QUANTITATIVE ASSESSMENT OF THE MARINE COMMUNITIES FRONTING THE KA LAE MANO DEVELOPMENT - 2011 ANNUAL SURVEY

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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. Five 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. This document presents the data from the 7-8 December 2011 "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 Hawaii 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 - 2011 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 Kaahumanu 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 fifth "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 on 7-8 December 2011. This document presents the results of the 2011 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 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 December 2011quantitative 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 December 2011survey. 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 7-8 December 2011.

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 brown surgeonfish or 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 whitebar surgeonfish or maiko'iko (*Acanthurus leucopareius*) 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 33 to 384 individuals (mean = 211 individual/transect). The estiamted 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*) conprising 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 evermanni, 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 brown surgeonfish or ma'i'i'i (*Acanthurus nigrofuscus*), the yellow tang or lau'ipala (*Zebrasoma flavescens*), the saddleback wrasse or hinalea lauwili (*Thalassoma duperrey*) and the palenose parrotfish or 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 include the whitebar surgeonfish or maikoiko (*Acanthurus leucoparieus*), the orangebar surgeonfish or na'ena'e (*Acanthurus oliveceus*), the black surgeonfish (*Ctenochaetus hawaiiensis*), redlip parrotfish or palukaluka (*Scarus rubroviolaeus*) and the bulletnose parrotfish or 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 brown surgeonfish or ma'i'i'i (*Acanthurus nigrofuscus*), the yellow tang or lau'ipala (*Zebrasoma flavescens*), the goldring surgeonfish or kole (*Ctenochaetus strigosus*), the bullethead parrotfish or uhu (*Scarus sordidus*) and the palenose parrotfish or uhu (*Scarus psittacus*). By weight, the most important contributors to the standing crop estimates in the biotope of boulders were the orangespine unicornfish or umaumalei (*Naso lituratus*) comprising from 10% to 69% of the estimated standing crop at a station, the orangeband surgeonfish or 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 2011 survey. Appendix 1 presents 2011 fish census results which are discussed below.

In the 2011 survey, nine coral species were found in the quadrats and the mean was six species per transect. Mean coral coverage was estimated to be 48.2% which is up 6.3% over the previous (2009) survey of this biotope. Coral coverage on the individual transects ranged from 38.8% to 52.0%. 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, Fungia scutaria, 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,* and *Porites rus*.

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 (the wana *Echinothrix diadema*, the banded urchin *E. calamaris*, the boring urchin *Echinostrephus aciculatum*, the green urchin *Echinometra mathaei*, the slate pencil urchin *Heterocentrotus mammillatus*, the black urchin *Tripneustes gratilla* and less commonly seen serrate urchin (*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 planci*. 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 textile cone (*Conus textile*) and hebrew cone (*Conus ebreus*).

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 the ma'i'i'i (*Acanthurus nigrofuscus*), the kole (*Ctenochaetus strigosus*), yellow tang or lau'ipala (*Zebrasoma flavescens*). Fishes contributing heavily to the 2011 standing crop estimates in the biotope of *Porites lobata* included the bulletnose parrotfish or uhu (*Scarus sordidus*) making up 13% to 42% of the total, the na'ena'e (*Acanthurus olivaceus*) adding 8 to 11%, the lau'ipala (*Zebrasoma flavescens*) contributing 18 to 24%, the uhu (*Scarus sordidus*) adding 13 to 42% and the kole (*Ctenochaetus strigosus*) comprising 11% to 32% on transects. Besides these species, other species contributing substantially on individual transects were as follows in the 2011 survey: at Station 2: the the whitebar surgeonfish or maikoiko (*Acanthurus leucoparieus*) adding 33%; at Station 5: the black triggerfish or humuhumu ele'ele (*Melichthys niger*) adding 9% and at Station 8: the redlip parrotfish or palukaluka (*Scarus rubroviolaceus*) adding 13%.

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 (the wana *Echinothrix diadema*, the banded urchin *E. calamaris*, the boring urchin *Echinostrephus aciculatum*, the green urchin *Echinometra mathaei*, the slate pencil urchin *Heterocentrotus mammillatus*, the black urchin *Tripneustes gratilla* and less commonly seen serrate urchin (*Chondrocidaris gigantea*). Other invertebrates encountered in the 2009 survey of this biotope include the boring bivalve (*Arca ventricosa*), rock oyster (*Spondylus tenebrosus*), Christmas tree worm (*Spirobranchus giganteus*), spindle shell (*Latirus nodatus*), black-lipped pearl oyster (*Pincada margaritifera*) the black sea cucumber (*Holothuria atra*) and the coral-feeding starfish (*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 the ma'i'i'i (*Acanthurus nigrofuscus*), the kole (*Ctenochaetus strigosus*), damselfish (*Chromis vanderbilti*), lau'ipala (*Zebrasoma flavescens*) and the bulletnose parrotfish or uhu (*Scarus sordidus*). Fishes contributing heavily to the 2009 standing crop estimates in the biotope of *Porites lobata* included the bulletnose parrotfish or uhu (*Scarus sordidus*) making up 13% to 24% of the total, the orangespine unicornfish or umaumalei (*Naso lituratus*) adding 10% to 25% and the kole (*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: the the whitebar surgeonfish or maikoiko (*Acanthurus leucoparieus*) adding 34%; at Station 5: the yellow tang or lau'ipala (*Zebrasoma flavescens*) adding 10%; at Station 8: the spectacled parrotfish or uhu uli'uli (*Scarus perspicillatus*) making up 13% and the redlip parrotfish or palukaluka (*Scarus rubroviolaceus*) adding 27% and at Station 11 the blue-spotted grouper or roi (*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 (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*). Other invertebrates encountered in the 2008 survey of this biotope include the boring bivalve (*Arca ventricosa*), rock oyster

