ECOLOGICAL EVALUATION OF CORAL REEF RESOURCES AT KAHALUʻU BAY, HAWAIʻI

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experienced many hardships but through our commitment to each other we have overcome much adversity. Grandpa, I want you to know I did it, I got my PhD and I love you very much. I hope to contribute much to the conservation of Hawai´i's natural resources. I also have faith in the generations to come as they may restore themselves as great stewards of the land, just like our ancestors.

ABSTRACT

The primary objectives of this research were to: assess coral reef resources (coral and fish communities) present at Kahalu´u Bay, Hawai´i; and integrate scientific ecological observations with Traditional Environmental Knowledge (TEK) and cultural practices. This localized assessment is the first to date at Kahalu‘u Bay where continuous coverage of data in a variety of habitats were assessed and mapped at such a small spatial scale. The major results of this research include: the identification of abiotic and biotic factors that influence the abundance and distribution of coral and fish communities at Kahalu´u Bay, and the identification of TEK significance in providing insights into western science, in particular marine ecology.

Research findings indicated that the spatial patterns of corals were not regulated by a sole factor. Instead, a combination of factors, which included depth and salinity, significantly explain the variance in coral community structure. Depth is an important factor at Kahalu´u as shallower depths are subjected to heavy human usage which includes coral trampling.

Analogous patterns exist for fishes, where both abiotic (depth, temperature, salinity, pH, location, shelf, sand, and rubble) and biotic (turf, macroalgal, and coral coverage) variables significantly influence fish biomass and numerical abundance (total fish and by trophic level). The impacts of abiotic factors are based on species thresholds. Individual biotic requirements of all fish and by trophic level are influenced by space or shelter availability and food. Differences in abiotic and biotic preferences between trophic levels were

observed. Understanding factors affecting fish communities is important in the development of future protected areas.

Traditional Environmental Knowledge was acquired and rigorously tested statistically. Results indicated that TEK, based on environmental observations, gathered by the kūpuna were identical to other findings that are published in the primary literature which were based on western science protocol. Findings support the importance of integrating western science and TEK.

This study provides the baseline for future monitoring and assessment of coral reef resources. Moreover research findings will be crucial in future resource management. With the integration of TEK and western science, a holistic approach can be used to make sound decision concerning reef resources.

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CHAPTER 1 INTRODUCTION

This project was designed as the marine component of an integrated coastal ecosystem study conducted under the National Science Foundation's (NSF) EPSCoR (Experimental Program to Stimulate Competitive Research) Program. Kahalu´u served as a "model system" to demonstrate how improved capacity and infrastructure could lead to mitigation of climate change impacts on water resources on watersheds across Alaska and the Hawaiian Islands. Traditionally in Hawai´i the land and inshore marine resources were divided into *ahupua´a*, which are watershed areas that extend from the uplands to the sea and were specifically designed to include all of the different resources (forest, agricultural land, marine resources) needed to sustain the population within this area (Kaneshiro et al. 2005). This research is unique in that it contained a component directed at integrating scientific ecological observations with traditional environmental knowledge and cultural practices. Cultural practices and traditional environmental knowledge is often very site specific. Fortunately these are being revitalized and driven by the community, cultural practitioners, and major land owners of the Kahalu´u *ahupua´a*. Scientifically, this area contains very rich and varied coral reef communities ranging from semi-protected shallow inshore reefs to highly developed coral communities offshore. Also, this area has become a very important site for ecotourism, yet there has been little fine scale ecological assessment of coral reef resources prior to my research. In this introductory chapter I will provide the foundation of my dissertation research. This chapter includes: a description of the Kahalu´u *ahupua´a*, a summary of the

area's history, a description of the Kahalu´u Bay study site, a summary of past research conducted at Kahalu´u Bay, a description of methodologies used in this study, and an overview of the research questions explored.

1.1 Historical Background of the Kahalu´u Ahupua´a

1.1.1 Description of the Kahalu´u Ahupua´a

The Kahalu´u *ahupua´a* was reportedly named after a high ranked chiefess, who was the wife of Keolonāhihi, and mother of Mākole´ā. Akin to other *ahupua´a*, its *mauka-makai* (land-sea) boundaries stretched from Hualalai (~1,500 m elevation) and extended to the outer reef crest at Kahalu'u Bay. It was calculated that this area was approximately 7,770 hectares (19,200 acres). The Kahalu´u *ahupua´a* is located within the Wai´aha watershed. The current state watershed delineations roughly follow the original *ahupua'a* boundaries. However, the Wai´aha watershed today measures 150,943 hectares, considerably larger than the former land division. The perennial stream in this watershed is the Wai´aha River partially fed by rainfall with minimum and maximum precipitation within this watershed of 250 mm (9.8 inches) and 2000 mm (78.7 inches) respectively. The residential human population of this area is 3,549 (US Census Bureau 2010). According to the literature, Kahalu´u was a very prosperous area and among the more favored places to live in the Kona (leeward) district of Hawai´i Island (Fig. 1.1).

Figure 1.1. Location of study site, Kahalu´u bay, on the leeward side of Hawai´i Island.

This prosperity was made evident by Reinecke in Maly (2004) when he suggested that Kahalu´u may have been able to support a large population because the area was *waiwai* (wealthy) in terms of the abundance in water supply making this *ahupua´a* an integral part of Hawai´i Island's history.

1.1.2 Brief History of the Kahalu´u Ahupua´a

Kahalu´u is mentioned frequently throughout Hawaiian literature and history providing supporting evidence of its importance. The most comprehensive compilation of oral and documented history has been compiled by Kepā Maly of Kumu Pono Associates LLC in 2004. The document is titled "*He Wahi Mo´olelo* – A Collection of Traditions and Historical Accounts from the Kahalu´u-Keauhou Vicinity in Kona, Hawai´i" Maly (2004) is based on the documented accounts from the *kūpuna* (elders), documentation from the *Māhele ´Āina* (land division) of 1848-1850, royal patent grants, and proceedings of the boundary commission.

1.1.2.1 Kahalu´u *Ahupua´a* and Associated *Ali´i*

Kahalu´u was an important site and many *ali´i* (chiefs) were known to have ties with this area. It was the royal residence for some, a place of worship for others, and even used as a recreational site (e.g. surfing). Of the chiefs mentioned, ´Umi-a-Līloa was the earliest *ali´i* associated with this area, using Kahalu‘u as his chiefly abode. While he resided in this area he was influential in *heiau* (ceremonial structures) development. Documentation by Stokes and Dye (1991) states that ´Umi-a-Līloa built Pā-o-´Umi, a heiau, Ho´oūluulu, which is a temple dedicated to the abundance of agricultural crops.

´Umi-a-Līloa was not the last *ali´i* to impact this area. As reported by Maly (2004), in the years after ´Umi-a-Līloa, historians referenced several places and events within the Kahalu´u and Keauhou area that were associated with various

ali´i. These accounts provide a window into the past between the 17th and 19th centuries. For example, in the 17th century Lono-i-ka-makahiki, the grandson of ´Umi-a-Līloa, resided at Kahalu´u after times of battle and travel (Fornander 1969). Lono-i-ka-makahiki was credited with the building or dedication of the following ceremonial sites within the Kahalu´u sector: Mākole´ā, Ke´ekū, Kapuanoni, Keahiolo, and ´Ōhi´amukumuku (Stokes and Dye 1991, cf. Fornander 1969, and Reinecke ms. 1930).

In the years following (c. 1730s), other renowned chiefs were associated with the Kona district on Hawai´i Island, with particular attention given to Kahalu'u. These chiefs were Alapa´i, Kalani´ōpu´u, and Kamehameha I. Like the chiefs that resided in the area before them, they also were instrumental in the construction or dedication of ceremonial sites (Maly 2004, Stokes and Dye 1991; Kamakau 1961).

Probably the most well-known ali´i to interact with this area was Kamehameha I (1782-1819). He was influential in the construction of Hawaiian temples in Kahalu´u, that were dedicated to the gods Kama-i-ke´ekū and ´Ōhi´a-mukumuku (Kamakau 1961). His construction and dedication of sacred sites were a result of his commitment to the gods and *kapu* or sacredness during his reign.

1.1.2.2 Archaeological and Historical Studies at Kahalu´u (1906-1980s)

Shortly after the first Western contact, Hawaiian knowledge was lost at an alarming rate. At the same time cultural sites were also being destroyed. There

was much concern about the retention of these sites from residents throughout the Hawaiian Islands, among them were those who resided in the Kahalu´u *ahupua´a*. Through the literature search of Maly (2004) it was found that had it not been for the hard work of a few dedicated individuals either through acquisition or compilation of records, a great deal of this knowledge would have been lost (Table 1.1).

Table 1.1 Compiled list of cultural sites associated with Kahalu´u Bay as documented by Stokes et al.

Type of Site	Name	Source
Heiau	Lahae	Stokes and Dye 1991; Thrum 1908
Heiau	Kuemanu	Stokes and Dye 1991; Thrum 1908
Heiau	Haleokane	Stokes and Dye 1991; Thrum 1908
Heiau	Kapuanoni	Reinecke ms; Stokes and Dye 1991; Thrum 1908
Heiau	Hanakalawai	Thrum 1908
Heiau	Kamaikeeku	Thrum 1908
Heiau	Paoumi	Stokes and Dye 1991; Thrum 1908
Heiau	Makole-a	Reinecke ms; Stokes and Dye 1991; Thrum 1908
Heiau	Kaioena	Stokes and Dye 1991; Thrum 1908
Heiau	Ohiamukumuku	Stokes and Dye 1991; Thrum 1908
Heiau	Halela'au	Stokes and Dye 1991
Heiau	Mokuahi'ole	Stokes and Dye 1991
Heiau	Hanakalau'ai	Reinecke ms; Stokes and Dye 1991
Heiau	Hāpaiali'i	Reinecke ms; Stokes and Dye 1991
Heiau	Ke'ekū	Stokes and Dye 1991
Heiau	Ke'ekū	Stokes and Dye 1991
Heiau	Kapukini	Reinecke ms
Boundary Point	Paniau Point	Reinecke ms
Cove	Kehau	Reinecke ms
Heiau	Papakoholua	Reinecke ms
House of God	Unknown	Kekahuna and Kelsey 1940s-1950s; Reinecke ms
Royal Bathing Pond	Poo Hawaii Pond	Reinecke ms
House of God	Poo Hawaii	Reinecke ms
Heiau	Makuahane	Reinecke ms
Stone	Lapauila	Reinecke ms
House of God/ Stone	Pohaku o Ulu-pala-kua	Reinecke ms
Cave	Kalopoipu	Reinecke ms
Plain	Kukui-pālua	Kekahuna and Kelsey 1940s-1950s
Water Source	Ka-´opapa-wai	Kekahuna and Kelsey 1940s-1950s
Planting Land	Ka-hoolele	Kekahuna and Kelsey 1940s-1950s
Farming Land	Kupeka	Kekahuna and Kelsey 1940s-1950s

Table 1.1 Compiled list of cultural sites as documented by Stokes et al. (cont.)		
Type of Site	**Name**	**Source**
Water	Lau-hue	Kekahuna and Kelsey 1940s-1950s
Church	He-lani Church	Kekahuna and Kelsey 1940s-1950s
Water	Wai-kua-´aala	Kekahuna and Kelsey 1940s-1950s
Break wall	Ka pa o ka Menehune	Kekahuna and Kelsey 1940s-1950s
Sacred Stone	Pohaku o Ka-lei-kini	Kekahuna and Kelsey 1940s-1950s
Bathing pool	Ka Wai o Kapo	Kekahuna and Kelsey 1940s-1950s
Sacred Stone	Ka La´au o Ka-lei-kini	Kekahuna and Kelsey 1940s-1950s
Wave	Ka Nalu o Ka-lei-kini	Kekahuna and Kelsey 1940s-1950s
Wave	Ka Nalu o Ka-pu´a	Kekahuna and Kelsey 1940s-1950s
Cave	Pā-māki	Kekahuna and Kelsey 1940s-1950s
Surf obs. spot	Kumu-noni	Kekahuna and Kelsey 1940s-1950s

Thomas Thrum, a historian, amassed a list of *heiau*, and briefly described them before they were completely demolished. His documentation served as the foundation for subsequent archeological investigations at Kahalu´u. As a result of his research, in a publication in 1908, he identified 15 heiau located with the Kahalu´u and Keauhou region (Maly 2004, Thrum 1908).

