fishes in the biotope of *Porites compressa* noted 50 species of fishes in the four transects (mean per transect 29 species, range = 24 to 32 species). The abundance estimates of fishes ranged from 150 to 368 individuals per transect with a mean abundance of 243 fishes seen per transect. The most abundant fishes were *Chromis agilis*, *Acanthurus nigrofuscus*, *Ctenochaetus strigosus*, *Zebrasoma flavescens*, *Naso lituratus*, *Acanthurus olivaceus*, *Naso hexacanthus* and *Acanthurus leucoparieus*. In the biotope of *Porites compressa* the estimated standing crop of fishes ranged from 51 to 257 g/m^2 on a transect (mean = 164 g/m^2). The largest contributors to this standing crop include *Ctenochaetus strigosus*, *Acanthurus nigrofuscus*, *Naso lituratus*, *Acanthurus leucoparieus*, *Myripristes amaenus*, *Naso hexacanthus*, *Naso brevirostris*, *Alutera scripta*, *Monotaxis grandoculis*, and *Aprion virescens*.

The relatively steep slope of the biotope of *Porites compressa* dropping from 12 to about 30 m along with occasional rock outcrops affording considerable shelter along this slope provides a habitat used by many fish species. Many solitary predator species will swim along the alignment created by the slope in search of prey; the drop-off provides foraging habitat for many planktivorous species that feed in the water column and the shelter created by the occasional rock outcrops affords shelter for many other species of fishes. Because of these attributes, many fish species not seen in the relatively small-scale transects will be encountered in this biotope when examining greater areas and many were (see discussion below).

Threatened and Endangered Species

Two turtle species and several cetaceans have been declared threatened or endangered in Hawaiian waters by Federal jurisdiction. Because of declining population sizes, the green sea turtle (*Chelonia mydas*) was granted protection under the federally mandated Endangered Species Act in 1977-78. Green turtles as adults are known to forage and rest in shallow waters around the main Hawaiian Islands. Reproduction in the Hawaiian population occurs primarily during the summer months in the Northwest Hawaiian Islands with adults migrating during the summer to these isolated atolls and returning in late summer or early fall. In the main Hawaiian Islands, green turtles will rest along ledges, caves or around large coral mounds in coastal waters usually from 40 to 60 feet in depth during the day. Under the cover of darkness turtles will travel inshore to shallow subtidal and intertidal habitats to forage on algae or limu (Balazs *et al.* 1987). The normal range of these daily movements between resting and foraging areas is about one kilometer (Balazs 1980, Balazs *et al.* 1987). Selectivity of algal species consumed by Hawaiian green turtles appears to vary with the locality of sampling but stomach content data show *Acanthothora spicifera* and *Amansia glomerata* to be quantitatively the most important (Balazs *et al.*

1987); the preferences may be due to the ubiquitous distribution of these algal species.

In the present study and more than 30 years of underwater observations along the West Hawai'i coast have found little macroalgae present (personal observations). This lack of limu is probably related to the relatively high densities of grazing fishes and sea urchins that are found everywhere along this coast thus forage for green turtles is not as abundant as seen elsewhere in the Hawaiian Islands. In West Hawai'i macrothalloid algae or limu are more prevalent in the intertidal (i.e., the wave wash) where many grazing species cannot easily forage. Species commonly seen include aki'aki (*Ahnfeltia concinna*) and occasionally limu palahalaha (*Ulva fasciata*).

No green sea turtles were encountered in the waters fronting the Ka Lae Mano project site in the 2005 survey nor did Marine Research Consultants (1993a, 2002a) note any in the area during their survey work. In the 2006 survey two green sea turtles were seen on the transect lines. The first was encountered on Transect 10 at 0940 hours on 5 October 2006 at a depth of 8 m. This turtle had no tags or tumors present and had an estimated straight line carapace length of 50 cm. The second individual was seen on 6 October 2006 at 0800 hours at a depth of 6 m about 30 m offshore. Again, there were no obvious tags or tumors present and the estimated straight-line carapace length was 60 cm. In 2007, one juvenile green turtle (~45 cm straight-line carapace length) was encountered swimming north close to the shoreline at transect 4 at 1620 hours on 9 October 2007. This turtle did not appear to have any tags or tumors visible. In the 2008 survey (carried out on 4 May 2009) a small green turtle (~25 cm straight-line carapace length) was seen swimming through the shallow transect at Station B and was moving south at 1505 hours. Earlier in the day at Station D at the shallow station at 0905 hours, a ~25-30 cm straight-line carapace length green turtle was seen swimming north along the coastline. No green turtles were sighted in the 15-16 September 2009 survey or in the 7-8 December 2011 survey. During the 2012 survey one small green turtle (~40 cm straight-line carapace length) was seen at Station 1 at 1605 hours on 14 November. This juvenile turtle was resting on the bottom in the area of the transect and did not appear to have any tags or tumors. It should be noted that juvenile green turtles are commonly seen both to the north (at Kiholo and Anaehoomalu) and to the south (at Kukio) thus encountering green turtles offshore of Ka Lae Mano would not be unexpected. As noted in the quantitative surveys conducted at the permanently marked stations, little appropriate algal forage for green turtles has been encountered thus their foraging in the Ka Lae Mano area is probably focused on the intertidal areas where some macroalgal (limu) species are present.

The second federally protected sea turtle is the hawksbill (*Eretmochelys imbricata*). Hawksbill turtles are quite rare in the Hawaiian Islands and encountering a hawksbill in the field is unusual. Not much is know about these turtles in Hawaiian waters other than they will nest at isolated beaches (such as Kamehame Puu in Ka'u District) and the adults are omnivorous but favoring sessile sponges and tunicates. No hawksbill turtles have been seen in these surveys.

The spinner porpoise (*Stenella longirostris*) is another federally protected species that is found in near shore Hawaiian waters. Spinner porpoises feed primarily on fishes often in offshore waters under the cover of darkness and rest in inshore areas by day. Marine Research Consultants (1993a, 2002a) did not note any spinner porpoises in the Ka Lae Mano area but during the 13-14 April 2005 field work three pods of spinner porpoises were seen offshore (~ 0.25 mile) of Ka Lae Mano on both days. These pods ranged in size from about 15-20 animals to about 40 individuals in a pod and appeared to be passing through the area in a northwest direction. On 5 October 2006, a pod of approximately ten porpoises were seen passing through adjacent to Transect 10 at the north end of the project site at about 0945 hours. This pod was swimming to the northwest when observed. Finally a small pod (~10 individuals) were seen on 10 October at 0700 hours swimming north outside of Makalawena.

In the 2008 survey (on 4 May 2009), at 0750 hours at Transect 12 approximately 25 spinner porpoises were seen just seaward of the transect and appeared to be moving in a northerly direction. On the next morning (5 May) at 0725 hours about 40 spinner porpoises in a pod approached the vessel while at anchor on Transect 3 (deep station). Because porpoises feed on fishes, the author waited for the majority of the porpoises to leave the area prior to conducting the fish census so that it would more accurately reflect the species present and their abundances. After about ten minutes about half of the pod left and the author entered the water to carry out the census work. Despite the presence of some porpoises directly above and around the vessel (all staying in proximity to the surface), the author commenced the fish census. About five minutes into the census, many of the fishes up in the water column rapidly descended to the coral reef below or rushed in to and hovered about the author. At the same time, all of the remaining porpoises immediately departed moving to the southeast (towards shore), the direction taken by the previously departing porpoises. In less than a minute, a large tiger shark (estimated total length in excess of 12 feet) came over the mound of coral where the transect is carried out and swam directly over the author who, at the sight of the shark, just laid down on the coral substratum. As the shark passed within ~ five feet of the author, it just looked and continued on in the direction taken by the departing porpoises. It is suspected that the shark was intent on following the porpoises which must serve as a source of food. Once the shark departed, the transect work recommenced and the census work was completed. (Note that this shark was not counted in the fish census). About two weeks later Wil Sulliban (Kukio Pond Manager) said that the beach boys at Kona Village just south of the Ka Lae Mano study area reported the presence of a large tiger shark which remained in the vicinity for a week or so.

In the 15 September 2009 survey approximately 25 porpoises were sighted just seaward of Transect 9 at 0945 hours swimming towards the north along the coastline. On the following day (16 September) at 0830 hours about 30 porpoises were again encountered seaward of Transect 3 and this pod appeared to be moving in a southerly direction along the coast. No green turtles were encountered in the September 2009 survey and no porpoises were seen in the 7-8 December 2011 or 14-15 November 2012 surveys. It is suspected that the porpoises seen in the 2005 -2009 surveys may be part of the well-known pod that has been seen by the author anywhere from Honokohau Harbor on the south to at least Ka Lae Mano on the north over the last twenty years.

The endangered humpback whale (*Megaptera novaeangliae*) is known to frequent island waters in their annual migrations to Hawaiian wintering grounds. They normally arrive in island waters about December and depart in April. In general their distribution in Hawaii appears to be limited to the 180 m (100 fathom) isobath and in shallower waters (Nitta and Naughton 1989). During the 13-14 April 2005 survey whales could be heard while working underwater thus were probably well-seaward of the project site and had not yet departed on their seasonal migration north and not unexpectedly, since the 2006 and 2007 surveys were carried out in October, the 2008 survey in May and the 2009 survey in September no whales were seen or heard. Similarly in the 7-8 December 2011 and 14-15 November 2012 surveys whales were neither seen nor heard underwater.

Statistical Analysis

Biological data have been collected at approximately the same locations fronting the Ka Lae Mano project site on nine occasions; in September 1993 and May-June 2002 (Marine Research Consultants, 1993a, 2002a) and under the present program in April 2005, October 2006, October 2007 May 2009 (for 2008 and noted as 2008 hereafter), in September 2009, December 2011 and in November 2012. Methods used in these surveys are reasonably comparable so that data are similar. The 1993 and 2002 surveys focused most effort on the stony corals and less effort was expended on other components such as the fish censuses. Thus the 1993 and 2002 fish data do not include standing crop estimates and the counts of diurnally-exposed macroinvertebtrates did not include species other than sea urchins. Other than these two items, the data are comparable between the surveys.

Table 2 presents summaries of the biological data from Ka Lae Mano from the 1993 and 2002 surveys (Marine Research Consultants 1993a, 2002a) as well as from the 2005, 2006, 2007, the two 2009 surveys , 2011 as well as the most recent survey completed in 2012. Questions that may be asked are: (1) Have the marine communities as reflected in the biological measures used here changed among the nine surveys spanning a eighteen-year period, and (2) if these changes have occurred among the various parameters, have they done so differentially among the three ecological zones or biotopes over the nine surveys spanning a eighteen-year period? To answer these questions two non-parametric statistical tests were used to make comparisons (SAS Institute Inc. 1985). Non-parametric statistics are used to avoid some of the assumptions that must be made when using parametric approaches (i.e., normality of data, homogeneity of variance in the data, etc.). The first test utilized was the Kruskal-Wallis analysis of variance (or ANOVA) and the Student-Newman-Keuls Test was also used. The Kruskal-Wallis ANOVA is used to discern statistically significant differences among ranked parameter means. The Kruskal-Wallis ANOVA can indicate that statistical differences among the means exist but it cannot discriminate as to which means are significantly different from the others. The Student-Newman-Keuls (SNK) Test is used to statistically separate those means that differ significantly from one another and group those means that are not significantly different from one another.

Using the data summarized in Table 2, we may address the question, "has there been any significant change in the annual means of biological parameters in the surveys carried out in 1993, 2002, 2005, 2006, 2007, 2008, 2009, 2011 as well as in 2012?" To address this question, the grand annual means of parameters measured in the nine surveys are compared and the statistical results are presented in Table 3. Referring to Table 3, the mean number of coral species per transect as well as the mean annual standing crop per transect has shown no significant change through this period utilizing the Kruskal-Wallis ANOVA but this test found that all of the other parameters (i.e., coral coverage, number of invertebrate species, number of invertebrate individuals, number of fish species and the number of fish individuals) all have significant differences among their annual means per transect. Furthermore, the SNK Test found no separation among the nine annual means for the number of coral species or the mean fish standing crop (Table 2). With respect to the other five parameters where the ANOVA did find significant differences among the years, the SNK did find some clearly significant differences. The 2002 annual mean coral coverage per transect was significantly greater than all other years which were related due to overlap in the SNK results (Table 2, Part 2). It should be noted that the mean coral coverage estimates in the more recent 2005-2012 surveys (26.0 to 42.5%) are right in the middle of average coral coverage for many other locations on the West Hawai'i coast. These changes are probably related to differences in methods used to estimate coverage (use of photographs in the 1993 and 2002 surveys and use of quadrats to estimate coverage while in the field in 2005-2012). Coral communities at Ka Lae Mano are well-developed and show no evidence of stress or decline. Furthermore, the mean coral coverage estimates in recent years (since 2006), have shown a reasonably steady increase (from 26.0 to 42.5%; see Table 3).

Referring to Table 3, the annual mean number of invertebrate species per transect was significantly less in the 2005 survey relative to the remaining eight annual means all of which were related (Table 2, Part 3). Despite statistical significance, these changes among years are small with 2005 having 5.9 species per transect (lowest) and 2007 having 8.8 species per transect (highest). The ANOVA did find a significant differences in the mean number of invertebrate individuals counted on a transect ($P<0.008$) as well as annual mean number of fish species ($P<0.001$) and the annual mean number of individual fish per transect ($P<0.0001$), however the SNK Test failed to clearly discern statistical separation among the annual means for any of these three parameters due to overlap (Table 2, Parts 4, 5 and 6) as discussed below.

The early (1993 and 2002) surveys did not attempt to enumerate all diurnally-exposed macroinvertebrates on a transect thus the statistical comparison of this parameter is only made for data from the 2005-2009 period. In this analysis the Kruskal-Wallis ANOVA found significant differences among the years for the mean number of invertebrates censused per transect. However the SNK failed to find clear separation among these annual means due to strong overlap thus there are probably no significant differences among these means.

The Kruskal-Wallis ANOVA found significant differences in the mean number of fish species seen per transect but the SNK Test failed to a clear significant differences among the different years again due to overlap (Table 3) suggesting that if significant differences truly exist, they are probably only with the extreme values (here 2007 being significantly greater than 1993). Similarly the ANOVA noted that significant differences exist among the years for the mean number of individual fish censused on a transect but again, the SNK Test found considerable overlap among these means suggesting that the statistical separation among these years is not strong and if differences actually exist, they would be found with the extremes (where the 2009 mean is significantly greater than the 2002 mean).