(*Spondylus tenebrosus*), Christmas tree worm (*Spirobranchus giganteus*), miter shell (*Mitra assimilis*), spindle shell (*Latirus nodatus*), pinna shell (*Streptopinna saccata*), the sea cucumbers or loli (*Actinopyge maruitana* and *Holothuria atra*), the hermit crab (*Dardanus deformis*) and the black-lipped pearl oyster or pa, *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 the ma'i'i'i (*Acanthurus nigrofuscus*), the kole (*Ctenochaetus strigosus*), damselfish (*Chromis vanderbilti*), lau'ipala (*Zebrasoma flavescens*) and the hinalea lauwili (*Thalassoma duperrey*). Fishes contributing heavily to the 2008 standing crop estimates in the biotope of *Porites lobata* included the umaumalei (*Naso lituratus*) making up from 7 to 16% of the total, the lau'ipala (*Zebrasoma flavescens*) adding from 8 to 14%, the brick soldierfish or menpachi (*Myripristes amaenus*) contributing 12 to 13% and the kole (*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: the palani (*Acanthurus dussumieri*) making up 7%, the palukaluka (*Scarus rubroviolaceus*) adding 31% and the black surgeonfish (*Ctenochaetus hawaiiensis*) contributing 6%; at Station 5, the uhu (*Scarus sordidus*) added 39% to the total and at Station 11, the roi (*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. 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 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 (the long-spine urchin *Diadema setosum*, the wana *Echinothrix diadema*, the banded urchin *E. calamaris*, the boring urchin *Echinostrephus aciculatum*, the green urchin *Echinometra mathaei*, the slate pencil urchin *Heterocentrotus mammillatus*, the black urchin *Tripneustes gratilla* and less commonly seen serrate urchin (*Chondrocidaris gigantea*). Other invertebrates encountered in the 2007 survey of this biotope include the boring bivalve (*Arca ventricosa*), rock oyster (*Spondylus tenebrosus*), Christmas tree worm (*Spirobranchus giganteus*), cone shells (*Conus vitulinus* and *C. striatus*), spindle shell (*Latirus nodatus*), burrowing ghost shrimp (*Callianassa variabilis*) and the coral-feeding starfish, *Acanthaster planci*. 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 hebrew cone (*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 the ma'i'i'i (*Acanthurus nigrofuscus*), the kole (*Ctenochaetus strigosus*), damselfish (*Chromis vanderbilti*), lau'ipala (*Zebrasoma flavescens*), menpachi or u'u (*Myripristes amaenus*), the sleek unicornfish or kala holo (*Naso hexacanthus*) and the parrotfishes or uhus (*Scarus sordidus* and *S. psittacus*). Fishes contributing heavily to the 2007 standing crop estimates in the biotope of *Porites lobata* included the bulletnose parrotfish or uhu (*Scarus sordidus*) making up 15% to 22% of the total, the black kole (*Ctenochaetus hawaiiensis*) adding 11% to 17%, the blue-spotted grouper or roi (*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: the eye-stripe surgeonfish or palani (*Acanthurus dussumieri*) making up 22% and the whitebar surgeonfish or maikoiko (*Acanthurus leucoparieus*); at Station 8: the brick soldierfish or menpachi (*Myripristes amaenus*) adding 21% and the goldring surgeonfish or kole (*Ctenochaetus strigosus*) making up 14%; at Station 11: the sleek unicornfish or kala holo (*Naso hexacanthus*) contributing 17% and the orange-spine unicornfish or umaumalei (*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 from19.3 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 kala holo (*Naso hexacanthus*) and the parrotfish or uhu (*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 the na'ena'e (*Acanthurus olivaceus*), the ma'i'i'i (*Acanthurus nigrofuscus*), the whitebar surgeonfish or maiko'iko (*Acanthurus leucoparieus*), the kole (*Ctenochaetus striogsus*), the palani (*Acanthurus dussumieri*), the black kole (*Ctenochaetus hawaiiensis*), umaumalei (*Naso lituratus*), roi (*Cephalopholis argus*), menpachi (*Myripristes amaenus*), uhu (*Scarus sordidus* and the lau'ipala (*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 the damselfish (*Chromis vanderbilti*), ma'i'i'i (*Acanthurus nigrofuscus*), kole (*Ctenochaetus strigosus*) and the lau'ipala (*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 include the lau'ipala (*Zebrasoma flavescens*), black triggerfish or humuhumu 'ele'ele (*Melichthys niger*), kole (*Ctenochaetus strigosus*), bullethead parrotfish or uhu (*Scarus sordidus*), umaumalei (*Naso lituratus*), Hawaiian surgeonfish (*Ctenochaetus hawaiiensis*) and the blue-spotted grouper or roi (*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 2011 fish census data are given in Appendix 1.

The 2011 quadrat survey of the biotope of *Porites compressa* noted seven coral species (*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 is 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 2011 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 rock oyster (*Spondylus tenebrosus*), boring bivalve (*Arca ventriosa*), christmas tree worm (*Spriobranchus giganteus*), the polychaete (*Sabellastarte sanctijosephi*), pearl oyster (*Pinctada margaritifera*), serrate urchin (*Chondrocidaris gigantea*), green urchin (*Echinometra mathaei*), black urchin (*Tripneustes gratilla*), wana (*Echinothrix diadema*), slate-pencil urchin (*Heterocentrotus mammillatus*), cushion starfish (*Culcita novaeguineae*), the coral-feeding starfish (*Acanthaster plancii*) and the black sea cucumber or loli (*Holothuria atra*). The number of individual invertebrates encountered per transect in 2009 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 the rock oyster (*Spondylus tenebrosus*), boring bivalve (*Arca ventriosa*), christmas tree worm (*Spriobranchus giganteus*), the polychaete (*Loimia medusa*), serrate urchin (*Chondrocidaris gigantea*), green urchin (*Echinometra mathaei*), black urchin (*Tripneustes gratilla*), wana (*Echinothrix diadema*), slate pencil urchin (*Heterocentrotus mammillatus*), the coral-feeding starfish (*Acanthaster plancii*) and the black sea cucumber or loli (*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 the rock oyster (*Spondylus tenebrosus*), boring bivalve (*Arca ventriosa*), christmas tree worm (*Spriobranchus giganteus*), serrate urchin (*Chondrocidaris gigantea*), green urchin (*Echinometra mathaei*), black urchin (*Tripneustes gratilla*), wana (*Echinothrix diadema*), slate pencil urchin (*Heterocentrotus *mammillatus*) and the drupe shell (*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 the leopard cone shell (*Conus leopardus*), imperial cone (*Conus imperialis*), banded shrimp (*Stenopus hispidus*), green shrimp (*Saron marmoraeus*) long-spined sea urchin (*Diadema setosum*), the cushion starfish (*Culcita novaeguineae*), starfishes (*Linckia multiflora* and *L. diplax*), and sea cucumbers or loli (*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 the rock oyster (*Spondylus tenebrosus*), boring bivalve (*Arca ventriosa*), christmas tree worm (*Spriobranchus giganteus*), serrate urchin (*Chondrocidaris gigantea*), green urchin (*Echinometra mathaei*), black urchin (*Tripneustes gratilla*), wana (*Echinothrix diadema*), slate pencil urchin (*Heterocentrotus mammillatus*), banded urchin (*Echinothrix calamaris*), the pinna shell (*Streptopinna saccata*) and the brown sea cucumber or loli (*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 the leopard cone shell (*Conus leopardus*), imperial cone (*Conus imperialis*), banded shrimp (*Stenopus hispidus*), green shrimp (*Saron marmoraeus*) long-spined sea urchin (*Diadema setosum*), the polychaete (*Loimia medusa*), the cushion starfish (*Culcita novaeguineae*), starfishes (*Linckia multiflora* and *L. diplax*), and sea cucumbers or loli (*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 the polychaete (*Loimia medusa*) and the and the cushion starfish (*Culcita novaeguineae*). The 2005 census of macroinvertebrates noted eleven species including the rock oyster (*Spondylus tenebrosus*), christmas tree worm (*Spriobranchus gigantea*), tiger cowry (*Cypraea tigris*), black-lipped pearl oyster or pa (*Pinctada margaritifera*) and sea urchins (*Tripneustes gratilla, Echinothrix diadema, Echinothrix calamaris, Heterocentrotus mammillatus, Echinometra mathaei* and *Chondrocidaris gigantea*).