In addition to the work conducted by Thrum, John Stokes, a Bishop Museum archaeologist with the aid of natives visited cultural sites around Hawai'i Island in 1906-1907. This recorded information was later published by Dye (Stokes and Dye 1991). Unlike Thrum, Strokes and Dye documented 16 *heiau* within the Kahalu´u-Keauhou area.

In 1929-1930 John Reinecke, a high school teacher, studied sites in the Kona District. Although his work remains unpublished it has been referenced throughout the years (Table 1).

In the 1940s and 1950s Henry Kekahuna and Theodore Kelsey also studied areas within the Kona district, mapping and recording important sites. Like others before them they relied on elders to gather information. For example, Nāluahine Ka´ōpua an elderly Hawaiian man who was the descendent of the last priest of Ka-pua-noni Heiau was pivotal in providing information about the sites and their associated history. From elder accounts they learned much about the place names and important sites within Kahalu'u. Upon learning these names many *mo´olelo* (stories) were communicated and documented. One such story was about the breakwater, Ka-pā-o-menehune, which is an engineering feat that partially encloses Kahalu´u Bay and presently still remains. It was approximately 1900 m, and extended from Kaumahaole point (north) to Inikiwai (south), running parallel to the reef. (Maly 2004) The legend tells of a rooster's crow preventing the *menehune* (legendary race of small people) from completing the breakwall. At the Ku'e-manu Heiau where ceremonies were performed to raise surf-waves to benefit royal surfers, the high priest Hina-moa did not want the wall to be completed because it would block these waves. Therefore, Hina-moa crowed and tricked the *menehune* into believing that it was daylight when they stop working.

Today boulders from this structure lay scattered on the makai side of three *heiau*: Kapuanoni, Hāpaiali´i, and Ke'ekū. In the past, the water was about a meter (3') in depth and was a very lucrative fishing spot for schooling fish, torching for crabs, and fish trapping.

1.1.2.3 Land Tenure in Kahalu´u as a Result of the Māhele ´āina

Victoria Kamāmalu, granddaughter of Kamehameha I acquired the Kahalu´u, and the Keauhou I *ahupua´a*, on January 27, 1848. It was from Kamāmalu that Chiefess Bernice Pauahi Bishop inherited these lands. It later became part of the estate of Bernice Pauahi Bishop whose trust supports the Kamehameha Schools. The acquisition of this land by Kamāmalu by higher chiefs, the *hoa´āina* (native tenants) were allowed to make claims on *kuleana* (right or privilege) holdings. Many applied but only 53 claims were actually awarded. As reported by Kumu Pono Associated LLC, Kepā Maly (2004) notes these numbers may be incomplete. Following the Māhele ´Āina, in 1862, a Commission of Boundaries was established within the Kingdom to set the boundaries of all *ahupua´a*. The commission was established as rapid globalization occurred, calling for a fee-simple land base property system. Boundary descriptions were based upon information provided by native residents. The modern boundary exists between Paniau Point and Keahio‘olo Heiau. As noted in research conducted by Maly (2004), the rest of Kahalu´u can be divided into sections which include: the beach strip; *pāhoehoe* (smooth lava) and *a‘a* (rough lava) flow south of Kahalu´u; an overgrown older flow in the north and middle of Kahalu´u; coffee plantation and *ohi‘a* (*Metrosideros polymorpha*) growth in the mauka section.

1.1.3 Remaining Cultural Sites in the Kahalu´u Bay Area

The location of the major cultural sites is shown in Fig. 1.2.

1.1.3.1 Nā Heiau (Pre-Christian Places of Worship)

Keʻekū Heiau: This *heiau* was a *luakini* or place of human sacrifice and a *puʻuhonua* or place of refuge. This *heiau* was for the first rank or the highest of chiefs.

Hāpaiali´i Heiau: This *heiau* has a fire pit that is circumscribed by a raised platform. This fire pit was the site where the *iwi* (bones) of the *aliʻi* (chiefs) were placed and on certain nights it was believed that their spirits were raised to the heaven. Atop the *mauka* (seaward) facing wall there are upright stones that mark solstices and equinox.

Kapuanoni Heiau: This *heiau* was an ancient *luakini* and *puʻuhonua* which was built during the reign of Lono. It also built to increase fish and food.

Kuʻemanu Heiau: Named after a warrior champion who served Chief Kahalu´u-kai-akea. This *heiau* was built to ensure that the good waves would continue to flow into Kahalu´u Bay.

1.1.3.2 Ka Loko Ku‘i (Man-made Pond)

Waikua‘ala : This pond was used as a swimming area by the king and other chiefs.

1.1.3.3 Bathing Areas

Poho o Kapo: Bathing area for chiefs and was dedicated to the sister of Pele, Kapo.

Po´o Hawai´i: Similar to Poho o Kapo, this was also a chiefly bathing area. The pond was named Po´o Hawai´i so the place name would never be lost (Fujisaka pers. com. 2012). At one time, Po´o Hawai´i was an *ahupua´a* within the Kahalu'u *ahupua´a*. This area was designated for *ali'i* only.

1.1.3.4 Ka Puna (The Spring)

Pūnāwai : Water from this spring was used for drinking purposes.

1.1.3.5 Ka Pā (The Wall)

Pāokamenehune: This wall structure was supposedly built by the *menehune* and encloses most of Kahalu'u Bay.

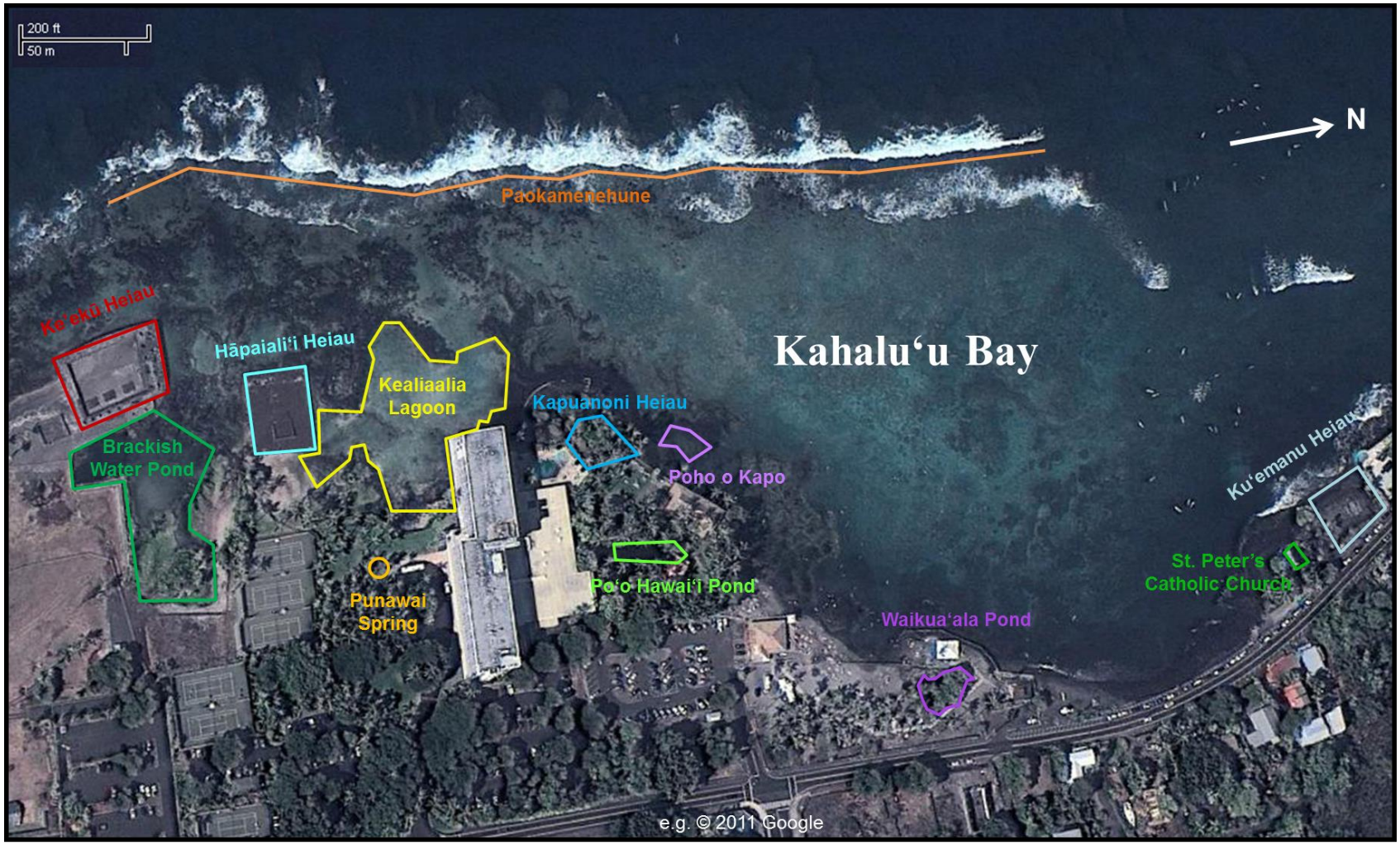

Figure 1.2. Locations of important cultural sites in the Kahalu´u Bay area

1.2 Background on Kahalu´u Bay

Kahalu´u Bay is roughly two hectares (4.94 acres) and is located within the Kona (leeward) district of Hawai'i Island. Many areas within the bay are less than one meter in depth. Kahalu´u Bay has played an integral role in the history of this *ahupua´a*. This bay marks the makai (seaward) boundary of the *ahupua´a* and has always been important to the community or the *´ohana nui* of this area. For generations and even to this day, many of the *´ohana* (families) who reside there have used the bay for various activities including skin diving, fishing, swimming, and family gatherings.

Kahalu´u Bay was leased to the County of Hawai´i and in 1953 officially became a county park. In September 1966, Richard Lyman, a former Bishop Estate trustee, handed over the property to the County of Hawai´i and they have remained the landowner ever since.

This bay is a popular snorkeling location for locals and tourists alike. It has been reported that there are approximately 400,000 visitors who visit the bay each year (The Kohala Center 2008). With a large number of resource users there is the potential that human interaction can adversely affect marine resources (Selkoe et al. 2009, Bruno 2007).