Fish standing crop estimates were not done in the earlier (1993 and 2002) surveys but have been carried out under the present program (2005-2012). As noted above and examining the annual mean standing crop of fish per transect, found no statistically significant differences among these years. The variability in the abundance and biomass of fishes over these recent (2005-2012) surveys are discussed below.

Reasons for these changes are related to the highly variable distributions of organisms in space and time. A single survey provides a “snapshot” of marine community structure at the time the sampling was done. Also, because coral reef communities are extremely diverse and highly variable through both time and space results in high variability in the data collected. No survey ever exactly samples exactly the same substratum and motile species such as fishes move in response to environmental factors such as food, local currents, tides, spawning, etc., which increases variability in the resulting data. Given this high variability, many of the statistically significant differences among the means from the different survey dates is not unexpected.

The next question, "Are there significant differences among means of the parameters measured in each of three biological zones over the nine survey dates"? may be addressed again using the Kruskal-Wallis ANOVA and the SNK Test. The results of this analysis are given in Table 4. Referring to Table 4 by biotope, we find:

1. Biotope of boulders - in the biotope of boulders only the parameter to show any clear significant differences among the annual means was the percent coverage by corals. Both the Kruskal-Wallis ANOVA as well as the SNK Test noted this statistically significant difference where the mean coverage in 2002 was significantly greater than it was for the other eight other survey dates (1993, 2005-2012 all of which were related). There were no statistically significant differences with the mean number of coral species, the number of invertebrate species, the number of invertebrate individuals, the number of fish species, the number of individual fish censused or the estimated standing crop of fishes in the biotope of boulders.

2. Biotope of *Porites lobata* - In the biotope of *Porites lobata* the Kruskal-Wallis ANOVA noted statistically significant differences among the annual means for four of the seven parameters measured. In one of these (the annual mean percent cover by corals), the significant differences were clearly supported by the SNK Test while among the other three parameters (the annual mean number of invertebrate species, the annual mean number of invertebrate individuals and the annual mean number of individual fishes censused) the SNK Test failed to note clear statistical separation due to overlap suggesting that if any significant differences exist, they may only occur with the extremes (Table 4). Finally there were no statistically significant differences among the annual means for the number of coral species, the number of fish species or the estimated biomass of fishes in the biotope of *Porites lobata*. Thus in summary only the mean coverage by corals was significantly greater in 2002 over all other years which are related due to strong overlap with the SNK Test (Table 4).

3. Biotope of *Porites compressa* - In the biotope of *Porites compressa* the Kruskal-Wallis ANOVA noted significant differences among the annual means for four parameters: the percent cover by corals, the number of invertebrate species, the number of fish species and the number of individual fish censused. The SNK Test found clear statistical separation among these four annual parameter means for only one of these as follows: the annual mean percent coral cover was significantly greater in 2002 and 1993 over all other survey dates (2005-2012). The SNK test failed to find clear statistical separation with the annual mean number of invertebrate species, the annual mean number

of fish species per transect as well as the mean number of individual fish due to overlap among the annual means. The Kruskal-Wallis ANOVA did not find any significant differences among the annual means for the number of coral species yet the SNK test found the 1993 mean to be significantly less than all other years which were related. Since the ANOVA is a more powerful statistical test, the separation noted by the SNK test is probably not correct. Neither the ANOVA nor the SNK Test noted any significant differences among the annual means for the number of invertebrate individuals or the estimated biomass of fishes on a transect over the nine surveys in the biotope of *Porites compressa* (Table 4).

Despite the apparent haphazard appearance of these statistically significance changes in the different biotopes and among the nine survey years, the important fact to note is that the biological data are demonstrating relatively high variability in the different zones and survey dates and as noted above, such variability is not unusual.

The fish census carried out on each transect in the 2005-2012 surveys included estimates of the length of each fish seen. These length data were later used in estimating the standing crop of fishes present at a station using linear regression techniques (Ricker 1975). Table 5 presents the percent contribution of each family of fishes to the total standing crop or biomass encountered on each transect for these seven years. Examination of this table reveals that two fish families contribute most heavily to the estimated standing crop at these sampled stations in the seven surveys; these are the surgeonfishes or Acanthuridae and the parrotfishes or Scaridae. In 2005 these two families comprised 66.2 percent of the total overall biomass, in 2006 they made up 63.6 percent, in 2007 they comprised 76.3%, in 2008 they made up 66.5 percent, in 2009 they comprised 68.6 percent, in the 2011 survey they made up 78.3 percent and in the 2012 survey these two familes comprised 67.3% of the total estimated standing crop across all of the twelve transect sites. The surgeonfish and parrotfish are primarily herbivorous.

Standing crop estimates are sometimes strongly influenced by the presence of single large predatory fish with no particular ties to any reef area or to often mixed schools of either wandering or resident fishes. Where a chance encounter occurs these large predators or mixed schools can comprise the majority of the estimated standing crop. In the 2006 survey a small school (9 individuals) of milkfish or awa (*Chanos chanos*) made up 96 percent of the total estimated standing crop at Transect 1, a resident school of sleek unicornfish or kala holo (172 individuals) was encountered at Transect 3 and these fish contributed 32 percent to the total at that location and at Transect 12, a school of migratory barracuda or kawalea (*Sphyraena helleri*; 39 individuals) entered the census area and comprised 34 percent of the standing crop at that station. In 2007 the uhu (*Scarus sordidus*) a resident schooling species contributed substantially to the estimated standing crop at many stations; Station 6 - 61% of the total, Station 8 - 22%, Station 9 -

34%, Station 10 - 25%, Stations 11 and 12 - 15%. Similarly, kala holo (*Naso hexacanthus*) which is also a resident schooling species added to the standing crop estimates at three stations; Station 9 - 15%, Station 11 - 17% and Station 12 - 28%. In the 2008 survey (carried out in May 2009), all of the major contributors to the estimated standing crop of fishes on all transects were resident species. The palukaluka (*Scarus rubroviolaceus*) comprised 31% of the standing crop at Station 2, the kala holo (*Naso hexacanthus*) made up 33% at Station 3 and 80% at Station 12, the black kole (*Ctenochaetus hawaiiensis*) contributed 25% of the biomass at Station 4, the uhu (*Scarus sordidus*) made up 39% at Station 5 and at Station 6, 24%, while the umaumalei (*Naso lituratus*) added 38% at Station 7 and at Station 10, 20%. The kole (*Ctenochaetus strigosus*) made up 20% at Station 8 while at Station 9 the roi (*Cephalopholis argus*) added 22% and at Station 11 this species contributed 15% to the standing crop present. In the 2009 survey most of the species making significant contributions to the estimated standing crop of fishes present were resident species; among these were the maiko'iko (*Acanthurus leucoparieus*) adding 34% at Station 2, the kala holo (*Naso hexacanthus*) - 34% and the na'ena'e (*Acanthurus olivaceus*) - 28% at Station 3 while at Station 4 the na'ena'e made up 29%. The uhu (*Scarus sordidus*) added 24% at Station 5 and 32% at Station 9, the umaumalei (*Naso lituratus*) added 25% at Station 5 and at Station 10 it contributed 27%. The palukaluka (*Scarus rubroviolaceus*) comprised 39% of the biomass at Station 7 while at Station 8 it made up 27%. The emperor or mu (*Monotaxis grandoculis*) moves and forages over a larger territory. This species comprised 30% of the biomass at Station 6 while at Station 12 it made up 19% of the standing crop present.

The 2011 survey found that resident herbivorous species made up the largest part of the estimated standing crop at most stations. The uhu (*Scarus sordidus*) comprised 12% at Station 3, 42% at Station 5, 38% at Station 6, 17% at Station 8, 14% at Station 10 and 13% Station 11. Similarly, the uhu (*Scarus psittacus*) comprised 17% at Station 7, 20% at Stations 10 and 12 and the palukaluka (*Scarus rubroviolaceus*) contributed 13% at Station 8 and 16% at Station 9 while the maiko'iko (*Acanthurus leucoparieus*) added 33% at Station 2, 11% at Station 4 and the na'ena'e (*Acanthurus olivaceus*) comprised 27% at Station 3, 26% at Station 4, 8% at Station 5, 14% at Station 6 and 11% at Station 11. The umaumalei (*Naso lituratus*) made up 34% of the standing crop at Station2 and 18% at Station 7 while the lau'ipala (*Zebrasoma flavescens*) added 12% at Station 3, 24% at Station 8 and 18% at Station 11. Resident schooling planktivorous surgeonfishes often added substantially to the estimated standing crops at station in 2011; the kala lolo (*Naso brevirostris*) made up 11% of the biomass at Station 3 and the kala holo (*Naso hexacanthus*) comprised 51% of the standing crop at Station 9 and 23% at Station 12. Finally a single wandering predaceous species, the kahala (*Seriola dumerili*) comprised 14% of the standing crop at Station 3 in the 2011 survey.

Not unexpectedly, the 2012 survey had similar findings where herbivorous species comprised a large part of the resident fish standing crop at most stations. The orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*) made up 49% of the biomass at Stations 1 and 6, 14% at Station 7, the bulletnose parrotfish or uhu (*Scarus sordidus*) comprised 16% at Station 5, 19% at Station 7, 12% at Station 8, 15% at Station 9 and 25% at Station 11. The red-lip parrotfish or palukaluka (*Scarus rubroviolaceus*) made up 15% at Station 6 and 14% at Station 10 while the palenose parrotfish or uhu (*Scarus psittacus*) comprised 23% at Station 7 and 20% at Station 10. Finally, the goldring surgeonfish or kole contributed 10% at Stations 8 and 12, 11% at Station 9 and 23% at Station 11. The yellow tang or lau'ipala (*Zebrasoma flavescens*) added 12% to the Station 4 total and 15% to Station 11. The planktivorous surgeonfishes were also important contributors to the 2012 standing crop estimates; the sleek unicornfish or kala holo (*Naso hexacanthus*) made up 38% of the biomass at Station 3 while the related paletail unicornfish or kala lolo (*Naso brevirostris*) added 23% at Station 3 and 32% at Station 1. Resident predaceous species added to the 2012 standing crop; the menpachi or u'u (*Myripristes amaenus*) added 34% to the total at Station 12 while the squirrelfish or 'ala'ihi (*Sargocentron spifierum*) contributed 26% to the total. The schooling mackerel scad or opelu (*Decapterus macarellus*) contributed 33% to the biomass at Station 9 while the blue spotted grouper or roi (*Cephalopholis argus*) added 32% at Station 2 and 12% at Station 5 while the emperor or mu *Monotaxis grandoculis*) made up 18% at Station 6.

DISCUSSION

1. Fish Communities

The nine surveys completed to date provide quantitative data on the structure (i.e., species present, their abundance and distribution) of the marine communities present in the near shore waters fronting the Ka Lae Mano project site. Coral communities are well-developed and are typical of those seen elsewhere along the West Hawai'i coastline and similarly, the fish communities parallel those seen along other parts of the Kona coast. This community structure has been reiterated by others (Hobson 1974, Walsh 1983, etc.) as well as by the present author at many Kona localities (Kukio, Waikoloa, Kohanaiki, Keahole Point, Hokuli'a, etc.). None of the species encountered in the nine Ka Lae Mano surveys are unusual (except the encounter with the large shark in the 2008 survey) and the abundances recorded are similar to those seen elsewhere.

The nine surveys noted similar numbers of fish species on the transects; in 1993, 57 fish species were counted (Marine Research Consultants 1993a), in 2002, 53 species were seen (Marine Research Consultants 2002a), in 2005, 67 species were enumerated, in 2006, 76 species were seen, in 2007, 81 species, in 2008, 71 species were recorded, in 2009, 71 species and in both 2011and 2012, 73 species were encountered in the twelve transects

(Appendix 1). The surgeonfishes were the most important in terms of abundance in all nine surveys.

Studies conducted on coral reefs in Hawaii and elsewhere have estimated fish standing crops to range from 20 to 200 g per square meter (Brock 1954, Brock *et al.* 1979). Eliminating the direct impact of man due to fishing pressure and/or pollution, the variation in standing crop appears to be related to the variation in the local topographical complexity of the substratum. Thus habitats with high structural complexity affording considerable shelter space usually harbor a greater estimated standing crop of coral reef fish; conversely, transects conducted in structurally simple habitats (e.g., sand flats) usually result in a lower estimated standing crop of fish (0.2 to 20 g/m^2). Goldman and Talbot (1975) noted that the upper limit to fish biomass on coral reefs is about 200 g/m^2. Ongoing studies (Brock and Norris 1989) suggest that with the manipulation (increasing) of habitat space or food resources (Brock 1987), local fish standing crops may approach 2000 g/m^2. Thus under certain circumstances, coral reefs may be able to support much larger standing crops of fishes than previously realized.

The estimated standing crops encountered in the 2005 survey range from 5 to 257 g/m^2 and the grand mean biomass estimate was 150 g/m^2 which is reasonably high. Overall, 52 percent of the standing crop of fishes at a station was comprised of surgeonfishes; this is related to (1) their abundance and (2) the relatively larger sizes of individuals encountered on the transects. In 2006, the biomass estimates range from 61 to 984 g/m^2 (mean = 326 g/m^2) and again surgeonfishes were the largest proportion of the estimated standing crop. Among the 12 transects sampled in 2007, the estimated fish standing crop ranged from 18 to 1,114 g/m^2 (mean = 329 g/m^2) and surgeonfishes again comprised an average of 52% of that estimated biomass. In the 2008 survey the biomass ranged from 4 to 996 g/m^2 (mean = 245 g/m^2) and the surgeonfishes overall comprised 48% of this standing crop. In the 2009 survey among the twelve transects, the estimated standing crop ranged from 2 to 670 g/m^2 and the mean was 310 g/m^2. In 2009 the surgeonfishes made up 41% of this estimated biomass. The estimated standing crop of fishes in the 2011 survey ranged from 9 to 578 g/m^2 and the overall mean was 191 g/m^2. Surgeonfishes comprised 57% of this biomass. In the 2012 survey the estimated standing crop among the twelve stations ranged from 93 to 594 g/m^2 and the overall mean standing crop was 253 g/m^2. Again, the surgeonfishes comprised 47% of the overall standing crop, thus this family continues to be the single largest contributor to the standing crop at all stations through most of the seven most recent surveys (2005-2012).