The results of the 2011 survey of fishes in the biotope of *Porites compressa* are resented 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 the kole (*Ctenochaetus* *strigosus*), lau'ipala (*Zebrasoma flavescens*), uhu (*Scarus sordidus*), ma'i'i'i (*Acanthurus nigrofuscus*) and the damselfish (*Chromis hanui*). Major contributors to the estimated standing crop included the uhu (*Scarus sordidus*) making up from 5 to 38% of the total, the na'ena'e (*Acanthurus olivaceus*) comprising from 14 to 27%, the kole (*Ctenochaetus strigosus*) adding 7 to 13%, the lau'ipala (*Zebrasoma flavescens*) contributing 6 to 12% and the sleek unicornfish or kala holo (*Naso hexacanthus*) contributing from 23 to 51% on these transects. Other species were important on individual transects; these included at station 3 the kala lolo (*Naso brevirostris* - 11%) and the amberjack or kahala (*Seriola dumerili*) adding 14% to the total. At station 6 the ringtail wrasse or 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 the damselfishes (*Chromis agilis* and *C. vanderbilti*), the sergeant major or mamo (*Abudefduf abdominalis*), the na'en'e (*Acanthurus olivaceus*), kole (*Ctenochaetus strigosus*), lau'ipala (*Zebrasoma flavescens*), kala holo (*Naso hexacanthus*), menpachi (*Myripristes amaenus*), uhu (*Scarus psittacus*), ma'i'i'i (*Acanthurus nigrofuscus*), kala lolo (*Naso brevirostris*) and the black triggerfish or humuhumu'ele'ele (*Melichthys niger*). Major contributors to the estimated standing crop included the uhu (*Scarus sordidus*) making up from 10 to 32% of the total, the na'ena'e (*Acanthurus olivaceus*) comprising from 5 to 28%, the kole (*Ctenochaetus strigosus*) adding 6 to 14% and the emperor or mu (*Monotaxis grandoculis*) contributing from 19 to 30% on these transects. Other species were important on individual transects; these included at station 3 the kala holo (*Naso hexacanthus* - 34%) and the humuhumu'ele'ele (*Melichthys niger*) adding 12% to the total. At station 6 the uhu (*Scarus psittacus*) added 14% and the palukaluka (*Scarus rubroviolaceus*) contributed 11% to the total and at station 9 the roi (*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 the damselfish (*Chromis* *agilis*), the ma'i'i'i (*Acanthurus nigrofuscus*), kole (*Ctenochaetus strigosus*), lau'ipala (*Zebrasoma flavescens*), kala holo (*Naso hexacanthus*) and the kala lolo (*Naso brevirostris*). Major contributors to the estimated standing crop included the uhu (*Scarus sordidus*) making up from 19 to 24% of the total, kala holo (*Naso hexacanthus*) comprising from 33 to 80% and the roi (*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, the na'ena'e (*Acanthurus olivaceus*) added 13%, kala lolo (*Naso brevirostris*) contributed 18%, at station 6 the weke (*Mulloides flavolineatus*) added 10% and the palukaluka (*Scarus rubroviolaceus*) contributed 18% and finally at station 9 the grey snapper or uku (*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 the damselfishes (*Chromis agilis* and *C. vanderbilti*), the sergeant major or mamo (*Abudefduf abdominalis*), the na'en'e (*Acanthurus olivaceus*), kole (*Ctenochaetus strigosus*), lau'ipala (*Zebrasoma flavescens*), kala holo (*Naso hexacanthus*), menpachi (*Myripristes amaenus*), uhu (*Scarus sordidus*), palukaluka (*Scarus rubroviolaceus*), kala holo (*Naso hexacanthus*) and the black triggerfish or humuhumu'ele'ele (*Melichthys niger*). Major contributors to the estimated standing crop included the uhu (*Scarus sordidus*) making up from 15 to 61% of the total, kala holo (*Naso hexacanthus*) comprising from 15 to 28% and on individual transects other species were important. These included at station 3 the na'ena'e (*Acanthurus olivaceus* - 32%), palukaluka (*Scarus rubroviolaceus* - 30%) and the milkfish or awa (*Chanos chanos*) adding 11% to the total. At station 9 the yellow tang or lau'ipala (*Zebrasoma flavescens*) contributed 12% to the total and at station 12, the menpachi or u'u (*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 the damselfish (*Chromis agilis*), the ma'i'i'i (*Acanthurus nigrofuscus*), the na'en'e (*Acanthurus olivaceus*), kole (*Ctenochaetus strigosus*), lau'ipala (*Zebrasoma flavescens*), kala holo (*Naso hexacanthus*), menpachi (*Myripristes amaenus*), uhu (*Scarus sordidus*), and the black triggerfish or humuhumu'ele'ele (*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 na'ena'e (*Acanthurus olivaceus*), kala holo (*Naso hexacanthus*), maiko'iko (*Acanthurus leucoparieus*), roi (*Cephalopholis argus*), menpachi (*Myripristes amaenus*), uhus (*Scarus sordidus* and *S. psittacus*), palukaluka (*Scarus rubroviolaceus*), lau'ipala (*Zebrasoma flavescens*) and the kole (*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 the damselfish (*Chromis agilis*), the ma'i'i'i (*Acanthurus nigrofuscus*), kole (*Ctenochaetus strigosus*), lau'ipala (*Zebrasoma flavescens*), umaumalei (*Naso lituratus*), na'ena'e (*Acanthurus olivaceus*), the sleek unicornfish or kala holo (*Naso hexacanthus*) and the whitebar surgeonfish or maiko'iko (*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 the kole (*Ctenochaetus strigosus*), ma'i'i'i (*Acanthurus nigrofuscus*), umaumalei (*Naso lituratus*), maiko'iko (*Acanthurus leucoparieus*), brick soldierfish or menpachi (*Myripristes amaenus*), kala holo (*Naso hexacanthus*), spotted unicornfish or kala lolo (*Naso brevirostris*), the scrawled filefish or 'o'ili (*Alutera scripta*), the porgy or mu (*Monotaxis grandoculis*), and the grey snapper or uku (*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 Hawaii 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 Hawaii 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. 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 survey. 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 survey 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 eight 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 and in December 2011. 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 as well as the most recent survey completed in 2011. Questions that may be asked are: (1) Have the marine communities as reflected in the biological measures used here changed among the eight surveys spanning a seventeen-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 eight surveys spanning a seventeen-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. May and September 2009 as well as in 2011?” To address this question, the grand annual means of parameters measured in the eight surveys are compared and the statistical results are presented in Table 3. Referring to Table 3, the mean number of coral species per transect has shown no change but the mean percent coral cover per transect was significantly greater in 2002 than any other year with the 1993 coral coverage being significantly greater than the other six years which are all related (i.e., having no significant differences). However it should be noted that the mean coral coverage estimates in the more recent 2005 - 2011 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 2005-2011). 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 steady increase (from 26.0 to 42.5%; see Table 3). The mean number of invertebrate species seen per transect showed a significant decline in 2005 over the other seven (1993, 2002, 2006 - 2011) surveys. 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 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 (2005-2011). 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 (2005-2011) 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 eight 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 seven other survey dates (1993, 2005-2011 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 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 two of these, the significant differences were clearly supported by the SNK Test; these included the annual mean percent coverage by corals, the annual mean number of invertebrate individuals annually censused. Mean coral coverage was significantly greater in 2002 over all other years and the mean coverage in 1993 was significantly greater than the coverage found in all other surveys (i.e., 2005-2011) all of which were related due to high overlap (Table 4). In 2005 the annual mean number of diurnally-exposed macroinvertebrate individuals was significantly less than all other years which were all related. Finally despite the ANOVA finding significant differences with the mean number of individual fishes annually censused as well as the number of invertebrate species seen on a transect in the biotope of *Porites lobata*, the SNK Test failed to find clear statistical separation due to overlap suggesting that if any significant differences exist, they may only occur with the extremes (where for fish the 2009 mean being significantly greater than the 2002 mean and for annual mean number of invertebrate species seen on a transect the 1993 mean is significantly greater than the 2005 mean; 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*.