Marine flora and fauna found along West Hawai´i has and continues to be impacted by many resource users including those from the public and commercial sectors (Asoh 2004, Tissot et al. 2004). In the years prior to the late 1990s there was considerable growth in the number of tropical fish being harvested by the aquarium trade along West Hawai´i. This drew concern from

resources users and conflict developed between tropical fish collectors and recreational divers. It was for these reasons that in July of 1998, the legislative body of the State of Hawai´i signed into law ACT 306 (HRS Ch. 188F). As a result of this law, the West Hawai´i Regional Fishery Management Area (WHR-FMA) was created to include the coastline area from Upolu Point to Ka Lae (Fig. 1.3). Kahalu´u Bay is located within this Kailua-Keauhou Fish Replenishment Area (FRA) (Friedlander and Cesar 2004). Regulations for this area as set by the Division of Aquatic Resources are as follows: "There will be no commercial or non-commercial collection of fish for aquarium purposes; feeding of fish are prohibited."

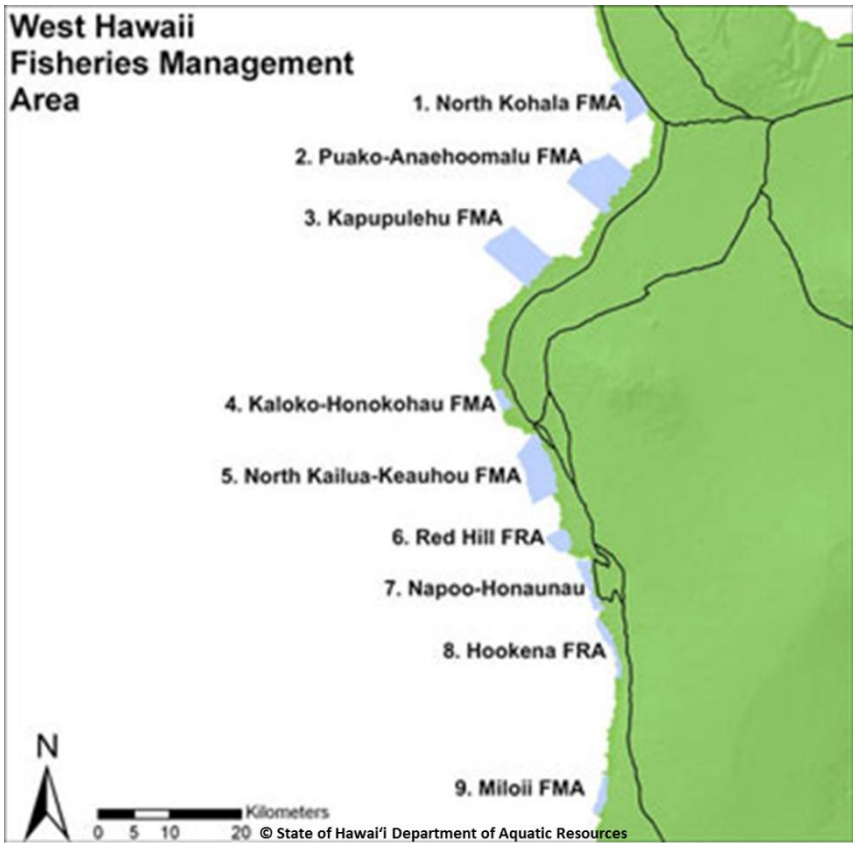

Figure 1.3. The West Hawai'i Regional-Fish Management Area as established by ACT 306.

1.2.1 Past Research Conducted at Kahalu´u Bay

Few biological studies conducted at Kahalu´u Bay are published in the primary literature. In 1999, Harrington qualitatively examined the impact of waders and skin divers on corals at Kahalu´u Bay and other sites as a University of Hawai‘i Marine Options Program report. Rodgers and Cox (2003) investigated the impact of trampling across a gradient of human use and determined that coral survivorship is inversely related to the number of users. Friedlander and Cesar (2004) compared fishery characteristics at Kahalu´u Bay with comparable habitat types within the Kailua-Keauhou FRA. They found that fishery assemblages at Kahalu´u Bay were lower in the number of individuals and number of species. It was also noted that the fishes at Kahalu´u Bay were less diverse and lower in biomass than at other sites within the Kailua-Keauhou FRA (Friedlander 2004).

Although not reported in the primary literature, other research has been conducted at Kahalu'u Bay. One such study by Becker et. al (2009) examined the connectivity between coral reef "health" and anthropogenic disturbance. They tested whether a correlation existed between Aggregated Anthropogenic Disturbance (ADD) [ex. tourism, urban development, and agriculture and the coral reef. Although they found a correlation, it was not statistically significant due to high environmental variability.

Other studies include fish surveys conducted by a number of groups/individuals such as Sea Grant's Reef Watchers, transects conducted adjacent to Kahalu´u Bay by the Division of Aquatic Resources (DAR), and

transects conducted by Torricer in 1999-2000. Their work has documented many aspects of fish distributions (including diversity and numerical abundance) that can be useful in the future to determine if temporal changes in fish assemblages have occurred.

1.3 Methodology

1.3.1 Site Selection

Kahalu´u was selected for many reasons. The first is for its scientific importance. There has been limited monitoring and assessment of marine resources and consequently few previous studies have been published in the immediate area. In addition, terrestrial and weather data are available for the adjacent watershed which will allow for the assessment of the entire *ahupua´a*. Kahalu´u also has great scientific importance globally. There is consensus within the science community that global climate change is occurring as a result of increased CO_2 emissions, urban development, and industrial production. The impacts are non-discriminative and will be felt globally. Pacific Islands (including Hawai´i) are projected to be impacted by climate change and experience an increase in temperature, sea level rise, ocean acidification, and increased intensities and frequencies of storm events coupled with periods of prolonged drought. Currently, Hawai´i is not prepared to deal with these impacts resulting in many ramifications that include a decline in natural resources (e.g. drinking water, biodiversity, coral reefs, etc.), failing local economies, and a compromise of physical infrastructure. Therefore, this site, the Kahalu´u *ahupua´a*, was

initially selected by the University of Hawai´i and the National Science Foundation (NSF) as a site of interest as this location encompassed 'mountain-to-sea' environments, and could serve as a model for monitoring, understanding, mitigating and adapting to climate change locally and applying what was learned throughout Oceania. This project was designed to build the infrastructure necessary for the community to deal with climate change impacts.

There were multiple components of this project. Another component was the development of cyberinfrastructure. InteleSense provided the technological foundation for collected data to be shared, managed, and integrated among researchers and community members in the *ahupua´a*. InteleSense also allowed for the near real-time monitoring of environmental parameters (abiotic and biotic) in order to assess the global-to-regional-to-local effects of climate change. In addition, this project was directed at improving the resiliency of the community to deal with climate change. As a result, local knowledge networks were formed. The Kahalu´u advisory committee was established to allow the public participation in decision making concerning resources at Kahalu´u as impacted by climate change. Stakeholders included members from the county, state, federal, and community. There was also an educational outreach component which included community lectures and regular classroom visits to encourage student interest in Science-Technology-Engineering-Mathematics (STEM) fields.

The selection of the Kahalu´u area is also based on its community and cultural importance. There is strong community support and concern for sustaining the area's natural resources. This is of even greater importance as

Kahalu´u Bay is exploited heavily by recreation and commercial activities. Community members nevertheless participate in a variety of activities (e.g. educational, outreach, and monitoring) to ensure the bay's health. In addition, there is a strong cultural presence within the *ahupua´a* which is evident in the number of cultural sites and practitioners who still remain. The knowledge of these individuals is immense and has provided the unique opportunity for two different disciplines, culture and science, to be bridged. These criteria made Kahalu´u an appropriate site for my dissertational research.

1.3.2 Abiotic Measurements

1.3.2.1 Temperature

Temperature data loggers and a water quality meter equipped with a temperature probe were used to collect data.

Temperatures were recorded at five locations within Kahalu´u Bay, between 19 December 2011 to 20 June 2012 to determine temperature differences between habitat types (Fig. 1.4).

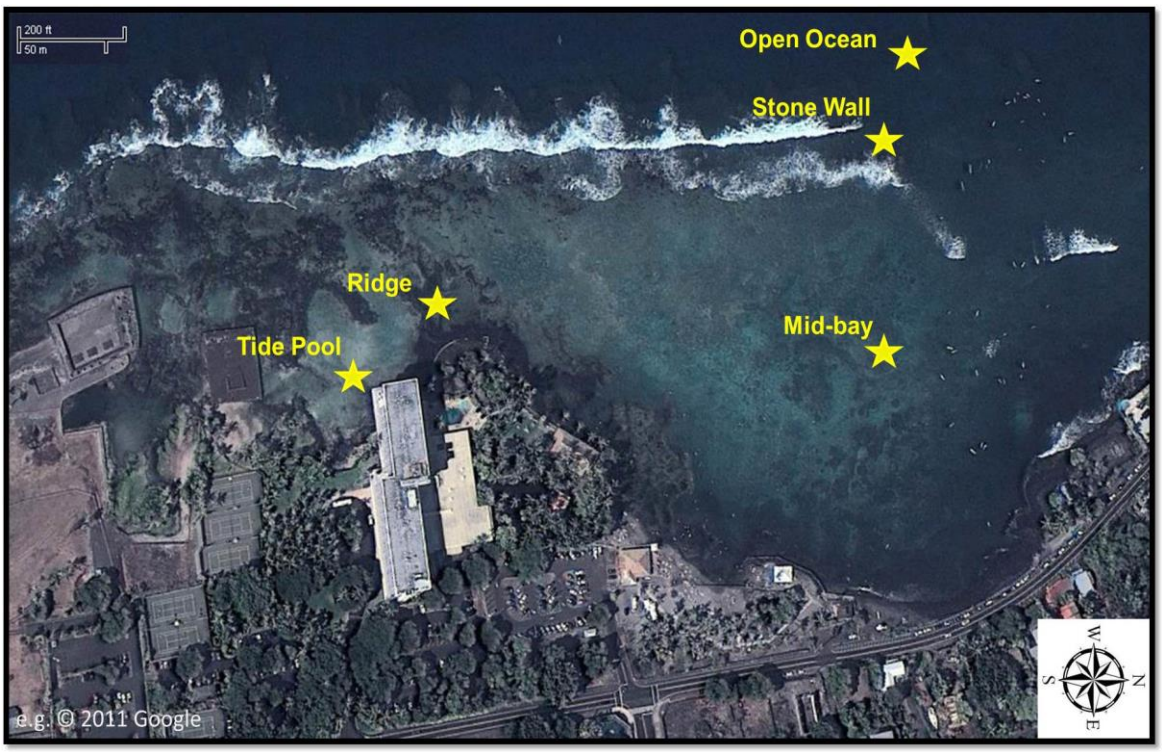

Figure 1.4. Location of temperature loggers in different habitat types.

Onset© Hobo Pendant (UA-001) temperature data loggers were deployed to record temperatures at each habitat type: tide pool, ridge, mid-bay, stone wall (interface between bay and open ocean), and open ocean. Instrument accuracy is ± 0.53° C with a range of between -20° C to 70° C. Temperature loggers were calibrated prior to field placement. Loggers were immersed in two water baths (0°C to 40° C), recording every five minutes for an hour. A certified liquid-in-glass thermometer was used to monitor bath temperatures and standardize loggers. Deviations from the certified thermometer were adjusted from logger readings to correct and ensure proper calibration.

In the field, loggers were fixed to non-living substrate using cable ties and electrical wire. Temperature gauges were programmed to record temperature

hourly. Gauges were retrieved on 20 June, 2011, downloaded into HOBOware Pro and a graph was generated.