The grand annual mean biomass estimates for the 2005-2012 surveys has shown considerable variation (range from 150 g/m^2 in 2005 to 329 g/m^2 in 2007; see Table 3). As noted above in Table 3, the Kruskal-Wallis ANOVA indicated that there were no significant differences in the mean standing crop over these seven annual surveys. Despite this, the question, "Why the differences in biomass among the seven years measured at the same locations?" This question is addressed below.

As noted in the 2005 annual report, the fish communities fronting the Ka Lae Mano project site had shown considerable change since the author first looked at them in 1972. As part of the first survey of anchialine resources along the West Hawai'i coast (Maciolek and Brock 1974), field notes were taken on the status of marine resources in some areas. This was done because at the time, access to much of the North Kona and South Kohala coastline was restricted due to the lands being in private ownership and public roads were many miles inland. The Queen Ka'ahamanu Highway which now traverses much of North Kona/South Kohala and lies within a mile or so of the shoreline, was not completed until the late 1970's. Thus, much of the coast was inaccessible to the majority of the fishing public that did not have a vessel to access the coastline. The abbreviated field notes served as the basis for a short publication on the marine fauna of the coastal waters (Brock and Brock 1974). In this publication the fish communities of Ka Lae Mano were found to be the most diverse and least disturbed of all sites studied in the survey (Brock and Brock 1974). Unfortunately the Brock and Brock (1974) report was based on qualitative field observations (due to a lack of sufficient field time) so quantitative comparisons are not available. However, the junior author remembers the Ka Lae Mano site as the best example of Hawaiian fish communities he had ever seen in the high Hawaiian Islands which at that time represented more than 20 years of diving in Hawai'i. The data from the 2005 quantitative survey revealed a fish community lacking many of the highly sought-after species or very reduced sizes in the individuals seen. Species present in the 1972 survey included moi *Polydactylus sexifilis*), mu (*Monotaxis grandoculis*), papio (members of the family Carangidae), menpachi (*Myripristes amaenus*), weke'ula (*Mulloides vanicolensis*), weke (*Mulloides flavolineatus*), aweoweo (*Priacanthus cruentatus*), moano kea (*Parupeneus cyclostomus*), munu (*Parupeneus bifasciatus*), kumu (*Parupeneus porphyreus*), uku (*Aprion virescens*), awa (*Chanos chanos*), ama'ama (*Mugil cephalus*), aholehole (*Kuhlia sandvicensis*), opelu (*Decapterus macarellus*), nenue (*Kyphosus bibbigus*), parrotfishes (family Scaridae), many of the surgeonfishes (family Acanthuridae) as well as a host of others. Some of these species were present in the 2005 survey but primarily were outside of the transect areas and at reduced numbers and/or sizes. The large reduction in abundance and sizes of parrotfishes or uhu (family Scaridae) was particularly evident in the 2005 survey.

Unfortunately neither the 1993 nor the 2002 fish community data (Marine Research Consultants 1993a, 2002a) had any information on sizes or biomass of the censused fish. However, the species lists from each of these surveys reveals that the highly sought-after fish species were not common or sometimes not present. These baseline (1993, 2002 and 2005) data suggest that the declines in the fish communities relative to the 1972 qualitative survey largely occurred before 1993. Of special note is the fact that in the 1972 survey (Brock and Brock 1974), the junior author has a strong memory of so many large opihi (ʻalinalina - *Cellana sandwicensis* and maka ia uli - *Cellana exarata*) that one could not cross the pahoehoe bench to reach the ocean without stepping on many of these limpets. Today, opihi are still present on the bench but at greatly reduced abundances and smaller sizes (personal observations).

What are the mechanisms responsible for these apparent declines? Are they due to heavy fishing pressure or are they part of long-term natural fluctuations in abundance of marine organisms? Added to this is the fact that the area has remained undeveloped until just recently so there are no local sources of pollution that could impact these marine species. The fact that many of the targeted marine species are still present but at much smaller sizes and reduced numbers suggests that fishing pressure may be the agent responsible for these changes.

The more recent 2006-2012 surveys found a greater number of fish species with individuals of greater sizes resulting in greater biomass estimates than seen in 2005. However, the diversity, abundance or biomass of fishes present in 2006-2012 surveys did not approach what was present in 1972, the communities appeared to be much more comparable to the fish communities presently encountered along other sections of the West Hawai'i coast where the author has similar ongoing marine community monitoring programs underway (e.g., Hokuli'a, Kohanaiki, etc.). Why were the fish census results from 2005 so different than those carried out subsequently (2006-2012)? The exact answer is unknown but we do know that fish are mobile and respond to the presence and/or absence of currents, tides, moon phases (these are related) as well as food, disease, predators and shelter. The availability of shelter has not changed so any of the other factors may have caused a local decrease in many fishes at the time of the 2005 survey.

2. Invertebrate Communities

The invertebrate censuses in the 2005-2012 surveys did not yield any unusual results; species common to the habitats examined in this study are the same as one would encounter elsewhere in the Hawaiian Islands in similar habitats. The same species were seen on the previous surveys. As noted in the methods section, the census techniques used here for macroinvertebrates (other than corals) assessed only those species that are large (greater than 2 cm in some dimension), diurnally exposed, and are mostly motile. The method is probably accurate for some of the echinoderm and mollusc species but little else. Thus the macroinvertebrate census data are of limited value for describing the benthic community. Sessile and/or colonial forms are assessed by use of the quadrat technique.

When viewed through time (i.e., the nine surveys), coral communities offshore of Ka

Lae Mano appear to have declined in coverage with the 2005-2012 surveys relative to the earlier 1993 and 2002 surveys. Despite the statistical significance, this change is probably related more to the (1) actual placement of permanent stations in the seven most recent surveys relative to the earlier (1993, 2002) surveys as well as (2) use of the photographic technique in 1993 and 2002 relative to *in situ* measurement of coverage with a quadrat in the field as has been done in the 2005-2012 surveys rather than to actual declines in coral coverage. Furthermore it should be noted that in the previous six surveys (2006-2012), annual mean coral coverage has steadily increased from 26.0% in 2006 to 42.5% in 2011 subsequently falling to 41.2% in 2012. These increases lend support to the fact that there have been few large storms generating sufficient surf emanating from the appropriate direction in this period to have had a major negative impact on the coral communities present in the study area.

3. Potential Impacts to Marine Communities at Ka Lae Mano with Development

The purpose of baseline surveys is to establish a quantitative benchmark against which future survey results can be compared. Changes (usually declines) in marine community components that are delineated through subsequent monitoring may indicate a negative impact coming from the shoreline development. The development of the Ka Lae Mano project site entails grading, vegetation removal, construction of roads and other infrastructure including landscaping as well as the development of residences. However, the area from the shoreline to a point about 100 m inland is to remain undisturbed thus residential development is set well back from the shoreline. Other than impacts due to shoreline use by the public (i.e., fishing pressure), potential impacts to the marine environment emanating from this project require the movement of materials from the project site to the ocean. Since rainfall in the area of Ka Lae Mano is low (less than 15 inches/year) and the substratum is extremely porous negating the possibility of direct runoff to the sea, the primary way materials could be carried from the project site to the ocean is through infiltration to groundwater and wind transport.

The marine community data collected commencing in 2006 and later represent the first six years of the "during construction" process; examining these data relative to data from earlier (1993, 2002 and 2005) baseline years, allows one to ascertain if the development is having an impact on these communities. This analysis was presented in Table 3 above but repeating the salient findings, coral cover was significantly greater in the 2002 survey over all other survey years (1993, 2005-2012). However as has been noted above, coral coverage has consistently increased from 2006 through 2011 (overall mean increase is 16.5%) but declining in 2012 to 41.2%. As noted above, some of these differences may be due to small changes in the placement of the quadrats on the transect lines as well as to large differences in the methods used to estimate coral cover in the early (1993-2002) period relative to the ongoing (2005-2012) study. The 16.5% increase in coral coverage during the present study suggests that the development is not having any negative impact to coral community at Ka Lae Mano.

The only other clear statistically separable distinction among the annual means is found with the annual mean number of diurnally exposed macroinvertebrate species where the 2005 mean is significantly less than all other of the eight other annual means which are all related (i.e., show no statistically significant differences).

The Kruskal-Wallis ANOVA noted statistically significant differences for three other parameters (annual mean number of invertebrate individuals, annual mean number of fish species and the annual mean number of individual fish censused). However the SNK Test failed to find any meaningful statistical separation among any of these means through the annual surveys due to overlap which suggests that if any real significant differences exist, they would be found only with the extremes for each of these parameters. Finally, two parameters (the annual mean number of coral species and the annual mean estimated standing crop) showed no statistical separation with either statistical test. Again as noted above, many of these changes have nothing to do with the adjacent construction activities but are related to currents, tides, moon phases, availability of food, etc. at the time that sampling was done. Thus in summary, the construction activities at Ka Lae Mano do not appear to be having an impact on the marine biota. However despite this lack of impact, there are potential impacts that could occur to these communities as development proceeds. These are discussed below.

A. Runoff and Sedimentation

Sedimentation has been implicated as a major environmental problem for coral reefs. Increases in turbidity may decrease light levels resulting in a lowering of primary productivity. Perhaps a greater threat would be the simple burial of benthic communities that may occur with high sediment loading. Many benthic species including corals are capable of removing sediment settling on them but there are threshold levels of deposition where cleaning mechanisms may be overwhelmed and the individual becomes buried. However, the impact of sedimentation on Hawaiian reefs may be overstated. Dollar and Grigg (1981) studied the fate of benthic communities at French Frigate Shoals in the Northwest Hawaiian Islands following the accidental spill of 2000 tons of kaolin clay. These authors found that after two weeks there was no damage to the reef corals and associated communities except where the organisms were actually buried by the clay deposits for a period of more than two weeks.

The opportunity for sedimentation to reach and enter the ocean from the Ka Lae Mano project site is extremely remote for the reasons stated above (large setback from the shoreline, high porosity of the natural substratum and low rainfall) but additionally the presence of natural berms created by sand dunes along the coastal area would serve to impede the surface flow of sediment and runoff from the project site. Surface runoff would only occur under the most adverse rainfall conditions owing to the high local porosity of the land.

B. Changes in Water Quality

The water chemistry studies conducted offshore of Ka Lae Mano suggest that considerable groundwater enters the sea along this coast; one estimate for the Kaupulehu area is from 3 to 6 million gallons per day per mile (Tom Nance as given in Marine Research Consultants 2002a). This naturally high nutrient groundwater effluxes along the shoreline and shallow subtidal area. Input of nutrients via an increased groundwater flow due to a high rainfall event is unlikely to show much change in marine water chemistry. For the development at Waikoloa which is 13 km north of Ka Lae Mano but in a similar rainfall/hydrologic/geologic regime, it was estimated that the annual discharge of storm water runoff is approximately equivalent to the amount of groundwater which enters the ocean each day (U.S. Army Corps of Engineers 1985). Therefore the only major effect of rain during grading would be to reduce the airborne dust.

A reoccurring concern with development on the West Hawai'i coastline has been with the development an operation of golf courses and associated landscaping. Although at this time the Ka Lae Mano project is comprised of single family residences, there could be golf course development in the future. Measurement of the inorganic nutrient concentrations at Waikoloa since the mid-1980's showed them to increase and then decrease through time. The increases were most apparent with the development of a new golf (King's) course in 1989-90 and again later with an accidental spill of nitrate nitrogen in 1993. Since that time nutrient levels have declined to levels similar to those measured prior to any development at Waikoloa. Despite the elevation of certain nutrients (primarily orthophosphorous and nitrate nitrogen) at Waikoloa due to anthropogenic activities, these concentrations are within the range encountered at other completely natural (undeveloped) control sample sites on the West Hawai'i coast. Naturally occurring nutrient concentrations on the West Hawai'i coast may appear to be relatively high to many temperate settings but in other insular locations, naturally occurring concentrations in coastal groundwater may be greater (Marsh 1977, Johannes 1980). Mean measured concentration of coastal groundwater at undeveloped West Hawai'i sites have found the two biologically important nutrients of nitrate nitrogen in the range from 280 to 2,800 ug/l and orthophosphorous in the range of 6 ug/l to 201 ug/l (Brock and Kam 1990, 1994, Brock 1995, 1996, 1997).

Annual sampling for pesticides is also carried out at Waikoloa as well as in an undeveloped control area. This sampling focuses on products that have either been in use for some time at Waikoloa or were used in relatively large quantities. Since many materials will bind with sediments, sampling of sediments and water is routinely carried out. These studies have not detected any pesticides at either Waikoloa or the undisturbed control site. Additionally, a one time sampling effort of tissues from a long-lived (greater than 10 years) anchialine species (the shrimp, *Halocaridina rubra*) was undertaken where a search was made for more than 40 different products. Shrimp were collected from a pool no more than 20 m from a golf course and from an undeveloped control site. No pesticide products were found in any sample. The explanation for the negative results with respect to pesticides is that most products allowed by the U.S. EPA for use on golf courses and elsewhere have short half-lives. These products are effective upon application but rapidly breakdown in the environment. Problems with pesticides in most Hawaiian settings are usually with the older products which characteristically have long (ca. many years to decades) half-lives (chlordane, etc.).

C. Threatened and Endangered Marine Species

As noted above in the Results section, spinner porpoises have been encountered offshore of the Ka Lae Mano project site and humpback whales could be heard well offshore (but not seen on the surface). These were the only federally protected species encountered during the April 2005 survey but in the 2006-2012 surveys green sea turtles and spinner porpoises were also seen. Spinner porpoises are known to use shallow protected waters and bays to rest during the day, moving out into offshore waters to feed usually commencing about dusk. The pods of porpoise seen in this survey were about a quarter of a mile offshore thus well away from the shoreline in the 2005 survey but were within 50 m of the shoreline in the 2006 survey thus this species must utilize the resources through this entire area. In 2007, spinner porpoises were seen to the south of Ka Lae Mano moving north thus utilize resources along this entire section of coastline. In 2005, the humpback whales were not see on the surface but could be heard. It is expected that the whales were more than a mile seaward of Ka Lae Mano at the time of the April 2005 survey and as noted above, no whales were seen or heard in the October 2006, October 2007, May 2009 , September 2009, early December 2011 or the November 2012 surveys because their annual appearance usually commences in December.