3. Biotope of *Porites compressa* - In the biotope of *Porites compressa* the Kruskal-Wallis ANOVA noted significant differences among the annual means for three parameters: the percent cover by corals, the number of fish species and the number of individual fish censused. The SNK Test found clear statistical separation among the annual means for only one of these three parameters as follows: the annual mean percent coral cover was significantly greater in 2002 and 1993 over all other survey dates (2005-2011). The SNK test failed to find clear statistical separation with 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 species, the number of invertebrate individuals or the estimated biomass of fishes on a transect over the

eight 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 eight 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 - 2011 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 six years. Examination of this table reveals that two fish families contribute most heavily to the estimated standing crop at these sampled stations in the six 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 and in the 2011 survey they made up 78.3 percent 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 maikoiko (*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.

DISCUSSION

1. Fish Communities

The eight 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 Hawaii 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 eight 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 eight 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 2011, 73 species were encountered in the twelve transects (Appendix 1). The surgeonfishes were the most important in terms of abundance in all eight 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. Thus surgeonfishes are the single largest contributor to the standing crop at all stations through most of the six most recent surveys (2005-2011).

The grand annual mean biomass estimates for the 2005-2011 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 six annual surveys. Despite this, the question, "Why the differences in biomass among the six 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 Hawaii 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 Kaahamanu 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 Hawaii. 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 (*Pricanthus 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 (‘alinalina - *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 2006-2011 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 2006-2011 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 - 2011)? 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 - 2011 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 eight surveys), coral communities offshore of Ka Lae Mano appear to have declined in coverage with the 2005 - 2011 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 six 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 was done in the 2005 - 2011 surveys rather than to actual declines in coral coverage. Furthermore it should be noted that in the last five surveys (2006-2011), annual mean coral coverage has steadily increased from 26.0% in 2006 to 42.5% in 2011. 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 five 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 less in the 2005 - 2011 period relative to the first (1993 and 2002) surveys but as noted above, has consistently increased from 2006 through 2011 (overall mean increase is 16.5%). 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 (2005-2011) 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 seven 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 Hawaii 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 2006-2011 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 or the early December 2011 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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APPENDIX 1. Results of the quantitative visual censuses conducted at 12 locations offshore of Ka Lae Mano, North Kona on 7-8 December 2011. 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
HOLOCENTRIDAE												
Myripristis amaenus			5									14
AULOSTOMIDAE												
Aulostomus chinensis								1	1		1	2
FISTULARIIDAE												
Fistularia commersoni											1	
SERRANIDAE												
Cephalopholis argus		1			1							
CARANGIDAE												
Seriola dumerili			2									
LUTJANIDAE												
Lutjanus kasmira		1										
MULLIDAE												
Parupeneus multifasciatus			5	1		1	3	1	1	4	1	3
Parupeneus bifasciatus				2			1			1		
KYPHOSIDAE												
Kyphosus bigibbus				1								
CHAETODONTIDAE												
Forcipiger flavissimus		2	2	2				1	1	1		3
Forcipiger longirostris				2							2	
Chaetodon kleini									3			
Chaetodon unimaculatus					1		2					
Chaetodon lunula		2		2		2						
Chaetodon ornatissimus		2				2		2			3	
Chaetodon quadrimaculatus		2		4	1					1		
Chaetodon multicinctus		2	4		2	4		2	6	2	8	1
POMACANTHIDAE												
Centropyge potteri									1			
POMACENTRIDAE												
Abudefduf abdominalis				7								
Plectroglyphidodon johnstonianus			2		2	1	1					
Plectroglyphidodon imparipennis	3						2					
Chromis vanderbilti		15			12		57			121		30
Chromis ovalis								1				
Chromis verater												9
Chromis hanui			11			11		4	7			
Chromis agilis		7	54		7	8		9	38		5	35
Stegastes fasciolatus		5	2					1				3
CIRRHITIDAE												
Paracirrhites arcatus	3	6	3	2	5	4	6	1	4	4	2	3
Paracirrhites forsteri						1					1	1
LABRIDAE												
Bodianus bilunulatus			1									
Cheilinus rhodochrous			1			2		1			3	
Pseudocheilinus octotaenia								1	1			

APPENDIX 2. Continued.

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12
LABRIDAE												
Thalassoma duperrey	4	16	5	44	26	4	50	11	10	52	4	
Thalassoma lutescens										1		
Gomphosus varius			3	3	1	1			2	6	1	1
Coris gaimard				2		1				1		
Stethojulis balteata	1	1			1		3			4		
Macropharyngodon geoffroy							1					
Anampses chrysocephalus		2										
Halichoeres ornatissimus				1		1	2		1	2	1	
SCARIDAE												
Calotomus carolinus		1										
Scarus dubius							1					
Scarus sordidus		2	19	1	14	16		13	8	37	10	23
Scarus psittacus					8	8	16			44	1	80
Scarus rubroviolaceus				1	1		1	2	2			1
BLENNIIDAE												
Plagiotremus ewaensis	1											
ACANTHURIDAE												
Acanthurus triostegus		7		4						11		
Acanthurus achilles				2				2	1			
Acanthurus leucopareius		103		21				7		7	1	1
Acanthurus nigrofuscus	16	66	41	36	50	28	51		12	51	38	38
Acanthurus nigroris				4								
Acanthurus blochi		1										
Acanthurus olivaceus			18	16	2	5	3				3	
Acanthurus dussumieri		3										
Ctenochaetus strigosus		29	115		12	24		43	43		101	68
Ctenochaetus hawaiiensis				6	2	1				1		
Zebrasoma flavescens	1	121	116	26	7	13	18	64	44	19	59	52
Zebrasoma veliferum				2								
Naso hexacanthus									20			16
Naso lituratus	1	35	8	3			4	1	1	3		4
Naso brevirostris		6	20									
ZANCLIDAE												
Zanclus cornutus			1		1		1					
BALISTIDAE												
Melichthys niger			4		8		1	1		9		
Melichthys vidua			1		1		1					1
Sufflamen bursa	1		2	1	2	2	1	2		2	1	1
Sufflamen fraenatus												1
MONACANTHIDAE												
Cantherhines sandwichiensis				1								
OSTRACIIDAE												
Ostracion meleagris		1										
Ostracion whitleyi									1			1
TETRAODONTIDAE												
Arothron meleagris		1										
Canthigaster coronata						1						
Canthigaster jactator	2					2	2					
Canthigaster rivulata							1					
Number of Species	10	27	25	27	23	24	24	22	22	23	21	25
Number of Individuals	34	442	448	246	172	149	236	179	217	394	258	404
Biomass (g/m2)	8.5	578.3	320.0	208.0	142.3	85.9	123.0	104.7	153.6	177.0	123.2	272.4