Temperature was also recorded at 202 stations (Fig. 1.5) in and around the Kahalu´u Bay area using a Yellow Springs Inc. (YSI) 6920V2-2 S Multiparameter Water Quality Sonde equipped with a 6560 conductivity/temperature probe to (Fig. 1.6). The probe was calibrated prior to in situ field measuring according to YSI protocol. At each station, replicate measurements were taken at the surface (<0.5m) and the bottom (range: 0.5m-10.1m). Measurements were recorded for one minute at 5 second intervals. The central data point was used to represent temperatures to ensure instrument stabilization. Measurements were collected between 10 March, 2011 and 25 July, 2011. Probe accuracy is ± 0.15° C with a range of -5° C to 60° C.

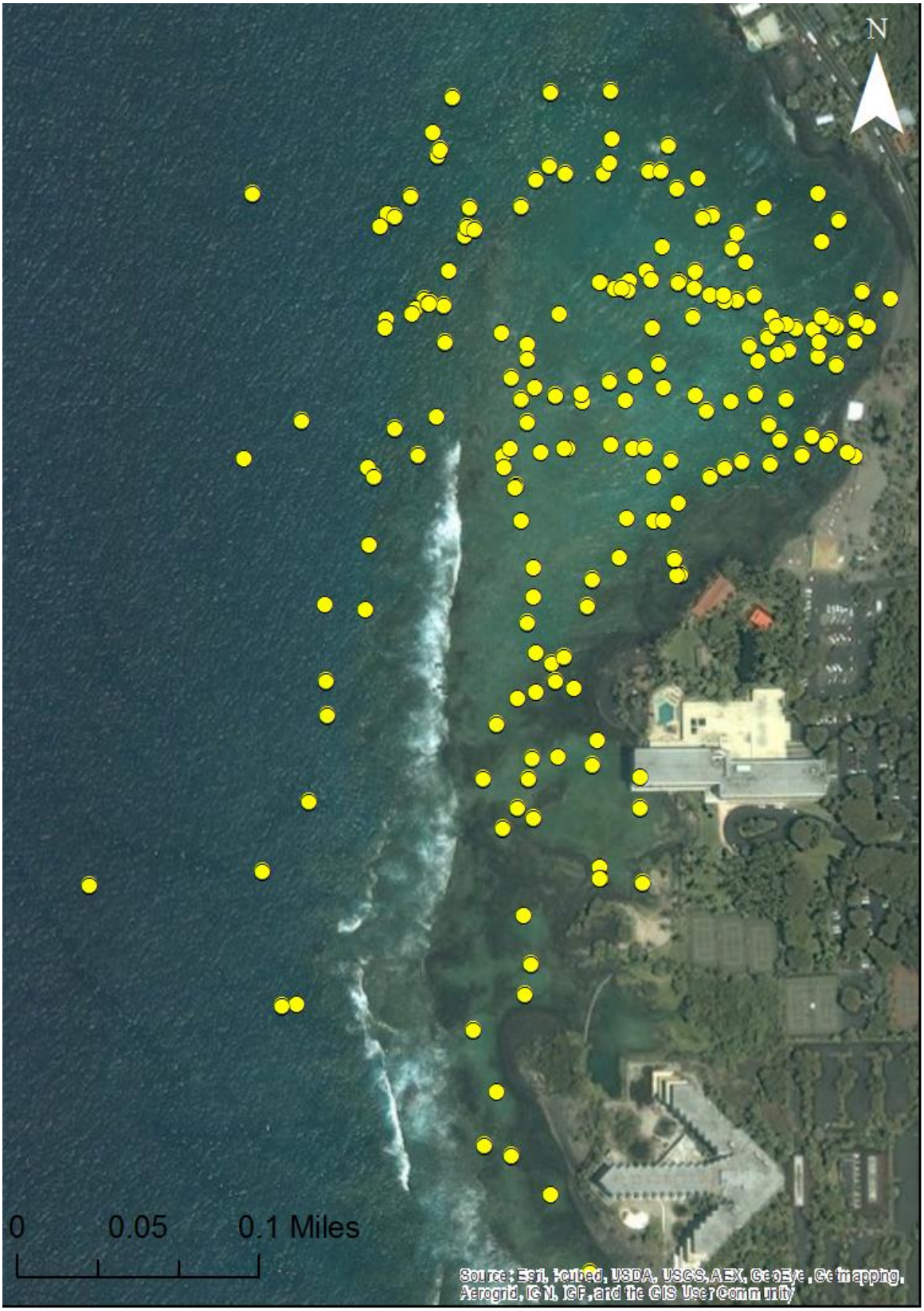

Figure 1.5. 202 Stations surveyed at Kahalu´u Bay, Hawai´i.

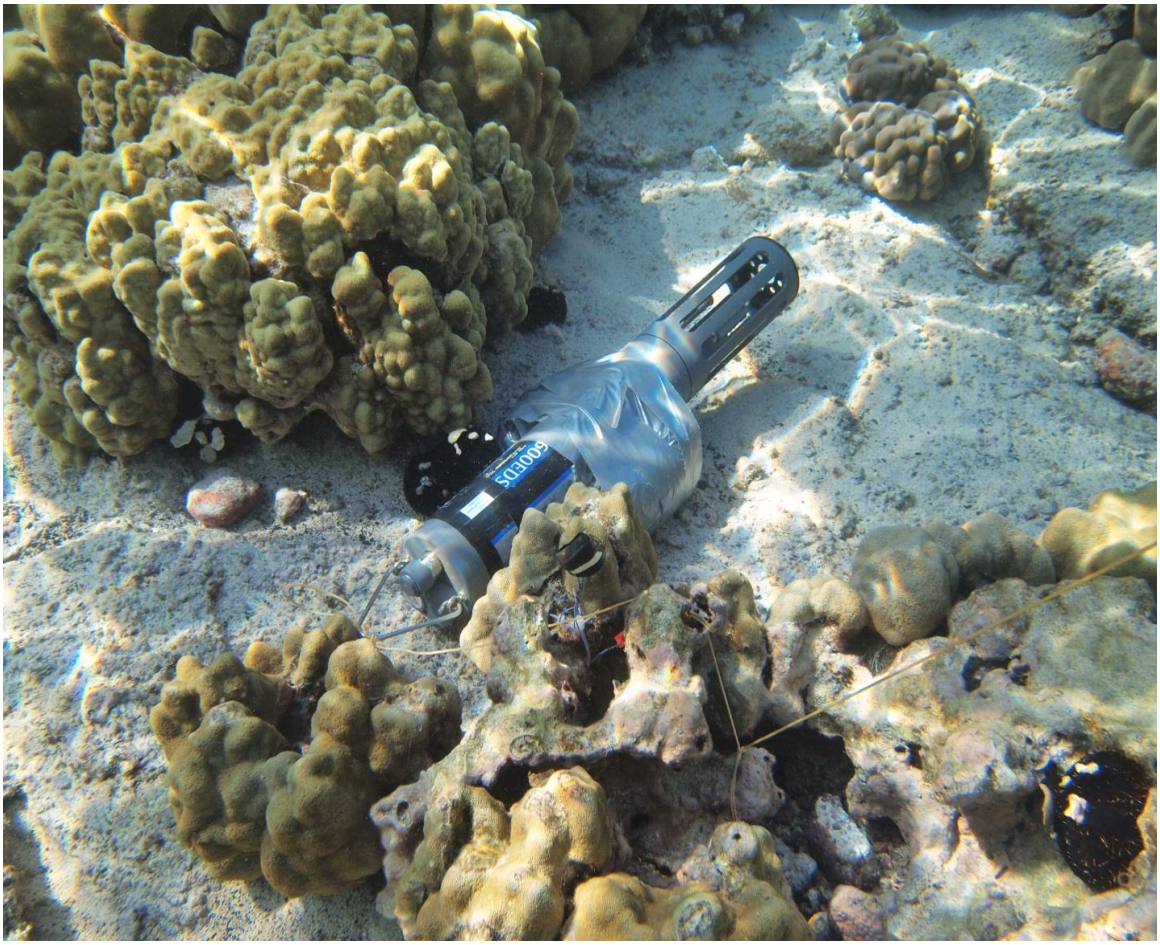

Figure 1.6 Shows the Yellow Springs Inc. (YSI) 6920V2-2 S Multiparameter Water Quality Sonde.

1.3.2.2 Water Quality

A YSI 6920V2-2 S Multiparameter Water Quality Logger equipped with four probes was used to measure water quality. A 6560 conductivity probe with accuracy of ±0.5% of reading plus 0.001 mS/cm, with a range of 0 to 100 mS/cm was used to calculate salinity based on algorithms from American Public Health Association (ed. 1989). A YSI 6150 ROX Optical Dissolved Oxygen (DO) Sensor with probe accuracy of ± 1%, with a range from 0-500% measured DO. A YSI 6136 turbidity sensor with probe accuracy of ± 2%, with a range of 0 NTU to 1,000 NTU determined turbidity. pH measurements were taken using a 6561 pH

sensor with probe accuracy of ± 0.2 units, with a range from 0 to 14. All probes were calibrated according to protocol in the YSI 6-series multiparameter water quality sonde user manual.

Two-hundred and two stations, in and around the bay, were surveyed between 10 March, 2011 and 25 July, 2011.

1.3.2.3 Bathymetry

Light Detection and Ranging data (LIDAR) collected by The US Army Corps of Engineers SHOALS (Scanning Hydrographic Operational Airborne LIDAR Survey) were available but absent for many stations due to shallow depths (< 1 m),wave action, and volcanic haze, therefore depth was measured using a 30 m Keason transect fixed to a 5 oz. lead weight at all stations. All depth measurements were taken between 10 March 2011 and 25 July 2011 and standardized to the mean low low water (MLLW) mark for each time and date.

1.3.2.4 Rugosity

Rugosity is a relative index of typographic relief or spatial complexity that can be derived in various ways. The Coral Reef Assessment and Monitoring Program (CRAMP) utilizes the chain and tape method (McCormick 1994) in which a light brass chain marked off in 1 m intervals is spooled out over the bottom along the length of a transect tape that is stretched tightly over a 10 m distance . The amount of chain necessary to follow the contour over the 10 m horizontal distance is divided by the straight-line tape measurement to generate an index of rugosity. For example, on a sand bottom only 10 m of chain will be

needed to follow the bottom along a 10 m transect line resulting in a rugosity of 10 m/10 m = 1.0. On a complex surface it might take 20 m of chain to follow the bottom over the 10 m transect line for a rugosity of 20 m/10 m= 2.0. Rugosity can also be estimated visually by trained observers (Jokiel et. al 2001), which is the desirable alternative at Kahalu´u because the fish and benthic data at each of the 202 stations was taken within a circle with a 7 m diameter. Vertical and oblique photos with a scale were taken at each location. Rugosity was later estimated in the lab by using the photo images and criteria shown in Fig. 1.7 to rank rugosity based on a scale from 1.0 to 2.0. Based on this criteria, sand is 1.0 (Fig. 1.7 A), rubble is 1.2 (Fig. 1.7 B), boulder/ low coral cover is 1.4 (Fig. 1.7 C), moderate coral cover is 1.6 (Fig. 1.7 D), high coral cover is 1.8 (Fig. 1.7 e) and high vertical relief with corals had the highest rugosity scored as 2.0 (Fig. 1.7 f). Rugosity assessment was completed by two observers (Kaipo Perez and Paul Jokiel) in a single viewing to insure uniformity and reduced observer variability.