The development at Ka Lae Mano is set well back from the shoreline and will have no construction activities either in the approximate 300-foot setback area or in the adjacent ocean. Thus, impacts to federally protected species are not expected.

In summary, the potential for impacts to marine communities as a result of the Ka Lae Mano development appear to be minimal. None of the development activities appear to the potential to induce long-term changes in the physio-chemical water quality parameters of a magnitude sufficient to result in changes to the marine community structure. The one element that appears to have created considerable change in the marine communities has been fishing pressure which apparently had its greatest impact sometime between 1972 and 1993. These fishing-related changes are reversible but require buy-in by the user community to reduce use. The political will must be there to curtail resource use if these resources are to return to their earlier abundance levels. However, the marine communities at Ka Lae Mano today are very similar to those found at other North and South Kona coastal areas which suggests that fishing impacts are probably similar and/or that there is an ongoing redistribution of many fish species along this entire coastline.

Changes to marine communities in the Ka Lae Mano project site will probably be mediated through changes in groundwater chemistry thus would first become evident in the groundwater passing beneath the project site. The implementation of the agency- and community-approved water quality monitoring program will insure that activities occurring in the Ka Lae Mano residential development do not impact the adjacent marine communities. This monitoring program not only samples groundwater (via wells drilled for this specific purpose) as it enters the project site on the mauka (inland) side, but also as it leaves the developed area on the makai or seaward side as well as in the ocean. Thus, changes in water chemistry are the first indication of a possible impact to marine communities offshore of the project site. The water quality monitoring program is designed to detect possible problems before they impact marine communities thus serves as a "early warning" mechanism to protect marine communities.

Similarly, the marine community monitoring program is designed to quantify change that may occur through use of a statistical comparison of the condition of the marine communities prior to the development to the conditions at subsequent times. These programs should insure that the Ka Lae Mano marine communities are not degraded by the residential development and should remain for future generations.

4. Natural Impacts - Storm Surf

Physical disturbance from occasional storm surf is one of the most important parameters in determining the structure of Hawaiian coral communities (Dollar 1982). Numerous studies have shown that occasional storm generated surf may keep coral reefs in a non-equilibrium or sub-climax state (Grigg and Maragos 1974, Connell 1978, Woodley *et al.* 1981, Grigg 1983). Indeed, the large expanses of near-featureless lava or limestone substratum present around much of the Hawaiian Islands at depths less than 30 m attest to the force and frequency of these events (Brock and Norris 1989). These same wave forces also impinge and impact fish communities (Walsh 1983).

Although not an anthropogenic source of impact, storm surf probably has the greatest impact of any insult on Hawaiian coral reefs. This impact is particularly evident in coral communities that are sessile and must be able to withstand the force of the waves impinging on them and the associated scouring caused by the movement of smaller materials by the surf or succumb. Storm wave events do not have to occur very frequently to keep a Hawaiian coral reef at a subclimatic state of development (i.e., relatively low coverage) because most Hawaiian corals have relatively slow growth characteristics. The hemispherical growth form of *Porites lobata* has a radial growth rate of about 1 cm per year (Buddemeier *et al.* 1974). Thus a 2 m diameter colony (which is not an uncommon size for this species offshore of Ka Lae Mano) would be about 100 years old. This suggests that storm waves emanating from the correct direction to impact these corals have not done so in a long time despite the occurrence of Hurricane Iwa in 1982, Hurricane Iniki in 1992 and the tsunami in March 2011. Both of these hurricanes did result in considerable patchy damage to coral reefs on the Kona coast. The damage from the 2011 tsunami apparently impacted coastal improvements adjacent to the ocean along certain parts coast including the Kona Village Resort adjacent to Ka Lae Mano. However, the numerous large colony sizes and continuing high coverage of corals at Ka Lae Mano suggests that these communities have suffered little wave damage in recent years. Storm surf is probably the single greatest threat to the continued existing status of the coral reefs offshore of Ka Lae Mano but for damage to occur, the direction of impingement is critical.

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TABLE 1. Coordinates of the twelve permanently marked marine biological monitoring stations located in three biological zones at each of four stations at Ka Lae Mano, North Kona sampled in April 2005, October 2006, October 2007, May and September 2009, 7-8 December 2011 and 14-15 November 2012. Where position data are missing (as for the middle depth transect), the three transects are spaced closely together (within visual distance of one another).

Station	Location	Zone or Biotope	Transect Number	Latitude	Longitude	Error (ft)
A	South	Boulder Zone	1	19°50.342'N	155°58.912'W	21.1
		Porites lobata Zone	2	19°50.407'N	155°58.969'W	18.0
		Porites compressa Zone	3	19°50.466'N	155°59.019'W	
B	South Middle	Boulder Zone	1	19°50.570'N	155°58.840'W	
		Porites lobata Zone	2			
		Porites compressa Zone	3	19°50.591'N	155°58.868'W	
C	North Middle	Boulder Zone	1	19°50.763'N	155°58.564'W	20.5
		Porites lobata Zone	2			
		Porites compressa Zone	3	19°50.791'N	155°58.607'W	20.3
D	North	Boulder Zone	1	19°50.910'N	155°58.398'W	18.6
		Porites lobata Zone	2			
		Porites compressa Zone	3	19°50.953'N	155°58.407'W	16.6

TABLE 2. Summary of quantitative biological data collected in 1993, 2002 (Marine Research Consultants 1993a, 2002a), April 2005, October 2006, October 2007, May and September 2009 where the May survey represents 2008 and the September survey covers 2009, December 2011 and November 2012 in the waters fronting Ka Lae Mano, North Kona. Under the 1993 and 2002 data sets, blanks indicate that data were not collected.

Zone & Transect No.	No. Coral Spp.	% Coral Cover	No. Invert Spp.	No. Invert Ind.	No. Fish Spp.	No. Fish Ind.	Fish Biomass (g/m^2)
1993							
Boulder Zone							
1	8	36.1	9		20	164	
4	7	24.9	8		18	122	
7	5	17.8	7		12	162	
10	7	17.7	7		24	192	
Means	7	24.1	8		19	160	
P. lobata Zone							
2	6	68.2	10		25	144	
5	7	52.7	9		19	127	
8	8	65.8	12		18	162	
11	8	65.4	12		26	140	
Means	7	63.0	11		22	143	
P. compressa Zone							
3	2	77.6	6		20	164	
6	4	80.7	6		16	121	
9	4	77.4	7		20	116	
12	4	78.9	8		21	145	
Means	4	78.7	7		19	137	
Grand Means	6	55.3	8		20	147	

TABLE 2. Continued.

Zone & Transect No.	No. Coral Spp.	% Coral Cover	No. Invert Spp.	No. Invert Ind.	No. Fish Spp.	No. Fish Ind.	Fish Biomass (g/m^2)
2002							
Boulder Zone							
1	7	52.3	10		13	55	
4	5	63.7	9		20	82	
7	8	46.4	8		23	197	
10	6	27.9	8		21	123	
Means	7	47.6	9		19	114	
P. lobata Zone							
2	6	64.2	10		24	101	
5	7	91.1	9		24	128	
8	6	78.9	12		31	134	
11	7	80.5	12		29	99	
Means	7	78.7	11		27	116	
P. compressa Zone							
3	6	93.4	6		18	55	
6	6	89.0	6		18	65	
9	5	66.7	7		19	107	
12	6	82.9	8		17	91	
Means	6	83.0	7		18	80	
Grand Means	6	69.8	9		21	103	

TABLE 2. Continued.

Zone & Transect No.	No. Coral Spp.	% Coral Cover	No. Invert Spp.	No. Invert Ind.	No. Fish Spp.	No. Fish Ind.	Fish Biomass (g/m^2)
2005							
Boulder Zone							
1	6	13.9	4	51	6	60	5
4	4	7.1	6	27	19	162	226
7	6	21.9	7	49	22	270	116
10	6	23.4	7	54	22	278	161
Means	6	16.6	6	45	17	193	127
P. lobata Zone							
2	7	29.4	6	50	26	221	134
5	6	19.3	6	67	28	239	218
8	6	26.4	5	38	26	240	152
11	5	35.5	6	69	24	243	136
Means	6	27.7	6	56	26	236	160
P. compressa Zone							
3	5	51.0	5	178	27	202	173
6	4	37.2	6	63	24	150	51
9	6	21.0	6	82	32	368	174
12	7	29.6	7	28	31	252	257
Means	6	34.7	6	88	29	243	164
Grand Means	6	26.3	6	63	24	224	150

TABLE 2. Continued.

Zone & Transect No.	No. Coral Spp.	% Coral Cover	No. Invert Spp.	No. Invert Ind.	No. Fish Spp.	No. Fish Ind.	Fish Biomass (g/m^2)
2006							
Boulder Zone							
1	6	9.4	11	64	8	175	292
4	4	16.1	4	54	33	231	230
7	6	13.6	9	51	23	265	161
10	6	28.0	8	73	24	412	212
Means	6	16.8	8	61	22	271	224
P. lobata Zone							
2	7	31.9	9	104	37	198	186
5	6	26.2	9	81	19	177	136
8	6	35.3	9	123	33	383	352
11	7	35.2	8	103	26	266	170
Means	7	32.2	9	103	29	256	211
P. compressa Zone							
3	6	39.5	8	310	36	640	759
6	6	16.8	6	97	26	136	61
9	5	34.0	7	73	31	408	367
12	5	26.0	7	144	40	482	984
Means	6	29.1	7	156	33	417	543
Grand Means	6	26.0	8	107	28	315	326

TABLE 2. Continued.

Zone & Transect No.	No. Coral Spp.	% Coral Cover	No. Invert Spp.	No. Invert Ind.	No. Fish Spp.	No. Fish Ind.	Fish Biomass (g/m^2)
2007							
Boulder Zone							
1	7	10.4	9	71	10	104	18
4	5	16.7	11	111	24	216	257
7	6	18.0	8	95	26	264	431
10	3	18.5	8	63	29	438	309
Means	5	15.9	9	85	22	256	254
P. lobata Zone							
2	5	37.5	12	80	33	217	146
5	8	33.8	7	131	28	219	187
8	7	31.2	9	189	31	249	261
11	7	52.3	10	144	29	326	353
Means	7	38.7	10	136	30	253	237
P. compressa Zone							
3	6	36.2	7	238	34	388	1114
6	7	58.2	10	95	25	172	112
9	5	29.2	7	95	31	251	201
12	6	20.9	8	135	41	441	555
Means	6	36.1	8	141	33	313	496
Grand Means	6	30.2	9	121	28	274	329

TABLE 2. Continued.

Zone & Transect No.	No. Coral Spp.	% Coral Cover	No. Invert Spp.	No. Invert Ind.	No. Fish Spp.	No. Fish Ind.	Fish Biomass (g/m^2)
May 2009 (representing the 2008 survey)							
Boulder Zone							
1	7	22.6	8	65	8	87	4
4	6	19.4	7	49	22	250	212
7	7	31.6	7	65	22	198	119
10	9	23.5	7	45	29	388	283
Means	7	24.3	7	56	20	231	155
P. lobata Zone							
2	8	38.6	9	138	32	185	202
5	8	34.7	12	159	16	108	77
8	6	33.0	8	110	29	199	121
11	8	57.3	9	129	22	208	158
Means	8	40.9	10	134	25	175	140
P. compressa Zone							
3	5	46.0	8	293	35	341	531
6	6	49.9	6	142	24	127	78
9	6	37.8	7	192	26	229	156
12	5	32.9	7	228	31	546	996
Means	6	41.7	7	214	29	311	440
Grand Means	7	35.6	8	135	25	239	245

TABLE 2. Continued.

Zone & Transect No.	No. Coral Spp.	% Coral Cover	No. Invert Spp.	No. Invert Ind.	No. Fish Spp.	No. Fish Ind.	Fish Biomass (g/m^2)
September 2009							
Boulder Zone							
1	8	16.8	7	54	12	130	2
4	6	27.3	9	99	27	309	419
7	5	28.0	8	77	25	425	307
10	7	29.3	11	58	26	467	326
Means	6	25.4	9	72	23	333	264
P. lobata Zone							
2	7	47.5	9	87	27	205	184
5	7	46.1	10	104	21	221	130
8	7	26.0	6	178	30	397	470
11	7	47.9	9	130	28	316	236
Means	7	41.9	9	125	27	285	255
P. compressa Zone							
3	6	36.5	8	256	32	510	670
6	6	54.4	9	146	29	232	318
9	6	36.7	7	147	26	243	182
12	5	29.9	9	111	29	365	483
Means	6	39.4	8	165	29	338	411
Grand Means	6	36.0	8	121	26	318	311

TABLE 2. Continued.

Zone & Transect No.	No. Coral Spp.	% Coral Cover	No. Invert Spp.	No. Invert Ind.	No. Fish Spp.	No. Fish Ind.	Fish Biomass (g/m^2)
December 2011							
Boulder Zone							
1	6	17.5	5	41	10	33	9
4	6	24.3	9	126	27	197	208
7	7	39.5	6	61	24	229	123
10	6	32.6	8	53	23	384	177
Means	6	28.5	7	70	21	211	129
P. lobata Zone							
2	5	38.8	8	209	27	440	578
5	7	52.0	9	171	23	167	142
8	6	50.4	8	136	22	171	105
11	7	51.4	6	139	21	247	123
Means	6	48.2	8	164	23	256	237
P. compressa Zone							
3	5	48.4	10	357	25	445	320
6	7	72.6	9	178	24	143	86
9	4	43.4	7	139	22	208	154
12	5	38.8	7	184	25	392	272
Means	5	50.8	8	215	24	297	208
Grand Means	6	42.5	8	150	23	255	191

TABLE 2. Continued.