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 8 December 2011. 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 17.5% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Corals						
Porites lobata	1.0	5.5		16.0	12.0	
Pocillopora meandrina	0.8	6.5		7.0	9.5	6.0
Pavona varians	0.3					
Montipora verrucosa		0.1			9.0	5.0
Montipora patula	3.5			14.0	4.0	2.0
Leptastrea purpurea	0.6			2.0		
Sand			100			27.0
Hard Substratum	93.8	87.9		61.0	65.5	16.0

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Porolithon onkodes	2
Corals	
Porites lobata	12
Pocillopora meandrina	2
Montipora patula	2
Pavona durdeni	2
Sand	14
Hard Substratum	66

(Table Continued On Next Page)

APPENDIX 2. Continued.

C. Invertebrate Census (4 x 25m)

Species	**Number**
Phylum Annelida	
Spriobranchus gigantea	12
Phylum Echinodermata	
Echinometra mathaei	21
Echinothrix diadema	5
Echinostrephus aciculatum	1
Tripneustes gratilla	2

D. Fish Census (4 x 25m)

10 Species
33 Individuals
Estimated Biomass = 9 g/m^2

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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 8 December 2011. 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 38.8% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Porolithon onkodes	2.0	2.0	2.0		3.0	
Peyssonellia rubra					2.0	
Pneophyllum conicum					1.0	
Corals						
Porites lobata	51.0	25.0	31.0	23.0	8.0	52.0
Pocillopora meandrina	3.0		3.0	6.0		0.8
Montipora patula	4.0	6.2				
Montipora verrucosa		1.8	4.0	5.0	2.0	6.0
Pavona duerdeni			0.7			
Sand			19.0			
Rubble					38.0	
Hard Substratum	40.0	65.0	40.3	66.0	46.0	41.2

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Porolithon onkodes	2
Corals	
Porites lobata	26
Montipora verrucosa	4
Pocillopora meandrina	2
Pavona varians	2
Sand	4
Rubble	2
Hard Substratum	58

(Table Continued on Next page)

APPENDIX 3. Continued.

C. Invertebrate Census (4 x 25m)

Species	**Number**
Phylum Mollusca	
Spondylus tenebrosus	7
Phylum Annelida	
Spirobranchus gigantea	21
Phylum Echinodermata	
Echinothrix diadema	15
Echinometra mathaei	103
Echinothrix calamaris	15
Tripneustes gratilla	43
Heterocentrotus mammillatus	4
Acanthaster plancii	1

D. Fish Census (4 x 25m)

27 Species
440 Individuals
Estimated Biomass = 578 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 8 December 2011. 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 48.4% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Porolithon onkodes	5.0	4.0		6.0	12.0	1.8
Porolithon gardineri					0.3	
Corals						
Porites lobata	47.0	21.0	33.0	13.0	0.9	34.0
Porites compressa	13.0	13.0	47.0	34.0	15.0	0.9
Pocillopora meandrina	5.5	1.2	2.0	2.0		
Montipora verrucosa		2.0			0.5	
Montipora patula		1.5	0.8	2.0	0.9	
Sand			4.0			
Rubble				20.0	29.4	18.0
Hard Substratum	29.5	57.3	13.2	23.0	41.0	45.3

B. 50-Point Analysis

Species	**Percent of the Total**
Algae	
Porolithon onkodes	6
Corals	
Porites lobata	22
Porites compressa	20
Pocillopora meandrina	6
Rubble	4
Hard Substratum	42

(Table Continued on Next Page)

APPENDIX 4. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	3
Arca ventriosa	6
Phylum Annelida	
Spirobranchus gigantea	27
Phylum Echinodermata	
Chondrocidaris gigantea	5
Echinometra mathaei	94
Tripneustes gratilla	216
Heterocentrotus mammillatus	3
Echinothrix diadema	1
Culcita novaguineae	1
Acanthaster plancii	1

D. Fish Census (4 x 25m)

25 Species
445 Individuals
Estimated Biomass = 320 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 7 December 2011. 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 24.3% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Peyssonellia rubra	1.8		2.0	7.0	13.0	
Porolithon onkodes	2.0	3.0				3.0
Corals						
Porites lobata	34.0	12.0	2.0	3.0	3.0	3.0
Pocillopora meandrina		8.5	5.5	8.5	9.0	9.0
Pavona duerdeni						1.5
Montipora patula	7.0	1.0	6.0	2.5		4.0
Montipora verrucosa	6.0	4.5	6.0	1.5	3.0	0.8
Montipora verrilli	3.0		1.3			
Sand			9.0		8.0	4.0
Hard Substratum	46.2	71.0	68.2	77.5	64.0	74.7

B. 50-Point Analysis

Species	**Percent of the Total**
Algae	
Peyssonellia rubra	4
Corals	
Porites lobata	18
Pocillopora meandrina	4
Montipora verrucosa	2
Montipora patula	2
Sand	4
Rubble	2
Hard Substratum	64

APPENDIX 5. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Conus lividus	1
Drupa morum	1
Spondylus tenebrosus	4
Phylum Annelida	
Spirobranchus gigantea	16
Phylum Echinodermata	
Echinometra mathaei	29
Tripneustes gratilla	71
Echinostrephus aciculatum	1
Echinothrix diadema	1
Echinothrix calamaris	2

D. Fish Census (4 x 25m)

27 Species
197 Individuals
Estimated Biomass = 208 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 7 December 2011. 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 52.0% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Porolithon onkodes			1.0			3.0
Sponges						
Spirastrella vagabunda				0.2		
Corals						
Porites lobata	76.2	45.0	27.0	48.0	25.0	47.0
Porites compressa	1.0	1.0		1.0	5.0	
Porites evermanni				4.0		
Montipora verrucosa	3.4	2.4	4.0	1.1	3.0	2.0
Montipora patula		1.5		1.0		1.0
Pocillopora meandrina	3.0		2.4		1.3	1.8
Pavona varians	0.4	1.1	0.8		1.9	
Sand				1.5		
Rubble		6.0			3.0	
Hard Substratum	16.0	43.0	64.8	43.2	60.8	45.2

B. 50-Point Analysis

Species	Percent of the Total
Corals	
Porites lobata	20
Pavona duerdeni	2
Montipora verrucosa	8
Rubble	4
Hard Substratum	66

(Table Continued on Next page)

APPENDIX 6. Continued.