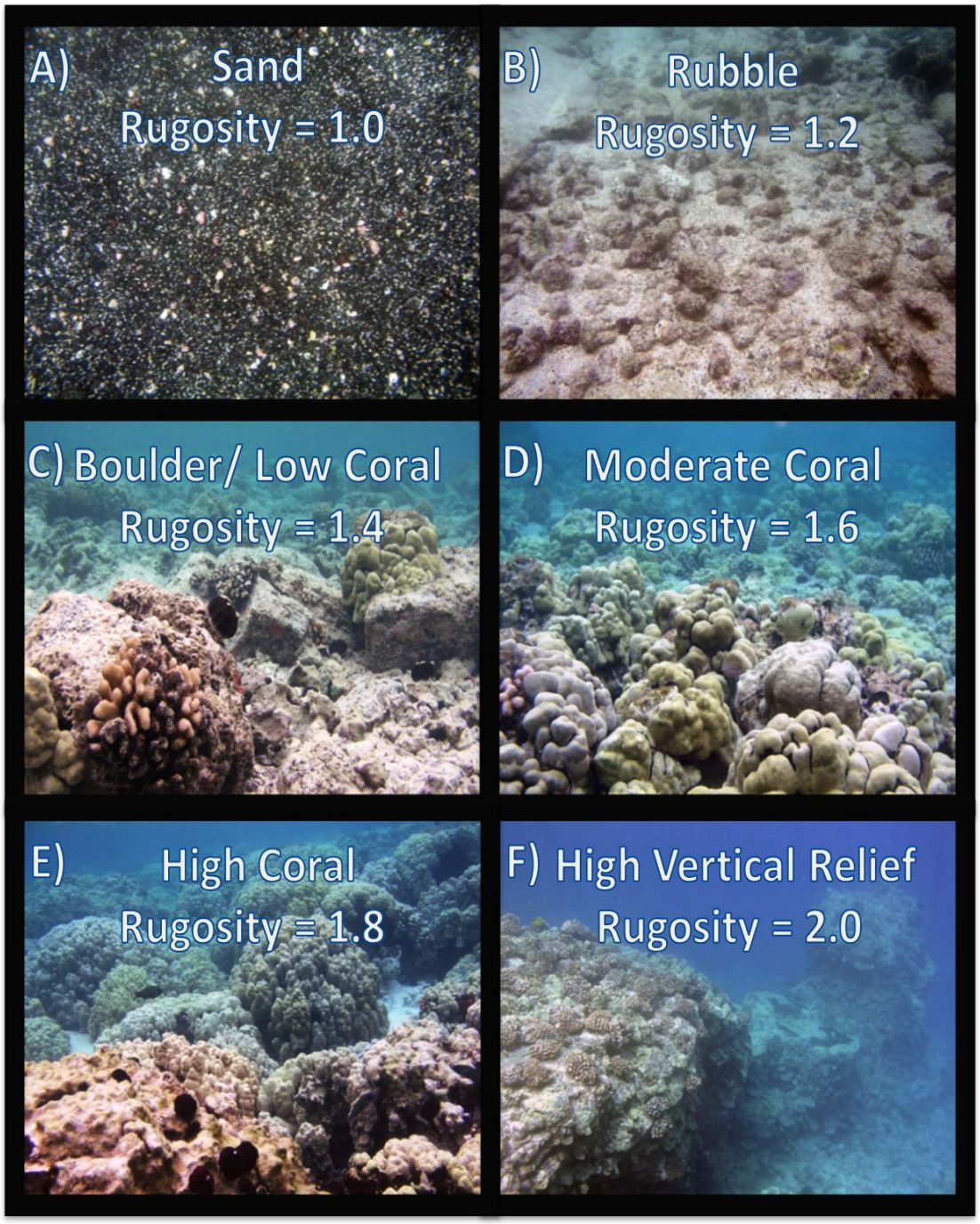

Figure 1.7. Scoring criteria for rugosity ranging from 1.0 for low vertical relief (e.g. sand) to 2.0 for areas of high vertical relief.

1.3.3 Biotic Measurements

1.3.3.1 Benthic Habitat Characterization (BHC)

Benthic coverage at the 202 stations was assessed using methods developed by National Oceanic and Atmospheric Administration (NOAA) for groundtruthing of benthic habitats (Fig. 1.5). A Global Positioning System (GPS) point was taken at the central point of each surveyed circle (seven meter radius). Visual estimates were taken for the following parameters: Presence or absence (P/A) of shelf, sand, boulder, and rubble; Percent macroalgae (MA), crustose coralline algae (CCA), turf algae (TA), total coral cover (TCC), and coral species. Surveys were conducted between 1 April 2010 and 5 June 2010.

Table 1.2 List of benthic habitats and benthic data collected within each habitat

Benthic Data	Data Type
Location	Inside or Outside
Primary Substrate Composition	Carbonate or Basalt
Shelf	P/A
Sand	P/A
Boulder	P/A
Rubble	P/A
Macroalgae (MA)	P/A and Percent Cover
Crustose Coralline Algae (CCA)	P/A and Percent Cover
Turf Algae (TA)	P/A and Percent Cover
Total Coral Cover (TCC)	P/A and Percent Cover
Coral Species	P/A and Percent Cover

P/A = Presence or Absence

1.3.3.2 Fish Abundances

Fish surveys were concurrently conducted with benthic assessments at all stations shown in Fig. 1.5. Visual estimates of abundance, species, and length

were recorded within a seven meter radius. Fishes were identified to the lowest taxonomic level possible and enumerated by size class. Surveys were conducted between 1 April 2010 and 5 June 2012.

1.3.4 Methods of Traditional Environmental Knowledge (TEK) Gathering

1.3.4.1 Pre-interview Stages

In the initial stages, I worked with the Kohala Center (TKC) to identify key individual(s) who hold knowledge about the Kahalu´u *ahupua´a* (past and present). TKC is a non-profit organization who has worked in this region for numerous years. They have developed an intimate relationship with its residents, and served as the liaison between these individuals and ourselves. Upon identification of these individuals there was a formal introduction. Subsequently informal "talk story sessions" or *kama´ilio* were scheduled. In the Hawaiian culture it is formal protocol that an intimate relationship be developed before any "personal or privately held information" is shared. In these informal gatherings, information about one's life (i.e. where you are from, where you grew up) was shared. In addition, these meetings were pivotal in fulfilling an aspect of the Hawaiian culture*: "kulikuli kou waha, a ho'olohe kou pepeiao"* or "close your mouth, and listen with your ears". It's necessary to listen first as all questions might be answered without uttering one word. Only after an ample amount of dialogue can questions be asked. All stages up until this point were not recorded as they are personal and confidential information.

Once the introductory period passed, these individuals were asked if they would like to be interviewed. Upon agreement, a time and a place was scheduled. At the same time, an exemption was filed and approved by the University of Hawai´i's Committee on Human Studies (CHS) to perform these interviews. Prepared questions for the interview were given ahead of time so they may prepare themselves. On the day of the interview, they were consulted one last time. Prior to being interviewed they were asked to sign a letter of consent describing project details.

1.3.4.2 Interview Stage

Two individuals were interviewed on the 13 April 2012. All interviews were recorded using a video camera. The interview started with foundation questions which built the credentials for each interviewee. Subsequently, these individuals were asked a series of questions about Kahalu‘u Bay and coral reef resources. At the conclusion of the interview they were asked if they had any questions. In addition, they were asked if the content documented can be used and distributed.

1.3.4.3 Post-interview Stage

The footage was reviewed and responses transcribed. When necessary the interview footage was edited. Edits were only made to improve quality of footage. Post-editing, interviewees were asked to review footage and sign a Transcript/ Video Release form, which indicates their approval of content. Responses from the interview were used to generate hypotheses about the coral

reef resources that were tested according to western science protocols, copies of the interviews will be given to the interviewees (for personal use and for family record), submissions to UH library will be made for archival purposes, posted on the UH/TKC portal website (http://portals.intelesense.net/tkc/), and excerpts included in this doctoral dissertation.

1.4 Data Analyses

1.4.1 Habitat Characterization

Primer® 5 was used to perform a Principal Components Analysis (PCA). This analysis is a basic eigenvector method of data clustering. It was proposed in 1901 and 1933 by Pearson and Hotelling respectively. In 1954, Goodall was the first to use PCAs in ecology. In this study, PCAs allowed for habitat characterization based on similar abiotic and biotic signatures.

1.4.2 Distribution of Biological Organisms (Based on Abiotic and Biotic Factors)

Minitab 16® was used to perform a suite of multivariate analyses. These statistical tests allowed for the comparison of abiotic factors with biological counts in order to determine if a relationship existed between the two. Similar analyses were also performed using benthic composition and fishery characteristics.

1.4.3 Analyzing Traditional Environmental Knowledge (TEK)

Minitab 16® was used to perform Chi-square tests. This test created a contingency table and included a single response variable with multiple levels. A Chi-square test predicts if a predictor and a response variable are related to each other. For this dissertation TEK from the kūpuna were tested against collected data using Western protocol to see if these TEK are still presently observed.

CHAPTER 2 LINKAGES BETWEEN ABIOTIC AND BIOTIC FACTORS

2.1 Introduction

The distribution and abundance of flora and fauna is regulated by many factors (Dunson and Travis 1991). These factors are either abiotic (not living) or biotic (living) in nature (Adjeroud 1997). This chapter focuses on the importance of abiotic factors in determining the biological distributions at Kahalu´u Bay, Hawai´i.

2.1.1. Background Information

Coral reefs represent less than 1% of all marine environments yet they are the most biologically diverse ecosystems in our ocean (Veron et al. 2009). Reefs have dynamic food webs and thus are highly productive (Lugo et al. 2000). As a result for centuries people have lived along coastal areas and relied heavily on reef resources to survive (Bryant et al. 1998). Currently it is estimated that millions of people from over a 100 nations are reliant on reef related products (Salvat 1992).

2.1.2. Importance of Reefs (Goods and Services)

Reef ecosystems provide a myriad of ecological goods and services (Hughes et al. 2003). They protect coastlines from erosion due to heavy water motion (Menard 1983). Reefs foster the growth of seagrass beds and mangroves, which are known nursery habitats (Moberg and Folke 1999). Coral ecosystems are also important economically. In 2004 Cesar and van Beukering

stated that reef-related recreational activities (i.e. snorkeling and diving) and fisheries contributed approximately $340 million and $2.5 million respectively to Hawai´i's economy annually. Moreover there is great medicinal value in reefs (Fenical 2002). Mycosporine-like amino acids or MAA's found within coral tissues have been used as sunscreens and sources of antioxidants (Dunlap et al. 1998). Coral environments are therefore integral in sustaining human life.

2.1.3 Factors Regulating Coral Reef Structures

Numerous factors determine the structure of coral reef ecosystems (Glynn 1994). Understanding each factor's contribution towards molding the community composition is important and is related to its source, scale, and frequency. These factors can originate from nature, anthropogenic forces, or a combination of the two (Adjeroud 1997). Examples of natural factors include temperature, salinity, irradiance, pH, and wave energy (Glynn 1994). Coastal development, overfishing, ocean acidification, and climate change on the other hand are anthropogenic impacts (Richmond 1993). Natural and human factors often occur concurrently and are difficult to differentiate their individual contributions (Nystrom et al. 2000). Nevertheless their synergistic effects shape coral reef ecosystems.