Zone & Transect No.	No. Coral Spp.	% Coral Cover	No. Invert Spp.	No. Invert Ind.	No. Fish Spp.	No. Fish Ind.	Fish Biomass (g/m^2)
November 2012							
Boulder Zone							
1	7	23.9	8	50	16	277	173
4	8	30.5	8	114	32	370	357
7	5	34.6	9	100	28	50	594
10	8	48.7	8	78	26	448	260
Means	7	34.4	8	86	26	401	346
P. lobata Zone							
2	6	40.4	9	242	29	145	167
5	6	55.0	8	155	26	194	93
8	5	45.5	9	165	27	270	245
11	7	55.2	7	93	19	193	136
Means	6	49.0	8	164	25	201	160
P. compressa Zone							
3	6	35.0	8	248	28	497	399
6	6	53.6	8	99	21	145	153
9	6	49.1	9	183	23	317	179
12	5	23.1	10	131	31	289	275
Means	5	40.2	9	165	26	312	252
Grand Means	6	41.2	8	138	26	305	253

TABLE 3. Summary of the Kruskal-Wallis ANOVA and SNK Test applied to the means of parameters measured in each of nine sample dates at Ka Lae Mano. These statistical tests address the question, "Has there been any significant change in the means of biological parameters over the nine surveys carried out in 1993 through November 2012?" In the body of the table are given the annual means. Under the SNK Ranking, letters with the same designation show means that are related; changes in letter designation show where significant differences exist. Overlaps in letters indicate a lack of significant differences; in such cases, only the extremes may be significantly different.

1. Number of Coral Species (Kruskal-Wallis: P>0.59, not significant)

Date	**Mean No. Species**	**SNK**
2008	6.8	A
2009	6.4	A
2012	6.3	A
2002	6.3	A
2007	6.0	A
2011	5.9	A
1993	5.8	A
2006	5.8	A
2005	5.7	A

Interpretation: No significant changes in the mean number of coral species among the nine surveys.

2. Coral Coverage (Kruskal-Wallis: P<0.0001, significant)

Date	**Mean Coverage**	**SNK**
2002	69.8	A
1993	55.3	B
2011	42.5	B C
2012	41.2	B C
2008	35.6	C
2009	35.5	C
2007	30.2	C
2005	26.3	C
2006	26.0	C

Interpretation: Coral coverage is significantly greater in the 2002 survey over subsequent surveys and all other surveys are related due to overlap in the SNK Test.

TABLE 3. Continued.

3. **Number of Invertebrate Species** (Kruskal-Wallis: P<0.001, significant)

Date	Mean No. Species	SNK
2007	8.8	A
2002	8.8	A
1993	8.4	A
2012	8.4	A
2009	8.2	A
2006	7.9	A
2008	7.9	A
2011	7.7	A
2005	5.9	B

Interpretation: The 2005 census found significantly fewer invertebrate species relative to the other eight surveys that were all related.

4. **Number of Invertebrate Individuals** (Kruskal-Wallis: P<0.008, significant)

Date	Mean No. Individuals	SNK
2011	149.6	A
2012	138.2	A B
2008	134.6	A B
2009	120.6	A B
2007	120.6	A B
2006	106.4	A B
2005	63.0	B

Interpretation: Despite significant differences with the ANOVA, the overlap in the SNK results suggests little differences among the annual surveys with respect to the mean number of invertebrates censused per transect over the nine surveys.

TABLE 3. Continued.

5. Number of Fish Species (Kruskal-Wallis: P<0.001, significant)

Date	Mean No. Species	SNK
2007	28.4	A
2006	28.0	A
2009	26.0	A B
2012	25.5	A B
2008	24.7	A B
2005	23.9	A B
2011	22.8	A B
2002	21.4	A B
1993	19.9	B

Interpretation: Despite the ANOVA finding significant differences among the annual means, the SNK Test noted considerable overlap indicating that there are no significant differences among the annual mean number of fish species.

6. Number of Fish Individuals (Kruskal-Wallis: P<0.0001, significant)

Date	Mean No. Species	SNK
2009	318.3	A
2006	314.4	A
2012	304.3	A
2007	273.8	A
2011	254.7	A B
2008	238.8	A B
2005	223.8	A B
1993	146.6	B C
2002	103.1	C

Interpretation: Again the ANOVA noted significant differences but due to overlap in the SNK test these differences are weak at best.

TABLE 3. Continued.

7. Standing Crop of Fish (Kruskal-Wallis: P>0.07, not significant)

Date	**Mean Biomass (g/m^2)**	**SNK**
2007	328.6	A
2006	325.9	A
2009	309.8	A
2012	252.6	A
2008	244.8	A
2011	191.4	A
2005	150.3	A

Interpretation: There are no significant differences in the estimated standing crop of fish among any of the seven most recent surveys where this parameter was measured.

TABLE 4. Summary of the Kruskal-Wallis ANOVA and SNK Test applied to the means of parameters measured in each of three biotopes at Ka Lae Mano in 1993, 2002, 2005, 2006, 2007, May 2009 (representing 2008), September 2009, December 2011 as well as in November 2012. These statistical tests address the question, "Within a biotope are there significant differences in the measured parameters among the nine survey periods at Ka Lae Mano?" Means are given in the body of the table. Under the SNK Ranking, letters with the same designation show means that are related; changes in letter designation show where significant differences exist. Overlaps in letters indicate a lack of significant differences; in such cases, only the extremes may be significantly different.

Biotope & Parameter	Year	Means	SNK Ranking
BOULDER ZONE			
No. Coral Species (Kruskal-Wallis P>0.31, not significant)			
	2008	7.3	A
	2012	7.0	A
	1993	6.8	A
	2009	6.5	A
	2002	6.5	A
	2011	6.3	A
	2005	5.5	A
	2006	5.5	A
	2007	5.3	A

Interpretation: There are no significant differences in the number of coral species among the boulder zone stations over the nine surveys.

Biotope & Parameter	Year	Means	SNK Ranking
Percent Coral Cover (Kruskal-Wallis P<0.01, significant)			
	2002	47.6	A
	2012	34.4	B
	2011	28.5	B
	2009	25.4	B
	2008	24.3	B
	1993	24.2	B
	2006	16.8	B
	2005	16.1	B
	2007	15.9	B

Interpretation: Coral coverage is significantly greater at boulder zone stations in 2002 over the other eight surveys.

TABLE 4. Continued.

Biotope & Parameter	Year	Means	SNK Ranking
BOULDER ZONE (Continued):			
No. Invertebrate Species (Kruskal-Wallis P>0.14, not significant)			
	2007	9.0	A
	2002	8.8	A
	2012	8.3	A
	2006	8.0	A
	2009	7.8	A
	1993	7.8	A
	2008	7.3	A
	2011	7.0	A
	2005	6.0	A

Interpretation: There are no significant differences in the number of invertebrate species seen in the boulder zone among the nine surveys.

Biotope & Parameter	Year	Means	SNK Ranking
No. Invertebrate Individuals (Kruskal-Wallis P<0.13, not significant)			
	2012	85.5	A
	2007	85.0	A
	2009	72.0	A
	2011	70.3	A
	2006	60.5	A
	2008	56.0	A
	2005	45.3	A

Interpretation: The ANOVA noted no significant differences between the seven most recent surveys.

Biotope & Parameter	Year	Means	SNK Ranking
No. Fish Species (Kruskal-Wallis P>0.51, not significant)			
	2012	25.5	A
	2009	22.5	A
	2007	22.3	A
	2006	22.0	A
	2011	21.0	A
	2008	20.3	A
	2002	19.3	A
	1993	18.5	A
	2005	17.3	A

Interpretation: No significant differences in the number of fish species at boulder zone stations over the eight surveys.

TABLE 4. Continued.

Biotope & Parameter	Year	Means	SNK Ranking
BOULDER ZONE (Continued):			
No. Individual Fish (Kruskal-Wallis P>0.06, not significant)			
	2012	400.5	A
	2009	332.8	A B
	2006	270.8	A B
	2007	255.5	A B
	2008	230.8	A B
	2011	210.8	A B
	2005	192.5	A B
	1993	160.0	A B
	2002	114.3	B

Interpretation: No significant difference in the number of individual fish counted at boulder zone stations among the nine survey periods.

Biotope & Parameter	Year	Means	SNK Ranking
Standing Crop of Fish (Kruskal-Wallis P>0.20, not significant)			
	2012	346.0	A
	2009	263.5	A
	2007	253.8	A
	2006	224.0	A
	2008	154.5	A
	2011	129.3	A
	2005	127.0	A

Interpretation: No significant differences in the number of fish species at boulder zone stations over the last six surveys where this parameter was measured.

(Table Continued on Next Page)

TABLE 4. Continued.

Biotope & Parameter	Year	Means	SNK Ranking
***PORITES LOBATA* ZONE:**			
No. Coral Species (Kruskal-Wallis P>0.20, not significant)			
	2008	7.5	A
	1993	7.3	A
	2009	7.0	A
	2007	6.8	A
	2002	6.5	A
	2011	6.3	A
	2006	6.5	A
	2005	6.0	A
	2012	6.0	A

Interpretation: No significant differences in the number of coral species at *Porites lobata* zone stations among the nine surveys.

Biotope & Parameter	Year	Means	SNK Ranking
Percent Coral Cover (Kruskal-Wallis P<0.001, significant)			
	2002	78.7	A
	1993	63.0	B
	2012	49.0	B C
	2011	48.2	B C
	2009	41.9	C D
	2008	40.9	C D
	2007	38.7	C D
	2006	32.2	C D
	2005	27.7	D

Interpretation: The 2002 survey had significantly greater mean coral coverage at stations in the biotope of *Porites lobata* over all subsequent annual surveys which did not show any significant differences due to strong overlap among dates.

TABLE 4. Continued.

Biotope & Parameter	Year	Means	SNK Ranking
PORITES LOBATA ZONE:			
No. Invertebrate Species (Kruskal-Wallis P<0.009, significant)			
	1993	10.8	A
	2002	10.8	A
	2007	9.5	A
	2008	9.5	A
	2006	8.8	A
	2009	8.5	A
	2012	8.3	A
	2011	7.8	A B
	2005	5.8	B

Interpretation: The Kruskal-Wallis ANOVA found a significant difference among the nine surveys but the overlap in the SNK test suggests that if it exists it would be with the two extremes.

Biotope & Parameter	Year	Means	SNK Ranking
No. Invertebrate Individuals (Kruskal-Wallis P<0.02, significant)			
	2011	164.0	A
	2012	163.8	A
	2007	136.0	A
	2008	134.0	A
	2009	124.8	A
	2006	102.8	A B
	2005	56.0	B

Interpretation: Despite the ANOVA finding significant differences in the annual mean number of invertebrate individuals among the nine surveys, overlap in the SNK Test suggests that only the two extremes may be significantly different.

TABLE 4. Continued.

Biotope & Parameter	Year	Means	SNK Ranking
PORITES LOBATA ZONE:			
No. Fish Species (Kruskal-Wallis P>0.25, not significant)			
	2007	30.3	A
	2006	28.8	A
	2002	27.0	A
	2009	26.5	A
	2005	26.0	A
	2012	25.3	A
	2008	24.8	A
	2011	23.3	A
	1993	22.0	A

Interpretation: There are no significant differences in the number of fish species encountered in *Porites lobata* stations among the nine surveys.

Biotope & Parameter	Year	Means	SNK Ranking
No. Individual Fish (Kruskal-Wallis P<0.006, significant)			
	2009	284.8	A
	2011	256.3	A B
	2006	256.0	A B
	2007	252.8	A B
	2005	235.8	A B
	2012	200.5	A B
	2008	175.0	A B
	1993	143.3	A B
	2002	115.5	B

Interpretation: Despite the ANOVA finding significant differences in the number of individual fish counted at *Porites lobata* zone stations among the years, the SNK Test failed to clearly and statistically separate these differences.

TABLE 4. Continued.

Biotope & Parameter	Year	Means	SNK Ranking
***PORITES LOBATA* ZONE:**			
Standing Crop of Fish (Kruskal-Wallis P>0.50, not significant)			
	2009	255.3	A
	2011	237.0	A
	2007	236.8	A
	2006	211.0	A
	2012	160.3	A
	2005	160.0	A
	2008	139.5	A

Interpretation: No significant differences in the mean standing crop at *Porites lobata* stations over the last seven surveys where this parameter was measured.

(Table Continued on Next Page)

TABLE 4. Continued.

Biotope & Parameter	Year	Means	SNK Ranking
PORITES COMPRESSA **ZONE:**			
No. Coral Species (Kruskal-Wallis P>0.11, not significant)			
	2007	6.0	A
	2002	5.8	A
	2009	5.8	A
	2012	5.8	A
	2005	5.5	A
	2006	5.5	A
	2008	5.5	A
	2011	5.3	A
	1993	3.5	B

Interpretation: The ANOVA which is a more powerful test did not find any significant differences among the mean number of coral species per survey in the *Porites compressa* zone but the SNK Test noted significantly fewer species of corals present in this zone in 1993 when compared to the eight later surveys.

Biotope & Parameter	Year	Means	SNK Ranking
Percent Coral Cover (Kruskal-Wallis P<0.005, significant)			
	2002	83.0	A
	1993	78.7	A
	2011	50.8	B
	2008	41.7	B
	2012	40.2	B
	2009	39.4	B
	2007	36.1	B
	2005	34.7	B
	2006	29.1	B

Interpretation: The mean percent coverage by corals in the *Porites compressa* zone is significantly less in the seven most recent surveys over the earlier (1993 and 2002) survey dates.

TABLE 4. Continued.

Biotope & Parameter	Year	Means	SNK Ranking
PORITES COMPRESSA ZONE (Continued):			
No. Invertebrate Species (Kruskal-Wallis P>0.03, significant)			
	2012	8.8	A
	2009	8.3	A B
	2011	8.3	A B
	2007	8.0	A B
	2008	7.0	A B
	2006	7.0	A B
	1993	6.8	A B
	2002	6.8	A B
	2005	6.0	B

Interpretation: The ANOVA noted a significant difference in the mean annual number of invertebrate species but the SNK Test failed to find clear significant differences due to overlap.

No. Invertebrate Individuals (Kruskal-Wallis P>0.19, not significant)			
	2011	214.5	A
	2008	213.8	A
	2012	165.3	A
	2009	165.0	A
	2006	156.0	A
	2007	140.8	A
	2005	87.8	A

Interpretation: There are no significant differences in the mean number of invertebrate individuals in the *Porites compressa* zone in the last seven surveys.

TABLE 4. Continued.

Biotope & Parameter	Year	Means	SNK Ranking
***PORITES COMPRESSA* ZONE (Continued):**			
No. Fish Species (Kruskal-Wallis P<0.002, significant)			
	2006	33.3	A
	2007	32.8	A
	2009	29.0	A
	2008	29.0	A
	2005	28.5	A
	2012	25.8	A B
	2011	24.0	B
	1993	19.3	B
	2002	18.0	B

Interpretation: Despite the Kruskal-Wallis ANOVA finding significant differences among the annual mean number of fish species in the biotope of *Porites compressa,* the SNK test found overlap suggesting that only the extremes may differ significantly.