C. Invertebrate Census (4 x 25m)

Species	**Number**
Phylum Mollusca	
Arca ventriosa	4
Spondylus tenebrosus	2
Phylum Annelida	
Spirobranchus gigantea	32
Phylum Echinodermata	
Heterocentrotus mammillatus	5
Echinothrix diadema	14
Echinometra mathaei	83
Tripneustes gratilla	29
Echinothrix calamaris	1
Acanthaster plancii	1

D. Fish Census (4 x 25m)

23 Species
167 Individuals
Estimated Biomass = 142 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 7 December 2011. 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 72.6% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Porolithon onkodes					1.0	3.0
Corals						
Porites lobata	33.0	49.0	63.0	37.0	85.2	41.0
Porites compressa	0.8	3.0	12.0	49.0	5.5	21.0
Porites evermanni			4.0			
Pocillopora meandrina		3.0			1.3	
Montipora verrucosa	5.0	2.0	14.0	3.0		
Montipora patula		1.0	1.0			
Pavona varians						1.5
Sand		30.0	3.0	11.0		
Hard Substratum	61.2	12.0	3.0		7.0	33.5

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Peyssonellia rubra	2
Corals	
Porites lobata	36
Porites compressa	8
Montipora verrucosa	4
Montipora verrilli	2
Sand	4
Hard Substratum	44

(Table Continued On Next Page)

APPENDIX 7. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Arca ventriosa	4
Spondylus tenebrosus	3
Pinctada margaritifera	1
Phylum Annelida	
Spirobranchus gigantea	27
Phylum Echinodermata	
Echinometra mathaei	54
Tripneustes gratilla	85
Heterocentrotus mammillatus	2
Acanthaster plancii	2

D. Fish Census (4 x 25m)

24 Species
143 Individuals
Estimated Biomass = 86 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 7 December 2011. 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 39.5% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Porolithon onkodes	3.0					
Peyssonellia rubra				5.0	3.0	
Sporolithon episoredion				2.0		3.0
Corals						
Porites lobata	37.0	43.0	18.0	16.0	14.0	
Pocillopora meandrina	13.5	4.0	9.5	3.0	16.0	5.0
Montipora patula		14.0	0.8	2.0	6.0	7.0
Montipora verrucosa	2.5		0.7		7.0	3.0
Leptastrea purpurea						2.0
Pavona varians					4.0	
Pavona duerdeni		3.0			6.0	
Sand		2.0	2.0	5.0	5.0	7.0
Hard Substratum	44.0	34.0	69.0	67.0	39.0	73.0

B. 50-Point Analysis

Species	**Percent of the Total**
Algae	
Peyssonellia rubra	2
Corals	
Porites lobata	22
Pocillopora meandrina	12
Montipora patula	4
Montipora verrucosa	2
Sand	10
Hard Substratum	50

(Table Continued on Next Page)

APPENDIX 8. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	4
Phylum Annelida	
Spribranchus gigantea	12
Phylum Echinodermata	
Echinometra mathaei	40
Tripneuistes gratilla	2
Echinostrephus aciculatum	2
Echinothrix calamaris	1

D. Fish Census (4 x 25m)

24 Species
229 Individuals
Estimated Biomass 123 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 7 December 2011. 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 50.4% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Porolithon onkodes	3.0					
Corals						
Porites lobata	51.0	16.0	4.0	30.0	85.8	85.2
Porites compressa		8.0		1.5		3.5
Pocillopora meandrina	3.0			3.5		
Montipora patula		1.0				1.0
Montipora verrucosa				2.0		2.5
Pavona varians		1.0	0.5	0.5	1.7	0.8
Rubble			19.0	6.0		
Hard Substratum	42.0	71.5	73.5	56.5	12.0	7.0

B. 50-Point Analysis

Species	**Percent of the Total**
Algae	
Peyssonellia rubra	2
Corals	
Porites lobata	20
Pocillopora meandrina	4
Montipora patula	2
Porites evermanni	2
Leptastrea purpurea	2
Pavona varians	2
Rubble	4
Hard Substratum	62

APPENDIX 9. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	3
Phylum Annelida	
Spirobranchus gigantea	19
Phylum Echinodermata	
Echinothrix diadema	22
Heterocentrotus mammillatus	25
Tripneustes gratilla	13
Echinometra mathaei	51
Echinothrix calamaris	2
Holothuria atra	2

D. Fish Census (4 x 25m)

22 Species
171 Individuals
Estimated Biomass = 105 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 7 December 2011. 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 43.4% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Porolithon onkodes	1.5	3.0	1.0	2.0	3.5	3.0
Porolithon gardineri	0.8	0.6	0.5	1.5		
Soft Corals						
Zoanthus pacificus			0.5			
Corals						
Porites lobata		9.0	20.0	14.0	27.0	79.7
Porites compressa	28.0	11.0	15.0	24.0	18.0	
Pocillopora meandrina			0.5		4.0	0.3
Montipora verrucosa					7.8	2.0
Rubble		64.4	37.5	35.5	6.0	
Hard Substratum	69.7	12.0	25.0	23.0	33.7	15.0

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Porolithon onkodes	6
Corals	
Porites lobata	16
Porites compressa	20
Montipora patula	2
Rubble	20
Hard Substratum	36

Table Continued on Next page

APPENDIX 10. Continued.

C. Invertebrate Census (4 x 25m)

Species	**Number**
Phylum Mollusca	
Spondylus tenebrosus	6
Phylum Annelida	
Spirobranchus gigantea	25
Phylum Echinodermata	
Echinothrix diadema	3
Heterocentrotus mammillatus	7
Tripneustes gratilla	68
Echinometra mathaei	29
Acanthaster plancii	1

D. Fish Census (4 x 25m)

22 Species
208 Individuals
Estimated Biomass = 154 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 7 December 2011. 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 32.6% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Porolithon onkodes	2.0	1.0	4.0	7.0	1.0	
Peysonnellia rubra	8.0	7.0	4.0			
Corals						
Porites lobata	21.0	13.0	13.0	7.0	38.0	19.0
Pocillopora meandrina	13.0	12.5	6.0	12.5	7.0	7.0
Montipora verrucosa		1.5	2.0	1.5	1.5	
Montipora patula	1.5	1.0			2.0	13.0
Montipora verrilli					2.0	
Pavona varians					0.5	
Sand	2.0					
Hard Substratum	52.5	64.0	71.0	72.0	48.0	61.0

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Porolithon onkodes	4
Corals	
Porites lobata	24
Pocillopora meandrina	10
Montipora patula	2
Leptastrea purpurea	2
Sand	2
Hard Substratum	66

(Table Continued on Next Page)

APPENDIX 11. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	5
Pinctada margaritifera	1
Phylum Annelida	
Spirobranchus gigantea	16
Phylum Echinodermata	
Echinostrephus aciculatum	4
Echinometra mathaei	23
Heterocentrotus mammillatus	1
Tripneustes gratilla	2
Echinothrix diadema	1