The scale over which a factor impacts an area influences its impact on reef assemblages (Hillebrand and Thorsten 2002). Scales range from local to global (Wilkinson 1999). Localized factors include the amount of effluent, trampling,

and sedimentation (Carilli et al. 2009). Events on a global level include climate change, temperature, and ocean acidification (Knowlton and Jackson 2008). The frequency or number of incidents is also important in understanding the intensities for which reef inhabitants are subjected (Connell 1978). A tsunami and winter swell are examples or acute and chronic impacts respectively. These characteristics shape and define reefs compositions as we know it.

2.1.3.1 Temperature

Temperatures influence ecosystems on a global level (Smith and Buddemeier 1992). Currently the sea surface temperature (SST) in Hawai´i is approximately 30° C depending on the season. In recent years anthropogenic impacts, such as the consumption of fossil fuels, have contributed significantly to rising temperature (King 2004). Exposing corals to temperatures above their summer thermal maximums can be detrimental. Zooxanthellae, single celled, symbiotic algae living within coral tissues photosynthesize to produce nutrients for the corals. Bleaching occurs when corals expel their zooxanthellae under thermal stress and lose their coloration. Research by Jokiel and Coles (1990) demonstrate that a reduction in growth, calcification, increased bleaching, increased mortality, and changes in reproduction can occur with increased temperatures. Studies have also shown that elevated temperatures reduced reef fish growth (Munday et al. 2008b) and respiration (Nilsson et al. 2008).

2.1.3.2 Salinity

Salinity has similar impacts on coral reef environments. In Hawai´i, the salinity of the ocean is approximately 36- 37 ppt (Englund 1999). Coles and Jokiel (1978) found that when *Montipora capitata (c.f verrucosa)*, a common hermatypic coral in Hawai´i, was exposed to lowered salinity concentrations their ability to survive short-term episodes of elevated temperatures was reduced. Complementary, Tandler et al. (1995) reported a negative relationship between salinity and survival in the seabream *Sparus aurata* larvae.

2.1.3.3. Irradiance

The amount of irradiance or solar light energy influences the presence or absence of biota. Research by Dunlap et al. (1986) reported that coral distributions were influence by irradiance and depth. Jokiel et al. (2004) noted that high irradiance levels accelerated coral bleaching and decreased survivorship.

2.1.3.4 pH

The ocean's chemistry, in particular pH, plays an integral role in defining reef ecosystems. Presently the ocean is slightly basic at a pH of 8.07. Deviations from mean pH can alter biotic communities (Munday et al. 2008a).

Findings by Marubini and Atkinson in 1999 indicated that corals grown in a pH of 7.2 calcified half as fast as those in a pH of 8.0. Under pCO2 levels exceeding present ambient conditions by 365±130 µatm, Jokiel et al. (2008) found that coral

calcification decreased by 14% to 26%. Rates of calcification per unit of linear extension decreased by 6-8%, showing that corals were laying down a somewhat more fragile skeleton under conditions of lower pH. The negative effect of pH on other organisms, such as fish (Munday et al. 2009), calcareous coralline algae (Kuffner et al. 2008), and invertebrates (Kleypas and Yates 2009) have also been widely demonstrated.

2.1.3.5 Wave Disurbance

Waves significantly influence the structure of coral reef communities (Dollar 1982). It has been shown to affect the distribution and abundance of coral species and other organisms (Yonge 1940). Wave action aerates waters providing oxygen to flora and fauna. Waves and currents are also known to increase water cycling and reduce residency time of harmful elements such as sediment and heavy metals (Jayaraju 2009). Waves are crucially important to reef ecosystems and their health.

2.1.3.6 Benthic Structure

The structure of the benthos plays an integral role in regulating the abundance and distribution of the flora and fauna (Friedlander and Parrish 1998a). Benthic structure is primarily based on spatial relief and depth (Wilson et al. 2007). Stations with low benthic structure (e.g. sandy locations) are often characterized as having low numerical abundances and less diversity of organisms while a

station with a complex benthic structure (e.g. coral reef) is characterized as having high spatial relief and diversity and a large abundance of organisms.

2.1.3.7 Anthropogenic Disturbance

In recent years, anthropogenic stress has amplified pressure on reefs consequently impacting benthic and fish assemblages (Richmond 1993). Many local and global anthropogenic stressors exist, however on a local level sedimentation, overfishing, and eutrophication are among the most significant (Richmond 1993).

Sedimentation, often attributed to urban development (e.g. deforestation), has degraded reef ecosystems on a local to global scale (Syvitski et al. 2005). In Hawai´i, research by Te (2001) has shown that reefs are being affected by terrigenous runoff. Sediment can impact reef ecosystems in a variety of ways. Sediment can abrade corals and cause tissue damage (Hawkins & Roberts, 1992). They can also smother corals and other organisms preventing the uptake of nutrients and oxygen (Fabricius and Wolanski 2000). Suspended sediment can reduce available irradiance (Telesnicki and Goldberg 1995) inhibiting photosynthesis and negatively affecting coral growth (Davies 1991).

Eutrophication is another anthropogenic stressor that has greatly impacted coastal marine environment (Chazottes and Campion-Alsumard 2002). It is largely influenced by runoff from point and non-point sources (Bryant et al. 1998). Often the source of these nutrients can be traced back to golf courses, agricultural farms, and factory farms which release waste products such as

pesticides, fertilizers, and sewage (Fabricius 2005). The introduction of excess nutrients can cause outbreaks of harmful algae and overgrowth of invasive algal species (Anderson et al. 2002). Consequently, “phase shifts” can occur and result in the replacement of corals with algae (Nystrom et al. 2000). This can negatively alter benthic and fish assemblages (McCook 1999).

Herbivore fish populations have dwindled due to overfishing (Pandolfi et al. 2003). In places such as Jamaica overfishing has caused fish markets to collapse because fish are taken out of the population before they are able to reproduce (Hughes 1994). In places like Hawai’i, declines have been felt financially (e.g. fisheries market) as well as biologically (Cesar and van Beukering 2004) The reduction of herbivores allows invasive algae to grow uncontrollably (Vermeij et al. 2009). Similar to eutrophication, “phase shifts” have occurred endangering coastal marine environments (Ling et al. 2009).

2.2 Research Questions

Recognizing the important role abiotic factors play in the biological design of an environment, this study investigated which factors influence the biological (benthic and fishery) distributions at Kahalu´u. There are numerous water quality factors that regulate the presence of biological organisms. For the purpose of this study only depth, temperature, salinity, turbidity, pH, and dissolved oxygen were measured. Other abiotic factors measured include depth, spatial relief, and habitat type. Criteria for selection was due to the established influence that these

factors have on biological distributions (Runcie 2002). Below are the hypotheses tested in this study.

2.2.1 General Hypothesis Being Tested

H_o = Abiotic factors are not related to the abundance and distribution of biological species at Kahalu´u Bay.

H_a = Abiotic factors are related to abundance and distribution of biological species at Kahalu´u Bay.

2.2.2 Detailed Hypotheses

The general hypothesis described above was tested statistically for measurements of specific abiotic factors including depth, temperature, salinity, turbidity, pH, dissolved oxygen in relationship to the biotic factors of fish numerical abundance, fish biomass and fish trophic level. Methodology used to obtain the abiotic data are described in section 1.3.2.

General multivariate regressions were used to determine if the abiotic factors (depth, temperature, salinity, turbidity, pH, and dissolved oxygen) measured could predict the distribution and abundance of biological organisms. The biological data collected includes: total coral cover, numerical abundance of fishes (by total number of fishes and trophic level), and biomass of fishes (by total and trophic level). Data transformations of abiotic factors varied for

biological variables. Transformations were only performed in order to normalize data and to meet the assumptions for statistical analyses.

2.3 Results

A description of the abiotic variables that made a contribution to explaining the variability is shown in Table 2.1.

Table 2.1 Descriptive statistics for abiotic factors surveyed at 202 stations in Kahalu‘u Bay.

Variable	Mean	SE	Min	Median	Max
Depth MLLW (m)	1.56	0.14	0.00	1.03	11.71
Temperature (°C)	25.77	0.05	23.61	25.61	28.30
Salinity (ppt)	32.73	0.52	0.17	34.93	35.17
Turbidity (ntu)	1.04	0.47	0.00	<0.01	92.20
pH	8.24	0.01	7.17	8.27	8.46
Dissolved Oxygen (% saturation)	120.43	0.72	104.10	118.00	169.10

2.3.1 Abiotic Factors

2.3.1.1 Bathymetry/Depth

Kahalu´u Bay is a relatively shallow bay. The mean depth calculated form the inshore stations is 1.6 m at Mean Low Low Water (MLLW). Depth ranged from 0 to 11.7 m (Table 2.1, Fig. 2.1). Most areas inside the breakwall are < m

with a range from 0 – 2 m. Locations outside of the breakwall are deeper with a mean of 4 m, ranging from 0.4 -12 m (Table 2.2).

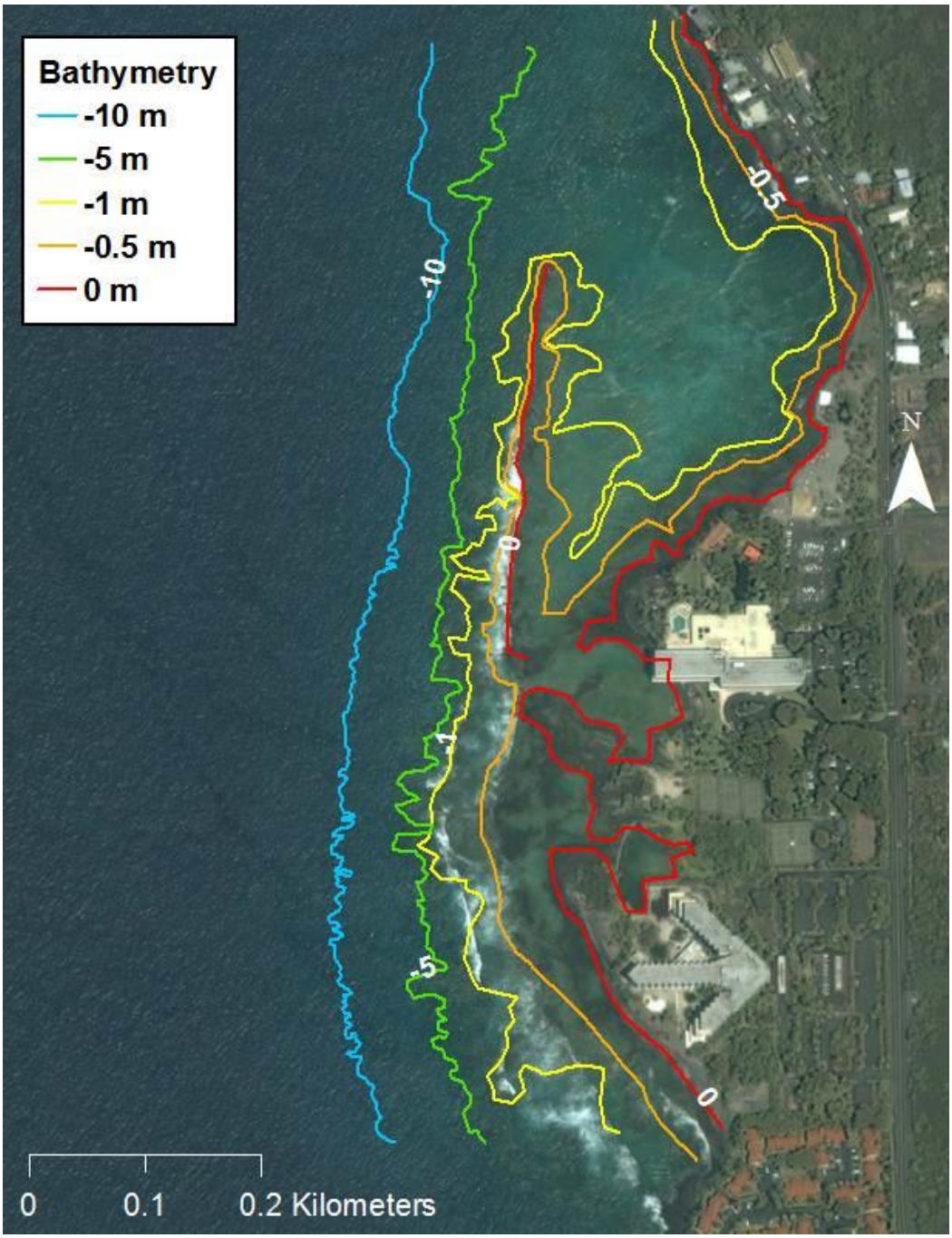

Figure 2.1. Bathymetry of Kahaluʻu Bay shown as depth in m at Mean Low Low Water (MLLW).