Biotope & Parameter	Year	Means	SNK Ranking
No. Individual Fish (Kruskal-Wallis P<0.03, significant)			
	2006	416.5	A
	2009	337.5	A B
	2007	313.0	A B
	2012	312.0	A B
	2008	310.8	A B
	2011	297.0	A B
	2005	243.0	A B
	1993	136.5	A B
	2002	79.5	B

Interpretation: Despite the ANOVA finding significant differences among the years for the mean number of individual fish counted at *Porites compressa* zone stations, the SNK Test failed to find clear statistical separation suggesting that only the extremes may be significantly different.

TABLE 4. Continued.

Biotope & Parameter	**Year**	**Means**	**SNK Ranking**
***PORITES COMPRESSA* ZONE (Continued):**			
Standing Crop of Fish (Kruskal-Wallis P>0.53, not significant)			
	2006	542.8	A
	2007	495.5	A
	2008	440.3	A
	2009	410.8	A
	2012	251.5	A
	2011	208.0	A
	2005	163.8	A

Interpretation: No significant differences in the mean biomass of fish at *Porites compressa* stations over the last six surveys where this parameter was measured.

TABLE 5. Summary of the contribution of each fish family (as a percent of the total) to the estimated biomass made for each transect sampled in the 13-14 April 2005, 5-6 October 2006, 9-10 October 2007, 4-5 May 2009 (representing 2008), 15-16 September 2009, 7-8 December 2011 and 14-15 November 2012 surveys. Biomass estimates are calculated from estimated individual fish lengths in the field for families of fishes that collectively contributed 99 percent or more to the standing crop of fishes at the ten sampled stations. Families of fishes that comprise less than 0.1 g/m^2 are not included in the table below.

2005 SURVEY:

	Transect Number											
Family	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Acanthuridae	0.2	67.6	46.4	75.4	47.8	75.1	73.5	41.6	44.1	51.9	55.9	45.1
Balistidae	85.0	13.1	3.7	5.1	14.9	3.3	3.6	9.5	1.6	5.1	5.6	1.4
Chaetodontidae		0.6	1.6	0.5	0.5	0.5	1.3	0.5	0.9	2.0	2.3	0.3
Cirrhitidae	5.2	0.3	0.1		0.2	0.5	0.2	0.3	0.4	0.1		0.1
Fistulariidae						3.3						
Holocentridae									11.5			3.4
Labridae	5.9	8.3	5.9	0.3	0.6	3.5	11.1	3.3	1.7	5.1	1.9	1.9
Lutjanidae			4.0	2.1				1.0	4.3	3.4		26.3
Monacanthidae			15.6									
Mullidae		1.2	0.3		0.4	2.9	2.0	1.6	5.9	1.0	0.7	5.3
Muraenidae					20.8		0.5					
Pomacentridae	3.7	0.5	0.1		0.3	1.0	0.6	0.7	2.2	0.2	0.1	0.8
Scaridae		7.6	4.0	16.5	14.1	7.0	7.0	23.6	26.7	31.2	23.1	8.9
Serranidae			5.0			2.9		17.9			10.4	6.5
Sparidae			13.2									
Synodontidae					0.1				0.1			
Tetraodontidae							0.2					
Zanclidae		0.8			0.3				0.6			
Total Station Percent	100	100	99.9	99.9	100	100	100	100	100	100	100	100

TABLE 5. Continued.

2006 SURVEY:

Family	**Transect Number** **1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Acanthuridae	0.4	70.2	69.7	59.5	32.1	43.2	49.5	29.5	55.4	20.3	59.4	30.9
Aulostomidae									0.1			0.6
Balistidae	0.8	4.4	8.2	1.9	40.1	4.7	1.6	1.3	0.7	2.4	4.3	0.4
Chaetodontidae		0.8	0.6	0.8	2.3	2.7		0.2	0.8	0.3	1.3	0.1
Chanidae	96.3											
Cirrhitidae	0.2	0.2		0.1	1.7	0.2	0.6	0.2		0.2	0.1	
Holocentridae			0.7	5.8				33.2	1.5			18.5
Kyphosidae		0.2										
Labridae	2.1	4.4	4.6	4.2	5.1	7.1	4.4	2.7	2.2	8.1	6.9	1.7
Lutjanidae			3.7	1.0					3.9	1.0		0.9
Mullidae		6.0	3.0	0.6	1.1	0.8	0.9	1.8		3.1		2.2
Muraenidae				2.9		0.4						
Pomacanthidae						0.1						
Pomacentridae	0.2	0.3		0.2	0.5	0.9	0.3	0.1	0.3	0.3	0.1	0.5
Scaridae		12.6	2.0	17.1		39.9	42.7	21.0	24.0	64.0	13.6	6.8
Serranidae			7.4	5.9	17.1			10.0	11.0		13.6	1.7
Sparidae												1.8
Sphyraenidae												33.9
Zanclidae		0.9								0.3	0.7	
Total Station Percent	100	100	100	100	100	100	100	100	99.9	100	100	100

TABLE 5. Continued.

2007 SURVEY:

	Transect Number											
Family	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Acanthuridae	69.1	77.3	39.2	59.8	56.7	23.0	73.1	39.7	50.9	40.0	48.2	47.4
Aulostomidae												0.6
Balistidae	19.1	8.4	0.4	0.3	4.3	5.1	1.1	2.6	1.4	2.7	0.8	8.3
Blennidae	0.1											
Chaetodontidae		1.1	0.1	0.2	0.4	2.6	0.5	0.9	1.0	0.3	0.9	0.3
Chanidae			11.0									
Cirrhitidae	3.2	0.3		0.1	0.2	0.2		0.2	0.1	0.1	0.1	
Dactylopteridae			0.4									
Holocentridae			1.6	6.8				21.1			1.6	10.0
Kyphosidae										1.4		
Labridae	6.1	3.4	0.4	1.9	2.7	5.4	2.6	0.7	2.0	8.4	1.2	4.7
Lutjanidae			6.1							0.7	1.0	2.5
Monacanthidae											0.6	
Mullidae		1.5	2.4	2.7	1.3		1.3	2.1		1.8	2.6	1.6
Muraenidae			0.6	17.7								
Ophichthidae												1.1
Pomacanthidae						0.1						
Pomacentridae	1.4	1.0	0.1	0.2	0.5	0.4	0.2	0.1	0.9	1.1		1.4
Scaridae		2.1	33.0	7.5	20.9	63.2	21.1	24.9	33.5	39.9	28.8	16.1
Serranidae		4.4	4.6		13.0			7.7	9.9	3.4	14.2	6.0
Synodontidae									0.3			
Tetradontidae	1.0	0.1		2.7								
Zanclidae		0.4								0.2		
Total Station Percent	100	100	99.9	99.9	100	100	99.9	100	100	100	100	100

TABLE 5. Continued.

2008 SURVEY (Carried out on 4-5 May 2009):

	Transect Number											
Family	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Acanthuridae		33.1	69.5	74.3	35.4	31.8	79.6	52.1	29.1	36.1	36.8	93.1
Balistidae	12.3	4.7	7.0	0.8	6.9	3.2	3.5	11.0	1.1	4.0	15.7	0.1
Blennidae	0.3											
Chaetodontidae		1.8	0.1	0.3	5.6	1.2	0.4	1.6	0.7	0.7	0.5	0.2
Cirrhitidae	8.9	0.2		0.2	0.5		0.3	0.3	0.1	0.7	0.3	
Holocentridae								12.8	3.6		11.7	1.2
Kyphosidae			0.6	1.4								
Labridae	72.2	9.2	6.5	5.1	12.3	7.3	7.5	7.8	4.4	9.8	3.2	0.6
Lutjanidae			1.8						13.8	0.7		0.8
Mullidae		1.2	0.7			13.0	2.0	4.6			2.2	0.2
Muraenidae			0.1						5.6			
Pomacanthidae											0.1	
Pomacentridae	5.3	0.5	0.1	0.5	0.3	0.4	0.2	0.3	0.8	0.5	0.1	0.3
Scaridae		39.2	6.4	6.7	39.0	43.0	6.4	5.6	19.0	47.1	14.0	0.5
Serranidae		10.1	3.8	10.7				3.9	21.8		15.4	3.0
Sparidae			3.4									
Tetradontidae	1.0											
Zanclidae										0.4		
Total Station Percent	100	100	100	100	100	99.9	99.9	100	100	100	100	100

TABLE 5. Continued.

2009 SURVEY (Carried out on 15-16 September 2009):

	Transect Number											
Family	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Acanthuridae	2.0	68.7	72.6	88.9	59.0	9.4	23.4	21.2	30.3	51.4	44.4	25.0
Aulostomidae								0.9				
Balistidae	24.5	3.9	12.7	1.4	3.7	1.1	4.3	1.2	1.6	2.5	6.2	0.2
Blennidae	1.8											
Carangidae				0.6								
Chaetodontidae	0.4	1.2	0.3	0.5	1.3	0.9	0.4	0.6	0.6	0.3	1.0	0.5
Cirrhitidae	14.2	0.2	0.1		1.0	0.3	0.4	0.2	0.2	0.2	0.2	
Fistulariidae					1.0							
Holocentridae								1.6			6.5	11.1
Labridae	43.2	1.5	1.7	5.2	5.8	3.6	5.3	3.3	2.3	8.2	2.5	7.8
Lutjanidae		0.8	0.3			8.5			0.8			4.6
Mullidae		2.6	1.0		1.8	0.3	0.6	6.7	1.3	4.4		0.5
Pomacentridae	14.0	0.8	0.2	0.1	0.3	0.2	0.2	0.1	0.5	0.1	1.0	5.2
Scaridae		20.3	5.3	3.2	26.2	44.2	65.3	58.6	33.6	32.9	24.8	15.4
Serranidae			5.8					5.2	28.7		13.4	10.8
Sparidae						29.9						18.8
Synodontidae								0.4				
Tetradontidae						1.5						
Zanclidae				0.1								
Total Station Percent	100	100	100	100	100	100	100	100	100	100	100	100

TABLE 5. Continued.

2011 SURVEY (Carried out on 7-8 December 2011):

	Transect Number											
Family	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Acanthuridae	64.5	90.7	61.3	82.7	19.5	31.8	49.2	52.8	71.8	32.0	71.0	52.3
Aulostomidae								0.3	0.2		1.7	1.9
Balistidae	10.2		3.2	0.4	12.9	2.0	3.6	3.2		9.3	0.7	3.1
Blennidae	0.1											
Carangidae			14.2									
Chaetodontidae		0.5	0.2	1.1	0.2	3.1	0.2	1.7	0.8	0.3	2.3	0.1
Cirrhitidae	2.9	0.1	0.1	0.2	0.3	0.8	0.4	0.1	0.2	0.2	0.6	0.2
Fistulariidae											0.8	
Holocentridae			2.2									7.2
Kyphosidae				2.8								
Labridae	21.2	1.4	5.4	8.1	6.1	16.3	22.9	8.8	3.3	21.6	7.9	0.1
Lutjanidae		0.8										
Monacanthidae				0.4								
Mullidae			0.8	2.2		4.0	3.2	3.3	1.5	2.7	1.3	1.9
Pomacanthidae									0.1			
Pomacentridae	0.3	0.2	0.4	1.1	0.1	0.3	0.2	0.4	0.4	0.2	0.1	1.0
Scaridae		3.2	11.8	1.1	52.6	41.6	19.2	29.6	21.7	33.6	13.8	32.1
Serranidae		1.9			7.6							
Tetraodontidae	0.8	1.2				0.2	0.1					
Zanclidae			0.3		0.7		0.8					
Total Station Percent	100	100	100	100	100	100	100	100	100	100	100	100

TABLE 5. Continued.

2012 SURVEY (Carried out on 14-15 November 2012):

	Transect Number											
Family	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Acanthuridae	89.3	35.8	72.1	77.8	31.5	55.8	49.4	27.0	23.1	37.1	45.0	22.5
Aulostomidae											0.1	0.1
Balistidae	1.6	4.7	10.8	2.9	19.8	1.3	1.5	2.0	0.5	6.9	2.4	1.6
Blennidae										0.1		
Carangidae	6.2								32.6			
Chaetodontidae	0.8	1.2	0.2	1.0	1.6	1.1	0.2	1.3	1.4	1.0	1.8	0.9
Cirrhitidae	0.2	0.3		0.1	0.4	0.2	0.2	0.1		0.1	0.1	
Holocentridae				0.2				14.5			9.0	59.5
Kyphosidae							0.3					
Labridae	1.4	9.3	3.7	2.3	15.4	6.9	4.7	4.8	7.7	5.9	2.2	2.1
Lutjanidae		2.1										1.3
Mullidae		0.5	3.7	3.4	3.0	1.5	2.0	1.4	3.3		0.7	2.7
Muraenidae								18.5				
Ostracidae						0.1						
Pomacentridae	0.3	0.4	0.5	1.8	0.1	0.3	0.3	0.1	0.6	0.1	0.6	0.2
Scaridae		14.0	2.8	10.5	16.5	15.1	41.4	30.3	21.4	48.7	35.0	5.9
Serranidae		31.7	6.1		11.6				9.4			2.3
Sparidae			0.1			17.7						
Tetraodontidae	0.1				0.1					0.1		
Zanclidae											3.1	
Total Station Percent	99.9	100	100	100	100	100	100	100	100	100	100	100