D. Fish Census (4 x 25m)

23 Species
384 Individuals
Estimated Biomass = 177 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 7 December 2011. 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 51.4% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Porolithon onkodes		5.0		2.0		
Pneophyllum conicum				1.0		
Corals						
Porites lobata	87.0	44.0	14.5	21.0	39.0	24.0
Porites compressa	6.0	6.0	5.0	2.8	1.5	8.0
Pocillopora meandrina	3.0		2.5	4.5		
Montipora patula		5.0	6.0		1.5	1.5
Montipora verrucosa		1.0	1.0	3.9	4.5	4.8
Fungia scutaria						0.9
Pavona varians		1.0	4.0	3.0	1.7	
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	4
Corals	
Porites lobata	38
Porites compressa	6
Pocillopora meandrina	4
Montipora patula	6
Pavona duerdeni	2
Rubble	2
Hard Substratum	38

(Table Continued on Next Page)

APPENDIX 12. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Annelida	
Spirobranchus gigantea	26
Phylum Echinodermata	
Echinothrix diadema	9
Echinometra mathaei	47
Heterocentrotus mammillatus	18
Tripneustes gratilla	38
Acanthaster plancii	1

D. Fish Census (4 x 25m)

21 Species
247 Individuals
Estimated Biomass = 123 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 7 December 2011. 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 38.8% (quadrat method).

A. Quadrat Survey

	Quadrat Number					
Species	**0m**	**5m**	**10m**	**15m**	**20m**	**25m**
Algae						
Porolithon onkodes	4.0	15.0	5.0	5.0	3.0	4.0
Hydrolithon reinboldii	2.0					
Porolithon gardineri						1.0
Pneophyllum conicum	3.0		2.0	7.0		2.0
Sporolithon episoredion	1.0					1.0
Soft Corals						
Palythoa tuberculosa				0.5		
Corals						
Porites lobata		31.0	48.0	27.0	22.0	23.0
Porites compressa	42.0	7.0	1.5		12.0	2.0
Pocillopora meandrina	5.8		1.3			
Montipora verrucosa			1.0	3.8	0.9	1.0
Pavona varians	2.3				1.0	
Rubble				18.0	15.0	
Hard Substratum	39.9	47.0	41.2	38.7	46.1	66.0

B. 50-Point Analysis

Species	Percent of the Total
Algae	
Peyssonellia rubra	2
Porolithon onkodes	6
Corals	
Porites lobata	20
Porites compressa	16
Porites evermanni	2
Pocillopora meandrina	4
Montipora patula	2
Rubble	10
Hard Substratum	48

APPENDIX 13. Continued.

C. Invertebrate Census (4 x 25m)

Species	Number
Phylum Mollusca	
Spondylus tenebrosus	6
Phylum Annelida	
Spirobranchus gigantea	23
Phylum Echinodermata	
Echinothrix diadema	7
Echinometra mathaei	72
Heterocentrotus mammillatus	2
Tripneustes gratilla	73
Acanthaster plancii	1

D. Fish Census (4 x 25m)

25 Species
392 Individuals
Estimated Biomass = 272 g/m^2

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 as well as in 7-8 December 2011. 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 and on 7-8 December 2011 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 3. Summary of the Kruskal-Wallis ANOVA and SNK Test applied to the means of parameters measured in each of four sample dates at Ka Lae Mano. These statistical tests address the question, “Has there been any significant change in the means of biological parameters in the seven surveys carried out in 1993, 2002, 2005, 2006, 2007, 2008 (carried out in May 2009), September 2009 and December 2011?” In the body of the table are given the 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>0.49, not significant)

Date	Mean No. Species	SNK
May 2009	6.8	A
Sep 2009	6.4	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 eight 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	C
May 2009	35.6	C
Sep 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 the 1993 survey is significantly greater than the six most recent surveys that are all related.

TABLE 3. Continued.

3. Number of Invertebrate Species (Kruskal-Wallis: P<0.002, significant)

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

Interpretation: The 2005 census found significantly fewer invertebrate species relative to the other seven surveys.

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

Date	Mean No. Individuals	SNK
2011	149.6	A
May 2009	134.6	A
Sep 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 in the six most recent 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
Sep 2009	26.0	A B
May 2009	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 years, the SNK Test noted considerable overlap suggesting that the annual mean number of fish species censused does not show a significant difference.

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

Date	Mean No. Species	SNK
Sep 2009	318.3	A
2006	314.4	A
2007	273.8	A
2011	254.7	A B
May 2009	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>0.06, not significant)

Date	Mean Biomass (g/m^2)	SNK
2007	328.6	A
2006	325.9	A
Sep 2009	309.8	A
May 2009	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 six 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 (representing 2008), September 2009 as well as in December 2011. These statistical tests address the question, "Within a biotope are there significant differences in the measured parameters among the eight 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)			
	May 2009	7.3	A
	1993	6.8	A
	Sep 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 eight surveys.

Biotope & Parameter	Year	Means	SNK Ranking
Percent Coral Cover (Kruskal-Wallis P<0.03, significant)			
	2002	47.6	A
	2011	28.5	B
	Sep 2009	25.4	B
	May 2009	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 seven surveys.

TABLE 4. Continued.

Biotope & Parameter	Year	Means	SNK Ranking
BOULDER ZONE (Continued):			
No. Invertebrate Species (Kruskal-Wallis P>0.16, not significant)			
	2007	9.0	A
	2002	8.8	A
	2006	8.0	A
	Sep 2009	7.8	A
	1993	7.8	A
	May 2009	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 eight surveys.

Biotope & Parameter	Year	Means	SNK Ranking
No. Invertebrate Individuals (Kruskal-Wallis P<0.12, not significant)			
	2007	85.0	A
	Sep 2009	72.0	A
	2011	70.3	A
	2006	60.5	A
	May 2009	56.0	A
	2005	45.3	A

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

Biotope & Parameter	Year	Means	SNK Ranking
No. Fish Species (Kruskal-Wallis P>0.58, not significant)			
	Sep 2009	22.5	A
	2007	22.3	A
	2006	22.0	A
	2011	21.0	A
	May 2009	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>0.22, not significant)			
	Sep 2009	332.8	A
	2006	270.8	A
	2007	255.5	A
	May 2009	230.8	A
	2011	210.8	A
	2005	192.5	A
	1993	160.0	A
	2002	114.3	A

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

Biotope & Parameter	Year	Means	SNK Ranking
Standing Crop of Fish (Kruskal-Wallis P>0.31, not significant)			
	Sep 2009	263.5	A
	2007	253.8	A
	2006	224.0	A
	May 2009	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>0.24, not significant)			
	May 2009	7.5	A
	1993	7.3	A
	Sep 2009	7.0	A
	2007	6.8	A
	2002	6.5	A
	2011	6.3	A
	2006	6.5	A
	2005	6.0	A

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

Percent Coral Cover (Kruskal-Wallis P<0.002, significant)			
	2002	78.7	A
	1993	63.0	B
	2011	48.2	C
	Sep 2009	41.9	C D
	May 2009	40.9	C D
	2007	38.7	C D
	2006	32.2	C D
	2005	27.7	D

Interpretation: Both the 2002 and 1993 surveys 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<0.01, significant)			
	1993	10.8	A
	2002	10.8	A
	2007	9.5	A
	May 2009	9.5	A
	2006	8.8	A
	Sep 2009	8.5	A
	2011	7.8	A B
	2005	5.8	B

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

No. Invertebrate Individuals (Kruskal-Wallis P<0.01, significant)			
	2011	164.0	A
	2007	136.0	A
	May 2009	134.0	A
	Sep 2009	124.8	A
	2006	102.8	A
	2005	56.0	B

Interpretation: The number of invertebrate individuals in the *Porites lobata* zone is significantly less in the 2005 survey over the five other subsequent surveys.