2.3.1.2 Temperature

The mean temperature for all survey stations is 25.77° C and ranged from 23.61 to 28.3° C (Table 2.1. Fig. 2.4). The mean temperature differed slightly by location: inside (25.6° C) and outside (26.0° C) which ranged in temperature from 23.6 – 28.3° C and 25.8 – 26.9° C respectively. Fluctuations are most salient in the tidepool and ridge (Fig. 2.2, 2.3).

<u>Tide Pool</u>

Hourly Changes

In the early morning hours till 0800 the temperature is fairly constant at approximately 24.75°C. At 0800 the temperature increase rapidly and peaks at 1700. This is the highest recorded temperature, approximately 29.5°C, of all temperature loggers. From the peak at 1700 temperatures sharply decrease and returns to early morning temperatures at 2300.

Monthly Changes

In the winter months of December and January the temperature drops from 25.2°C. In January the temperature rises rapidly and peaks in the summer. By June the temperature is approximately 25.9°C. This is highest mean temperature recorded from all locations.

Ridge

Hourly Changes

Unlike any of the other locations in the early morning hours till 0700 the water temperature drops to approximately 22.75°C. This is the lowest recorded temperature at any site. At 0700 the temperature steadily increases until peaking at approximately 28.75°C at 1700. Similar to the tide pool site temperature gradually declines until 2300. This site has the greatest temperature range (22.75°C – 28.75°C).

Monthly Changes

The ridge has the highest winter temperature of approximately 25.3°C. Like the tide pool habitats the temperature falls slightly until January. In the months following January the temperature steadily rises to 25.7°C.

Mid Bay

Hourly Changes

The temperature is approximately 24.5°C at 0000 and slightly drops to 23.75°C until 0800. Subsequently, there is a rapid increase in temperature, for which it peaks and levels of at 1430 at approximately 26.5°C. At 1800 the temperature sharply drops close to temperature recorded in the early morning.

Monthly Changes

In December the temperature is 24.9°C. The temperature drops in January, rises in February to 24.8°C, then fall again in March to 24.7°C. After falling for a second time, temperatures rapidly rise to 25.5°C in the summer months.

Break Wall

Hourly Changes

The temperature is approximately 24.5°C at 0000 and slightly drops to 23.75°C until 0600. Subsequently, there is a slight incline in temperature, for which it peaks at 1500 at approximately 25.75°C. Thereafter, the temperature declines again and is returns to early morning temperatures.

Monthly Changes

Similarly to temperatures in the Mid Bay, the temperature is approximately 24.9 in December. Temperatures fall in January, then rise in February and then fall again in March to 24.7°C. After the spring the temperature increases gradually and peak in the summer months at 25.7°C.

Open Ocean

Hourly Changes

Open ocean temperatures are fairly constant throughout the day and smallest range. In the early morning hours the temperature is approximately

24.5°C and remains constant until 1000. The temperature rises incrementally until peaking 25.5°C at 1630. Subsequently the time falls again to temperatures close to temperatures recorded in the early morning.

Monthly Changes

In the open ocean the temperature is 25.0°C in December. The temperature drops in January, rises in February, and falls again in March to 24.7°C. As summer approaches the temperature increases to 25.5 °C .

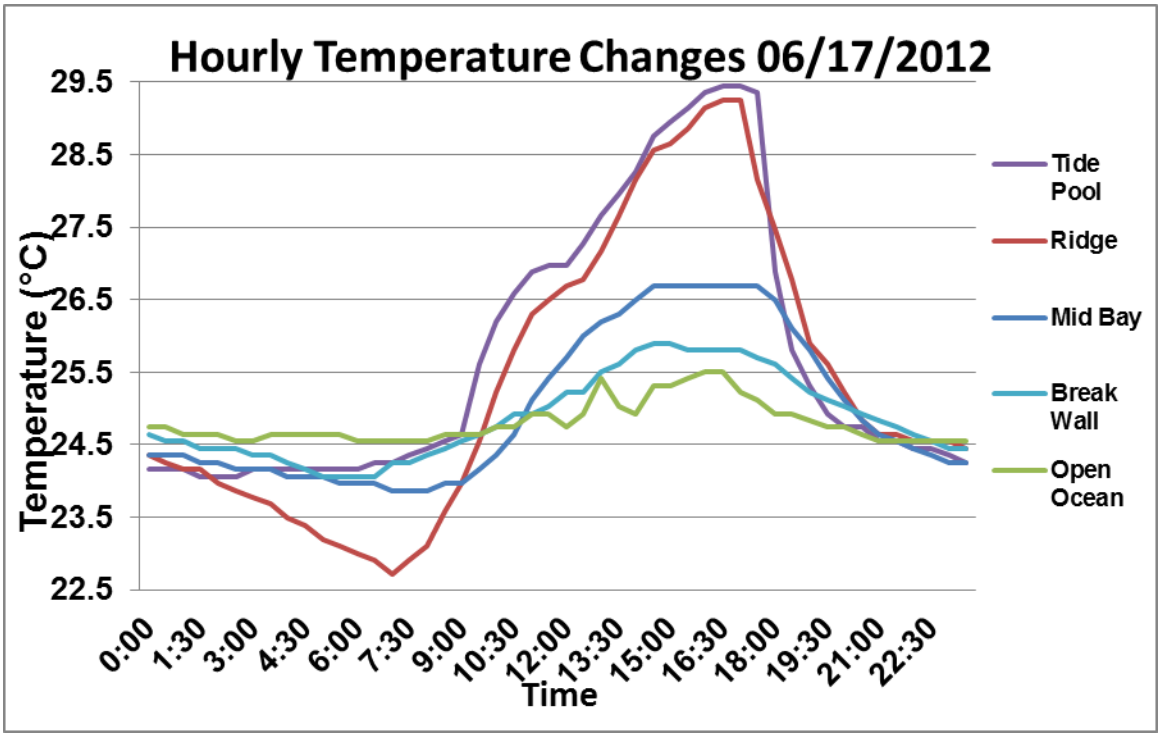

Figure 2.2. Hourly temperature changes at five locations at Kahalu´u Bay, Hawai´i.

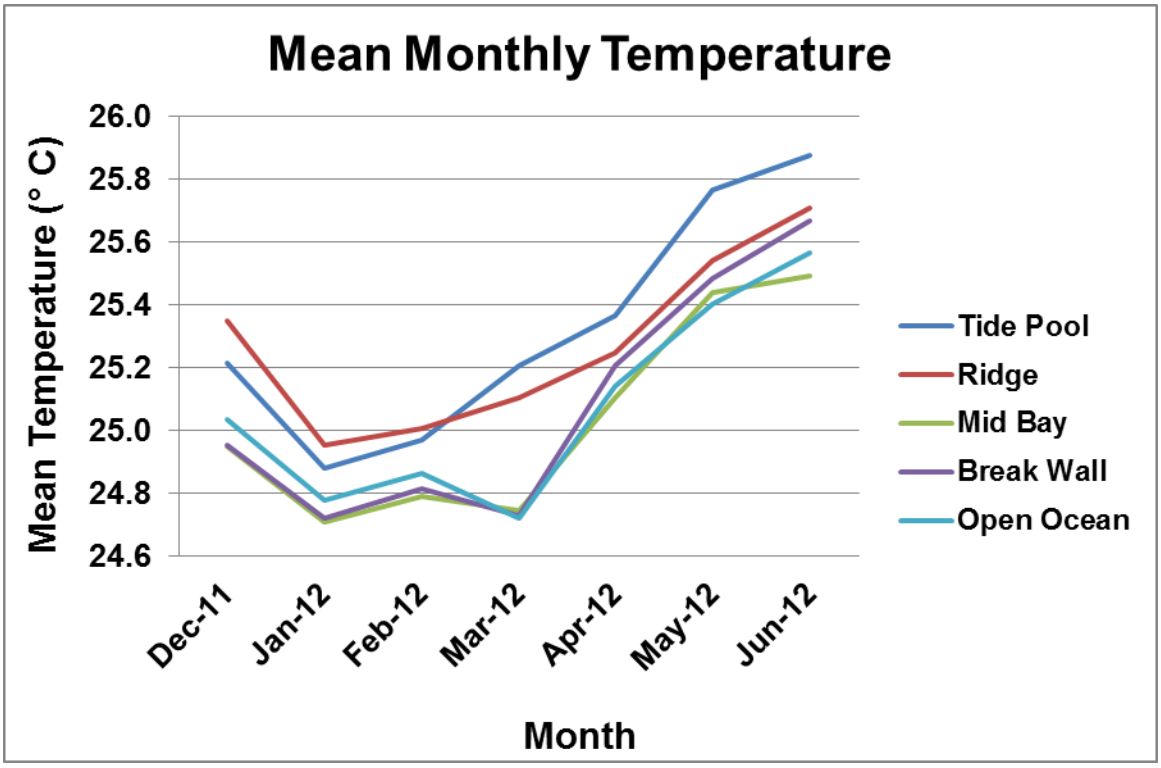

Figure 2.3. Mean monthly temperature changes at five locations at Kahalu´u Bay, Hawai´i.