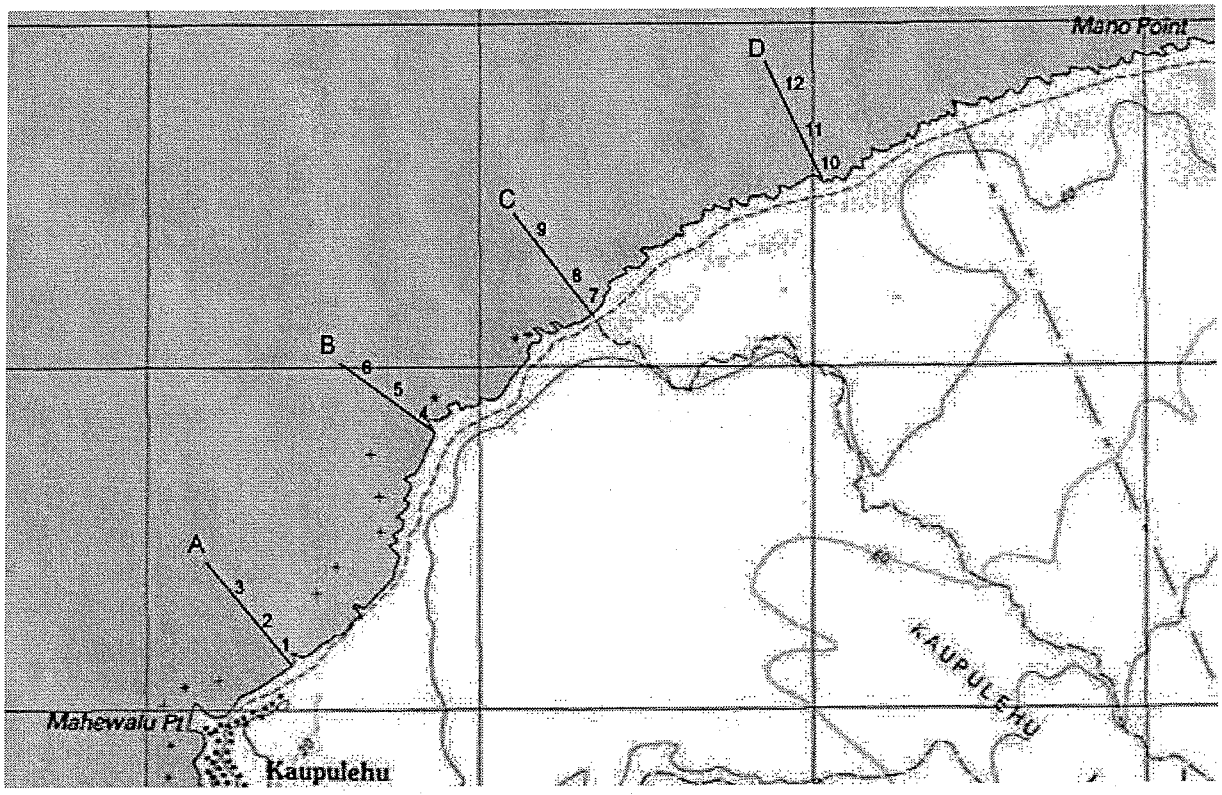

FIGURE 1. Map showing the approximate locations of the twelve permanently marked transects (numbered) at each of 4 locations (lettered) at Ka Lae Mano.

APPENDIX 1. Results of the quantitative visual censuses conducted at 12 locations offshore of Ka Lae Mano, North Kona on 14-15 November 2012. Each entry in the body of the table represents the total number of individuals of each species seen; totals are presented at the foot of the table along with the estimate of the standing crop (g/m2) of fishes present at each station.

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12
MURAENIDAE												
Gymnothorax flavimarginatus								1				
SYNODONTIDAE												
Saurida gracilis							1					
Synodus flamma												1
HOLOCENTRIDAE												
Adioryx spinifer								1			1	5
Myripristis amaenus								9				33
Flammeo sammara				1				1				
AULOSTOMIDAE												
Aulostomus chinensis											1	1
SERRANIDAE												
Cephalopholis argus		2	2		1				1			1
CARANGIDAE												
Decapterus macarellus	4								70			
LUTJANIDAE												
Aphareus furcatus		1										1
SPARIDAE												
Monotaxis grandoculis			1			1						
MULLIDAE												
Mulloides vanicolensis			13									
Parupeneus cyclostomus												1
Parupeneus multifasciatus		2	3	1	3	1	3	2	3		1	1
Parupeneus bifasciatus				2								1
KYPHOSIDAE												
Kyphosus bigibbus							1					
CHAETODONTIDAE												
Forcipiger flavissimus					2				2	1	4	2
Forcipiger longirostris		2							2		1	
Chaetodon kleini			7									
Chaetodon auriga				2								
Chaetodon unimaculatus					2							
Chaetodon lunula		1		2								1
Chaetodon ornatissimus	2	2		2	2	2		4	2	2	2	2
Chaetodon quadrimaculatus				2	3		4	2		2		
Chaetodon multicinctus			4		2	4	2	6	6	7	6	4
POMACANTHIDAE												
Centropyge potteri								1	1			
POMACENTRIDAE												
Abudefduf abdominalis				15								
Plectroglyphidodon johnstonianus		1			3	3	7			2		2
Plectroglyphidodon imparipennis	4		2	1			1					
Chromis vanderbilti	176	7		12	12		13	27		94		23
Chromis hanui			9		3	17		4	4			
Chromis agilis		3	91			17			77		4	17
Stegastes fasciolatus		4	4	9			6			2	3	

APPENDIX 2. Continued.

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12
CIRRHITIDAE												
Paracirrhites arcatus	6	4		4	5	3	12	4		5	1	1
Paracirrhites forsteri				1								
LABRIDAE												
Labroides phthirophagus			5							2		2
Bodianus bilunulatus			1									
Cheilinus rhodochrous		1	1		1	1		1	1			
Pseudocheilinus octotaenia			1					1				
Thalassoma duperrey	11	20	13	13	9	3	37	10	5	17	4	6
Gomphosus varius		2										
Coris gaimard					1	1	3					
Pseudojuloides cerasinus			3									
Stethojulis balteata	1			4		1				6		
Halichoeres ornatissimus		2		4	1		2	2	2	3		
SCARIDAE												
Scarus perspicillatus								1				
Scarus sordidus		4	5	1	2		53	9	9	37	10	6
Scarus psittacus			1		2		53	24		57		7
Scarus rubroviolaceus		1		2		2			1	4	2	1
BLENNIIDAE												
Exallias brevis										1		
Plagiotremus ewaensis	1											
ACANTHURIDAE												
Acanthurus triostegus				80			11	7	7	17		
Acanthurus achilles								3	2			
Acanthurus glaucopareius							2					
Acanthurus leucopareius	1	3		21			6	1	1			
Acanthurus nigrofuscus	4	33	16	22	64	21	89	24	18	120	38	34
Acanthurus nigroris		1				1						
Acanthurus blochi							3					
Acanthurus olivaceus	15	2	10	10		19	19					1
Acanthurus dussumieri				2			3					
Ctenochaetus strigosus		20	82	38	46	32	97	64	52	17	59	86
Ctenochaetus hawaiiensis		4		21	2					4		13
Zebrasoma flavescens		15	65	77	11	13	60	57	45	29	49	29
Zebrasoma veliferum				4								
Naso hexacanthus			80									
Naso lituratus	2	2	1	3	1	1	10	1	5	4	1	4
Naso brevirostris	45		50	4								
ZANCLIDAE												
Zanclus cornutus											4	
BALISTIDAE												
Melichthys niger		1	24	4	9		5	3		7	2	1
Melichthys vidua	1	1	1		1	1				2		1
Sufflamen bursa	1	3	2	3	2		1		1	3		1
OSTRACIIDAE												
Ostracion meleagris						1						
TETRAODONTIDAE												
Canthigaster jactator	3	1		3	4		3			3		
Number of Species	16	29	28	32	26	21	28	27	23	26	19	31
Number of Individuals	278	147	500	454	199	151	514	278	326	458	204	301
Biomass (g/m2)	173.4	167.4	399.2	356.9	93.1	153.4	593.5	245.3	179.3	260.2	136	274.6

APPENDIX 2. Summary of the benthic survey conducted at Station A (South Location) in the boulder zone (Transect 1) at Ka Lae Mano, North Kona on 14 November 2012. Results of the 6 m^2 quadrat sampling of the benthic community (expressed in percent cover) are given in Part A; a 50-point analysis is presented in Part B and counts of invertebrates in Part C. A short summary of the fish census is given in Part D. Water depth 4 m; mean coral coverage is 23.9% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Hydrolithon reinboldii	1.8	2.0				
Corals						
Porites lobata	5.5	2.0		18.0	12.0	4.5
Pocillopora meandrina	7.8	5.0		8.0	5.0	7.0
Pavona varians	1.0				2.0	
Montipora verrucosa	0.1	3.2		4.0	9.0	2.0
Montipora patula	10.0			25.0	4.0	6.0
Montipora verrilli					1.0	
Leptastrea purpurea				1.5		
Sand	9.0	12.0	100	3.0	9.0	35.0
Hard Substratum	64.8	75.8		40.5	58.0	45.5

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Hydrolithon onkodes	2
Corals	
Porites lobata	14
Pocillopora meandrina	4
Montipora patula	2
Pavona durdeni	2
Sand	20
Hard Substratum	56

(Table Continued On Next Page)

APPENDIX 2. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	1
Phylum Arthropoda	
Ciliopagurus strigatus	1
Phylum Echinodermata	
Echinometra mathaei	39
Echinothrix calamaris	3
Echinostrephus aciculatum	1
Tripneustes gratilla	4
Heterocentrotus mammaillatus	2

D. Fish Census (4 x 25m)

16 Species
277 Individuals
Estimated Biomass = 174 g/m^2

APPENDIX 3. Summary of the benthic survey conducted at Station A (South Location) in the biotope of *Porites lobata* (Transect 2) at Ka Lae Mano, North Kona on 15 November 2012. Results of the 6 m^2 quadrat sampling of the benthic community (expressed in percent cover) are given in Part A; a 50-point analysis is presented in Part B and counts of invertebrates in Part C. A short summary of the fish census is given in Part D. Water depth 8.5 m; mean coral coverage is 40.4% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Hydrolithon onkodes	1.0	1.0		2.0	2.0	
Hydrolithon reinboldii		2.0		2.0	4.0	
Sponges						
Halichondria melanadocia				1.0		
Corals						
Porites lobata	28.0	57.0	26.0	32.0	9.0	53.0
Porites compressa	0.8			1.5		
Porites lutea	3.0					
Pocillopora meandrina	3.0	7.0	2.5	2.0		1.0
Montipora patula	1.7	0.3				
Montipora verrucosa			4.0	2.0	1.8	7.0
Sand			28.0		3.0	3.0
Rubble					12.0	
Hard Substratum	62.5	32.7	39.5	57.5	68.2	36.0

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Hydrolithon onkodes	4
Corals	
Porites lobata	30
Montipora verrucosa	4
Pocillopora meandrina	6
Pavona varians	2
Sand	4
Rubble	2
Hard Substratum	48

(Table Continued on Next page)

APPENDIX 3. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	7
Arca ventricosa	5
Phylum Annelida	
Spirobranchus gigantea	23
Phylum Echinodermata	
Echinothrix diadema	20
Echinometra mathaei	62
Echinothrix calamaris	11
Tripneustes gratilla	106
Heterocentrotus mammillatus	7
Chondrocidaris gigantea	1

D. Fish Census (4 x 25m)

29 Species
145 Individuals
Estimated Biomass = 167 g/m^2

APPENDIX 4. Summary of the benthic survey conducted at Station A (South Location) in the biotope of *Porites compressa* (Transect 3) at Ka Lae Mano, North Kona on 15 November 2012. Results of the 6 m^2 quadrat sampling of the benthic community (expressed in percent cover) are given in Part A; a 50-point analysis is presented in Part B and counts of invertebrates in Part C. A short summary of the fish census is given in Part D. Water depth 15.0 m; mean coral coverage is 35.0% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Hydrolithon onkodes	3.0			2.0		
Hydrolithon gardineri	0.7				2.0	3.0
Hydrolithon reinboldii		4.0	5.0	29.0	18.0	16.0
Peyssonellia rubra					1.0	
Corals						
Porites lobata	4.0	1.5	2.0	1.7	2.0	1.0
Porites compressa		15.0	75.5	21.0	22.0	9.5
Porites solida	47.0					
Pocillopora meandrina	2.7		1.0			
Montipora verrucosa		1.5	2.2			
Montipora patula			0.3			
Sand			2.0			
Rubble		35.0		14.0	38.0	55.0
Hard Substratum	42.6	43.0	12.0	32.3	17.0	15.5

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Hydrolithon reinboldii	6
Corals	
Porites lobata	18
Porites compressa	22
Pocillopora meandrina	2
Montipora patula	2
Rubble	6
Hard Substratum	44

(Table Continued on Next Page)

APPENDIX 4. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	4
Arca ventriosa	8
Drupa morum	1
Phylum Annelida	
Spirobranchus gigantea	12
Phylum Echinodermata	
Chondrocidaris gigantea	3
Echinometra mathaei	68
Tripneustes gratilla	147
Heterocentrotus mammillatus	5
Echinothrix diadema	1

D. Fish Census (4 x 25m)

28 Species
497 Individuals
Estimated Biomass = 399 g/m^2

APPENDIX 5. Summary of the benthic survey conducted at Station B (South-Middle Location) in the boulder biotope (Transect 4) at Ka Lae Mano, North Kona on 14 November 2012. Results of the 6 m^2 quadrat sampling of the benthic community (expressed in percent cover) are given in Part A; a 50-point analysis is presented in Part B and counts of invertebrates in Part C. A short summary of the fish census is given in Part D. Water depth 4 to 6.5 m; mean coral coverage is 30.5% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Peyssonellia rubra			3.0	1.0		6.0
Hydrolithon onkodes	3.5	1.0				6.0
Hydrolithon reinboldii	4.0					4.0
Corals						
Porites lobata	53.0	12.0	9.0	5.0	9.0	2.0
Pocillopora meandrina	7.0	8.0	10.0	9.0	9.0	8.5
Pavona varians			1.5		0.9	
Montipora patula	1.0	7.0		3.0		1.0
Montipora verrucosa	2.0	2.0	7.0	4.5		
Montipora verrilli	3.5					5.0
Leptastrea purpurea					0.6	
Leptastrea bewickensis						2.5
Sand		6.0	12.0	4.0	14.0	3.0
Hard Substratum	26.0	64.0	57.5	73.5	66.5	62.0

B. 50-Point Analysis

Species	**Percent of the Total**
Algae	
Peyssonellia rubra	2
Hydrolithon onkodes	2
Corals	
Porites lobata	20
Pocillopora meandrina	6
Montipora verrucosa	2
Montipora patula	4
Sand	8
Hard Substratum	66

APPENDIX 5. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	9
Phylum Annelida	
Spirobranchus gigantea	15
Phylum Echinodermata	
Echinometra mathaei	53
Tripneustes gratilla	32
Echinostrephus aciculatum	2
Echinothrix diadema	1
Echinothrix calamaris	1
Heterocentrotus mammillatus	1