No. Fish Species (Kruskal-Wallis P>0.21, not significant)			
	2007	30.3	A
	2006	28.8	A
	2002	27.0	A
	Sep 2009	26.5	A
	2005	26.0	A
	May 2009	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 seven surveys.

TABLE 4. Continued.

Biotope & Parameter	Year	Means	SNK Ranking
***PORITES LOBATA* ZONE:**			
No. Individual Fish (Kruskal-Wallis P<0.006, significant)			
	Sep 2009	284.8	A
	2011	256.3	A B
	2006	256.0	A B
	2007	252.8	A B
	2005	235.8	A B
	May 2009	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.

Biotope & Parameter	Year	Means	SNK Ranking
Standing Crop of Fish (Kruskal-Wallis P>0.44, not significant)			
	Sep 2009	255.3	A
	2011	237.0	A
	2007	236.8	A
	2006	211.0	A
	2005	160.0	A
	May 2009	139.5	A

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

(Table Coninued on Next Page)

TABLE 4. Continued.

Biotope & Parameter	Year	Means	SNK Ranking
***PORITES COMPRESSA* ZONE:**			
No. Coral Species (Kruskal-Wallis P>0.10, not significant)			
	2007	6.0	A
	2002	5.8	A
	Sep 2009	5.8	A
	2005	5.5	A
	2006	5.5	A
	May 2009	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 seven later surveys.

Biotope & Parameter	Year	Means	SNK Ranking
Percent Coral Cover (Kruskal-Wallis P<0.004, significant)			
	2002	83.0	A
	1993	78.7	A
	2011	50.8	B
	May 2009	41.7	B
	Sep 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 six 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>0.08, not significant)			
	Sep 2009	8.3	A
	2011	8.3	A
	2007	8.0	A
	May 2009	7.0	A
	2006	7.0	A
	1993	6.8	A
	2002	6.8	A
	2005	6.0	A

Interpretation: There are no statistically significant differences in the mean number of invertebrate species encountered over the eight surveys in the *Porites compressa* zone.

Biotope & Parameter	Year	Means	SNK Ranking
No. Invertebrate Individuals (Kruskal-Wallis P>0.16, not significant)			
	2011	214.5	A
	May 2009	213.8	A
	Sep 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 among the last six 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
	Sep 2009	29.0	A B
	May 2009	29.0	A B
	2005	28.5	A B
	2011	24.0	B C
	1993	19.3	C
	2002	18.0	C

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.

No. Individual Fish (Kruskal-Wallis P<0.02, significant)			
	2006	416.5	A
	Sep 2009	337.5	A B
	2007	313.0	A B
	May 2009	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 lobata* 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>0.33, not significant)			
	2006	542.8	A
	2007	495.5	A
	May 2009	440.3	A
	Sep 2009	410.8	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 and the 7-8 December 2011 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

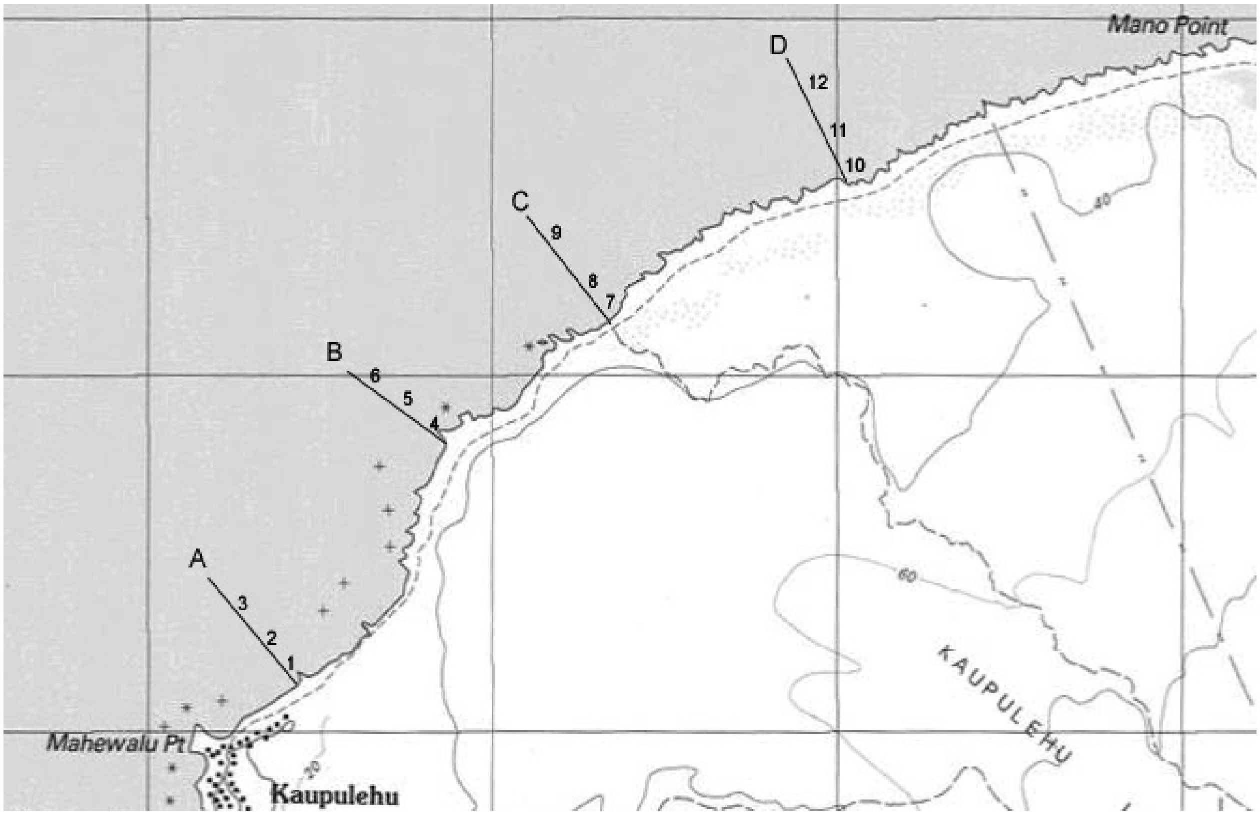

FIGURE 1. Map showing the approximate locations of the twelve permanently marked transects (numbered) at each of 4 locations (lettered) at Ka Lae Mano.