D. Fish Census (4 x 25m)

32 Species
370 Individuals
Estimated Biomass = 357 g/m^2

APPENDIX 6. Summary of the benthic survey conducted at Station B (South-Middle Location) in the biotope of *Porites lobata* (Transect 5) at Ka Lae Mano, North Kona on 14 November 2012. Results of the 6 m^2 quadrat sampling of the benthic community (expressed in percent cover) are given in Part A; a 50-point analysis is presented in Part B and counts of invertebrates in Part C. A short summary of the fish census is given in Part D. Water depth 4 to 7.6 m; mean coral coverage is 55.0% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Corals						
Porites lobata	78.0	62.0	15.0	37.0	37.0	29.0
Porites compressa	1.0				4.0	
Montipora verrucosa	3.0	3.0	6.0	2.0	2.5	8.0
Montipora patula		2.0	3.0	3.0	4.0	0.5
Pocillopora meandrina	6.0		9.0		6.0	7.0
Pavona varians		1.0			1.0	
Sand			38.0	4.0		30.5
Rubble				3.0		6.0
Hard Substratum	12.0	32.0	59.0	51.0	45.5	19.0

B. 50-Point Analysis

Species	**Percent of the Total**
Corals	
Porites lobata	28
Pavona duerdeni	2
Montipora verrucosa	8
Montipora patula	6
Sand	2
Rubble	4
Hard Substratum	50

(Table Continued on Next page)

APPENDIX 6. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Arca ventriosa	5
Spondylus tenebrosus	3
Phylum Annelida	
Spirobranchus gigantea	17
Phylum Echinodermata	
Heterocentrotus mammillatus	9
Echinothrix diadema	5
Echinometra mathaei	85
Tripneustes gratilla	30
Acanthaster plancii	1

D. Fish Census (4 x 25m)

26 Species
194 Individuals
Estimated Biomass = 93 g/m^2

APPENDIX 7. Summary of the benthic survey conducted at Station B (South-Middle Location) in the biotope of *Porites compressa* (Transect 6) at Ka Lae Mano, North Kona on 14 November 2012. Results of the 6 m^2 quadrat sampling of the benthic community (expressed in percent cover) are given in Part A; a 50-point analysis is presented in Part B and counts of invertebrates in Part C. A short summary of the fish census is given in Part D. Water depth 13 m; mean coral coverage is 53.6% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Hydrolithon onkodes						3.0
Hydrolithon reinboldii	1.0				3.5	
Sponges						
Spirastrella vagabunda			0.1			
Corals						
Porites lobata	38.0	49.0	52.0	0.7	86.5	41.0
Porites compressa	5.0	3.0	5.0			23.0
Pocillopora meandrina	1.7					
Montipora verrucosa	7.0	4.0	1.7			
Montipora patula	1.0	1.0				
Pavona varians						2.0
Sand	3.0	39.0	41.2	99.3		
Hard Substratum	43.3	4.0			10.0	31.0

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Peyssonellia rubra	2
Corals	
Porites lobata	30
Porites compressa	6
Montipora verrucosa	4
Montipora verrilli	2
Sand	6
Hard Substratum	50

(Table Continued On Next Page)

APPENDIX 7. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Cypraea tigris	1
Cypraea reticulata	1
Phylum Annelida	
Spirobranchus gigantea	22
Phylum Echinodermata	
Echinometra mathaei	45
Tripneustes gratilla	24
Heterocentrotus mammillatus	4
Eucidaris metularia	1
Echinothrix diadema	1

D. Fish Census (4 x 25m)

21 Species
145 Individuals
Estimated Biomass = 153 g/m^2

APPENDIX 8. Summary of the benthic survey conducted at Station C (North-Middle Location) in the biotope of boulders (Transect 7) at Ka Lae Mano, North Kona on 14 November 2012. Results of the 6 m^2 quadrat sampling of the benthic community (expressed in percent cover) are given in Part A; a 50-point analysis is presented in Part B and counts of invertebrates in Part C. A short summary of the fish census is given in Part D. Water depth 4.9 m; mean coral coverage is 34.6% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Hydrolithon onkodes		2.0		3.0	2.0	
Peyssonellia rubra	3.0		2.0	5.0	5.0	8.0
Corals						
Porites lobata	11.0	9.5	15.0	11.0	8.5	12.0
Pocillopora meandrina	6.5	11.0	13.0	13.0		16.0
Montipora patula	18.0	2.0	28.0			12.0
Montipora verrucosa	1.5	5.0		3.0	1.0	5.0
Pavona varians		5.0	0.8			
Sand	3.5		6.0	2.5	7.0	5.0
Hard Substratum	56.5	65.5	35.2	62.5	76.5	42.0

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Peyssonellia rubra	4
Sporolithon erythraeum	2
Corals	
Porites lobata	20
Pocillopora meandrina	16
Montipora patula	6
Montipora verrucosa	4
Sand	10
Hard Substratum	38

(Table Continued on Next Page)

APPENDIX 8. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	8
Conus rattus	1
Drupa morum	1
Latirus nodatus	1
Phylum Annelida	
Spribranchus gigantea	12
Phylum Arthropoda	
Calcinus latens	1
Phylum Echinodermata	
Echinometra mathaei	67
Tripneustes gratilla	6
Echinostrephus aciculatum	3

D. Fish Census (4 x 25m)

28 Species
507 Individuals
Estimated Biomass 594 g/m^2

APPENDIX 9. Summary of the benthic survey conducted at Station C (North-Middle Location) in the biotope of *Porites lobata* (Transect 8) at Ka Lae Mano, North Kona on 14 November 2012. Results of the 6 m^2 quadrat sampling of the benthic community (expressed in percent cover) are given in Part A; a 50-point analysis is presented in Part B and counts of invertebrates in Part C. A short summary of the fish census is given in Part D. Water depth 11 m; mean coral coverage is 45.5% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Hydrolithon onkodes			4.0			1.0
Hydrolithon reinboldii	5.0	3.0				2.0
Soft Corals						
Palythoa tuberculosa				0.1		
Corals						
Porites lobata	40.0	41.0	42.0	41.0	11.0	46.0
Porites compressa	1.0	8.0	2.0	5.5	1.3	11.0
Pocillopora meandrina	4.5	5.0	5.0		3.0	
Montipora verrucosa	3.0		1.2	0.9		
Pavona varians				0.5		
Sand	2.0				2.0	
Rubble	6.0	3.0	3.0	12.0	58.7	
Hard Substratum	38.5	40.0	42.8	40.0	24.0	40.0

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Peyssonellia rubra	2
Corals	
Porites lobata	22
Porites compressa	8
Pocillopora meandrina	6
Montipora patula	4
Leptastrea purpurea	2
Rubble	4
Hard Substratum	52

APPENDIX 9. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	4
Conus miles	1
Arca ventricosa	3
Phylum Annelida	
Spirobranchus gigantea	19
Phylum Echinodermata	
Echinothrix diadema	5
Heterocentrotus mammillatus	70
Tripneustes gratilla	13
Echinometra mathaei	49
Eucidaris metularia	1

D. Fish Census (4 x 25m)

27 Species
270 Individuals
Estimated Biomass = 245 g/m^2

APPENDIX 10. Summary of the benthic survey conducted at Station C (North-Middle Location) in the biotope of *Porites compressa* (Transect 9) at Ka Lae Mano, North Kona on 14 November 2012. Results of the 6 m^2 quadrat sampling of the benthic community (expressed in percent cover) are given in Part A; a 50-point analysis is presented in Part B and counts of invertebrates in Part C. A short summary of the fish census is given in Part D. Water depth 13-14 m; mean coral coverage is 49.1% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Hydrolithon onkodes	3.0	3.0	2.5	3.0		
Hydrolithon gardineri		1.5		1.5		
Hydrolithon reinboldii	3.0	4.0	6.0	4.5	5.0	3.0
Peysonellia rubra					1.0	
Corals						
Porites lobata	29.0	13.5	29.0	18.0	19.0	61.0
Porites compressa	29.0	16.0	23.0	31.0		
Porites solida	11.0				4.0	
Porites lutea					2.0	
Pocillopora meandrina					3.0	
Montipora verrucosa				1.0	3.9	1.0
Sand					3.0	
Rubble		32.0		18.0		
Hard Substratum	25.0	30.0	39.5	23.0	59.1	35.0

B. 50-Point Analysis

Species	**Percent of the Total**
Algae	
Hydrolithon onkodes	6
Corals	
Porites lobata	20
Porites compressa	16
Montipora patula	4
Rubble	12
Hard Substratum	42

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APPENDIX 10. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	6
Pictada margaritifera	1
Arca ventricosa	2
Phylum Annelida	
Spirobranchus gigantea	24
Phylum Echinodermata	
Echinothrix diadema	1
Heterocentrotus mammillatus	8
Tripneustes gratilla	80
Echinometra mathaei	60

D. Fish Census (4 x 25m)

23 Species
317 Individuals
Estimated Biomass = 179 g/m^2

APPENDIX 11. Summary of the benthic survey conducted at Station D (North Location) in the biotope of boulders (Transect 10) at Ka Lae Mano, North Kona on 14 November 2012. Results of the 6 m^2 quadrat sampling of the benthic community (expressed in percent cover) are given in Part A; a 50-point analysis is presented in Part B and counts of invertebrates in Part C. A short summary of the fish census is given in Part D. Water depth 5.8 m; mean coral coverage is 48.7% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Hydrolithon onkodes	3.0	4.0				3.0
Peysonnellia rubra	9.0					
Corals						
Porites lobata	38.0	20.0	34.0	35.0	35.0	51.0
Porites lutea						5.0
Pocillopora meandrina	6.0	12.5	8.0	7.5	5.0	3.0
Montipora verrucosa		0.6		1.0	3.0	1.0
Montipora patula		6.0	5.0	1.0	5.0	7.0
Montipora verrilli	1.2					
Pavona varians				0.5		
Pavona duerdeni			0.9			
Sand			1.0			
Hard Substratum	42.8	56.9	51.1	55.0	52.0	30.0

B. 50-Point Analysis

Species	**Percent of the Total**
Algae	
Hydrolithon reinboldii	2
Corals	
Porites lobata	28
Pocillopora meandrina	14
Montipora patula	6
Leptastrea purpurea	2
Hard Substratum	48

(Table Continued on Next Page)

APPENDIX 11. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	8
Conus lividus	1
Phylum Annelida	
Spirobranchus gigantea	21
Phylum Echinodermata	
Echinostrephus aciculatum	8
Echinometra mathaei	34
Holothuria atra	1
Tripneustes gratilla	2
Echinothrix diadema	3

D. Fish Census (4 x 25m)

26 Species
448 Individuals
Estimated Biomass = 260 g/m^2

APPENDIX 12. Summary of the benthic survey conducted at Station D (North Location) in the biotope of *Porites lobata* (Transect 11) at Ka Lae Mano, North Kona on 14 November 2012. Results of the 6 m^2 quadrat sampling of the benthic community (expressed in percent cover) are given in Part A; a 50-point analysis is presented in Part B and counts of invertebrates in Part C. A short summary of the fish census is given in Part D. Water depth 9-10 m; mean coral coverage is 55.2% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Hydrolithon onkodes		1.0	2.0	1.5		
Hydrolithon reinboldii		1.5	3.0	1.0	1.5	1.0
Corals						
Porites lobata	19.0	47.0	34.0	32.0	43.0	17.0
Porites compressa	11.0	6.0	7.0	6.0	3.0	6.5
Porites lutea	66.0					
Pocillopora meandrina	1.0		2.0	3.5	1.0	
Montipora patula		6.0				4.0
Montipora verrucosa		1.5	1.0	3.8	4.0	3.0
Pavona varians		0.7	1.5		1.0	
Rubble						6.0
Hard Substratum	4.0	38.0	67.0	61.8	51.8	54.8

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Porolithon onkodes	2
Pneophyllum conicum	2
Corals	
Porites lobata	28
Porites compressa	10
Porites lutea	2
Pocillopora meandrina	4
Montipora patula	4
Pavona duerdeni	2
Rubble	2
Hard Substratum	44

(Table Continued on Next Page)

APPENDIX 12. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Arca ventricosa	1
Spondylus tenebrosus	3
Phylum Annelida	
Spirobranchus gigantea	19
Phylum Echinodermata	
Echinothrix diadema	5
Echinometra mathaei	32
Heterocentrotus mammillatus	14
Tripneustes gratilla	19

D. Fish Census (4 x 25m)

19 Species
193 Individuals
Estimated Biomass = 136 g/m^2

APPENDIX 13. Summary of the benthic survey conducted at Station D (North Location) in the biotope of *Porites compressa* (Transect 12) at Ka Lae Mano, North Kona on 14 November 2012. Results of the 6 m^2 quadrat sampling of the benthic community (expressed in percent cover) are given in Part A; a 50-point analysis is presented in Part B and counts of invertebrates in Part C. A short summary of the fish census is given in Part D. Water depth 12-13.5 m; mean coral coverage is 23.1% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Hydrolithon onkodes	5.0	4.0	5.0	2.0		4.0
Hydrolithon reinboldii	2.5	2.0	2.0	4.0	3.0	3.0
Pneophyllum conicum				2.5		
Corals						
Porites lobata	12.0	13.0	24.0	31.0	33.0	11.0
Porites compressa	14.0	4.0	14.0		5.5	1.0
Montipora patula					0.6	
Montipora verrucosa	0.5		0.7	1.3	3.0	
Pavona varians					0.2	
Rubble		12.0	3.0	15.0	4.0	14.0
Hard Substratum	66.0	65.0	51.3	44.2	50.7	67.0

B. 50-Point Analysis

Species	**Percent of the Total**
Algae	
Peyssonellia rubra	2
Hydrolithon reinboldii	6
Corals	
Porites lobata	22
Porites compressa	16
Porites lutea	2
Pocillopora meandrina	2
Montipora patula	4
Rubble	10
Hard Substratum	36

APPENDIX 13. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	5
Latirus nodatus	1
Arca ventricosa	1
Phylum Annelida	
Spirobranchus gigantea	23
Phylum Echinodermata	
Echinothrix diadema	1
Echinometra mathaei	58
Heterocentrotus mammillatus	9
Tripneustes gratilla	31
Chondrocidaris gigantea	1
Eucidaris metularia	1

D. Fish Census (4 x 25m)

31 Species
289 Individuals
Estimated Biomass = 275 g/m^2