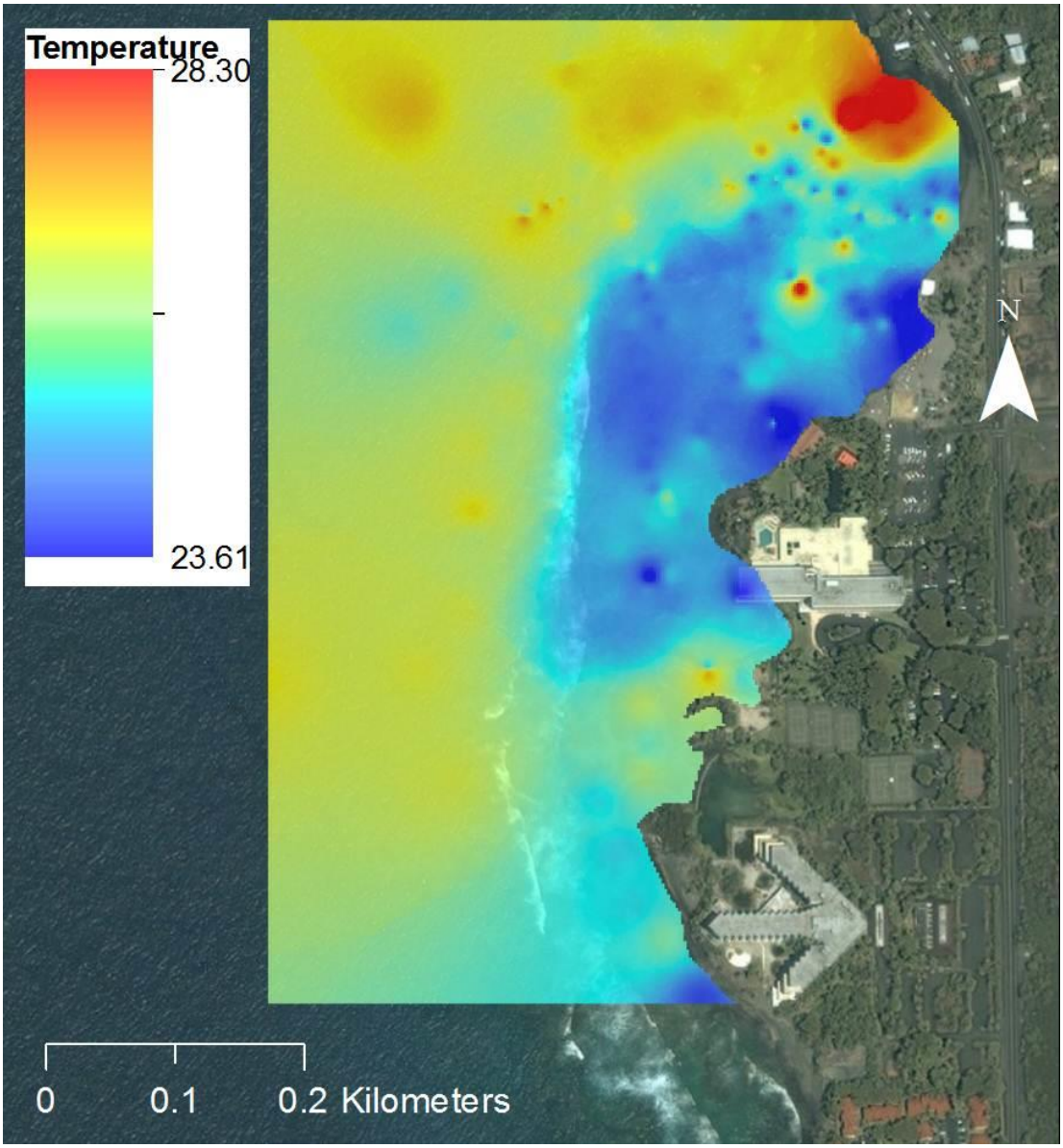

Figure 2.4. Temperature distribution in Kahalu‘u Bay

2.3.1.3 Salinity

The mean salinity for all survey stations was 32.7 (ppt) and ranged from 0.2 – 35.2 ppt (Table 2.1, Fig. 2.5). The mean salinity differed by location: inside stations (32.3 ppt) and outside stations (34.3 ppt) which ranged in salinity from 0.17 – 35.2 ppt and 5.2 -35.1 ppt respectively.

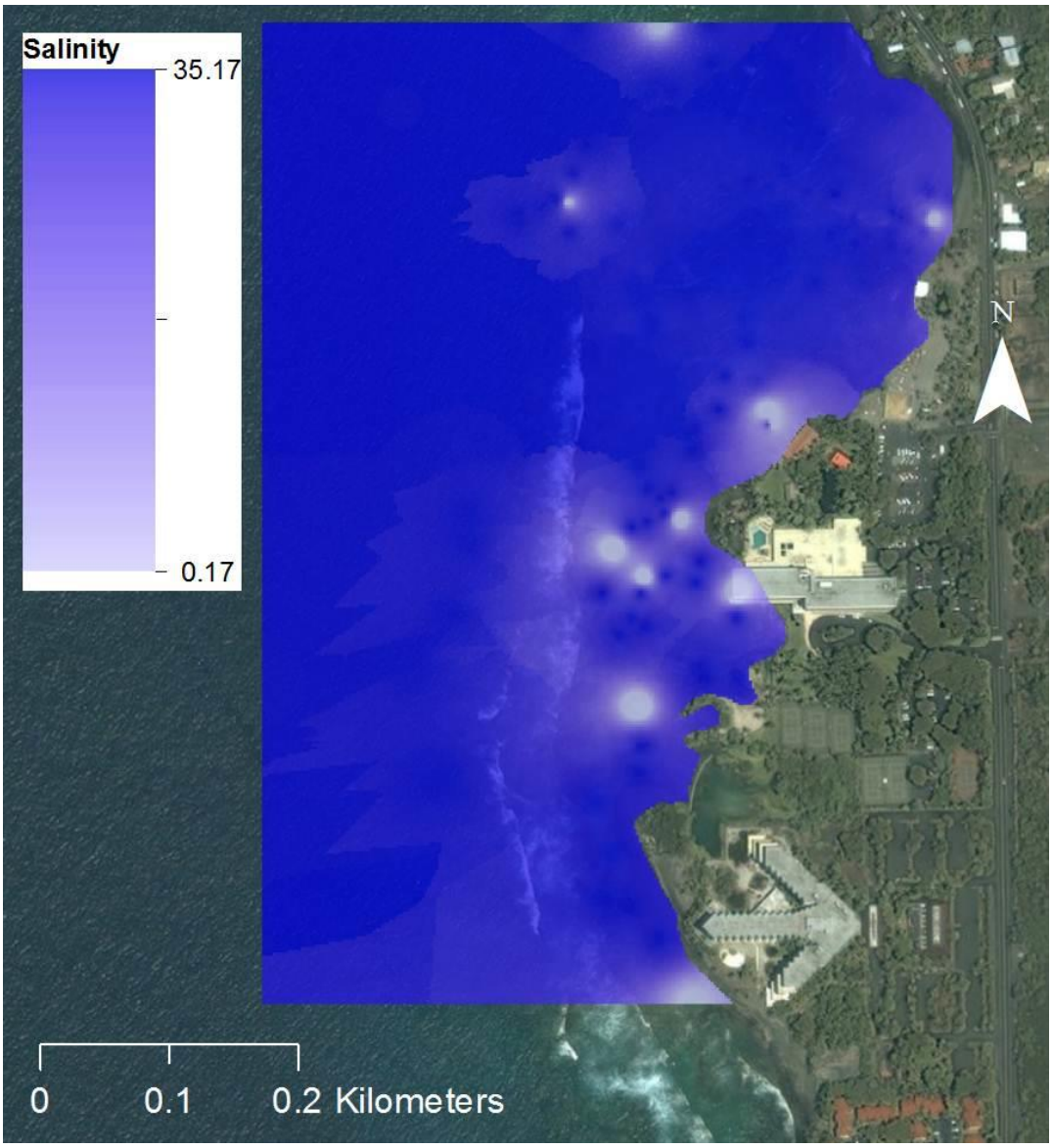

Figure 2.5. Salinity in Kahalu‘u Bay.

2.3.1.4 Turbidity

The mean turbidity for all survey stations is 1.04 nephelometric turbidity units (ntu) and ranged from 0 – 92.2 ntu (Table 2.1, 2.6). The mean turbidity differed by location: inside (1.26 ntu) and outside (0.18 ntu) which ranged in turbidity from 0 – 92.2 ntu and 0 – 6.2 ntu respectively (Table 2.2, Fig. 2.6).

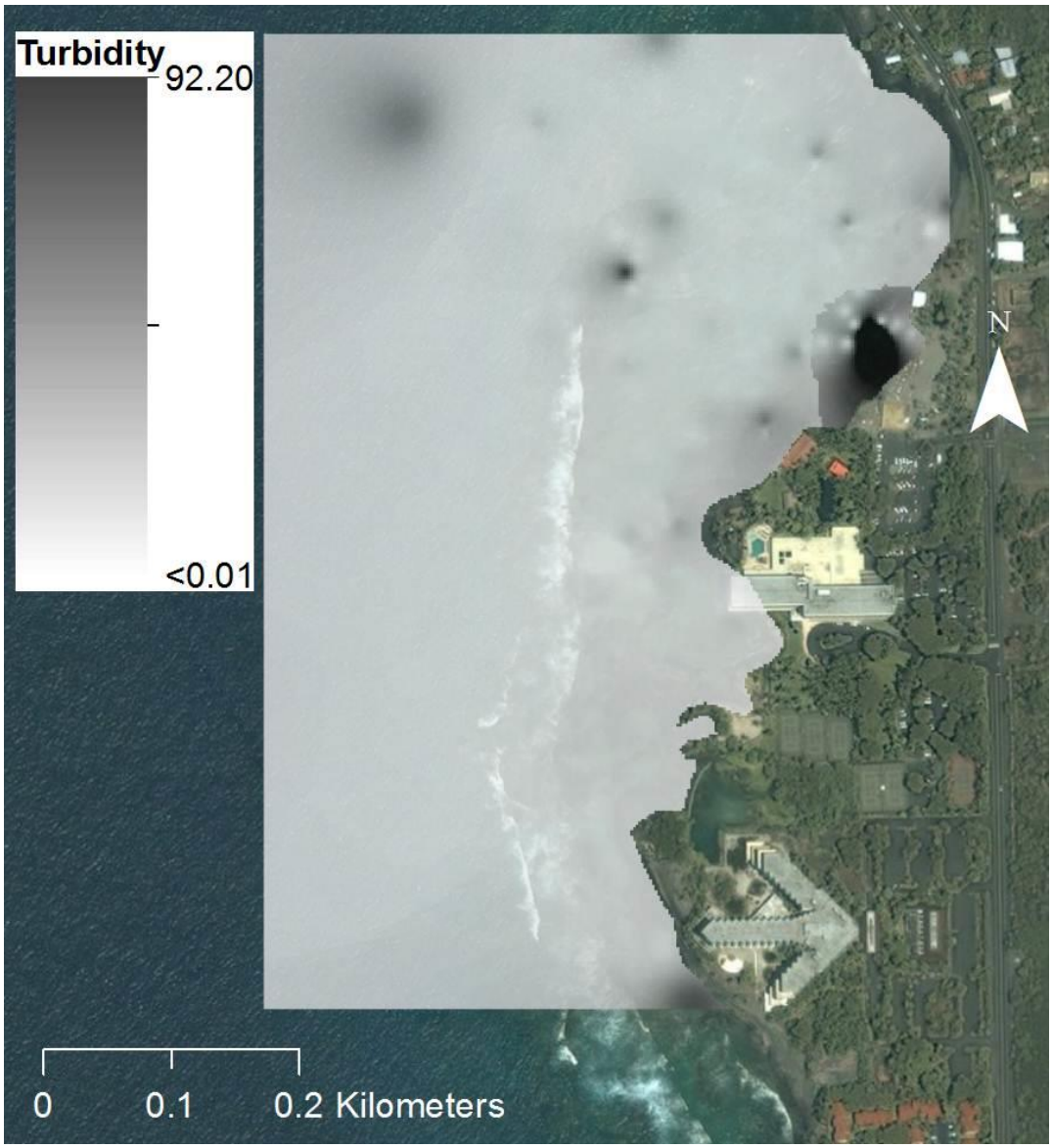

Figure 2.6. Turbidity distribution in Kahalu‘u Bay

2.3.1.5 pH

The pH ranged from 7.17 – 8.46, with a mean of 8.24 (Table 2.1, 2.2, Fig. 2.7). The inside of the bay has a mean pH of 8.27 and ranged from 7.17-8.46. The mean outside pH is 8.2 ranging from 8.1 – 8.2.

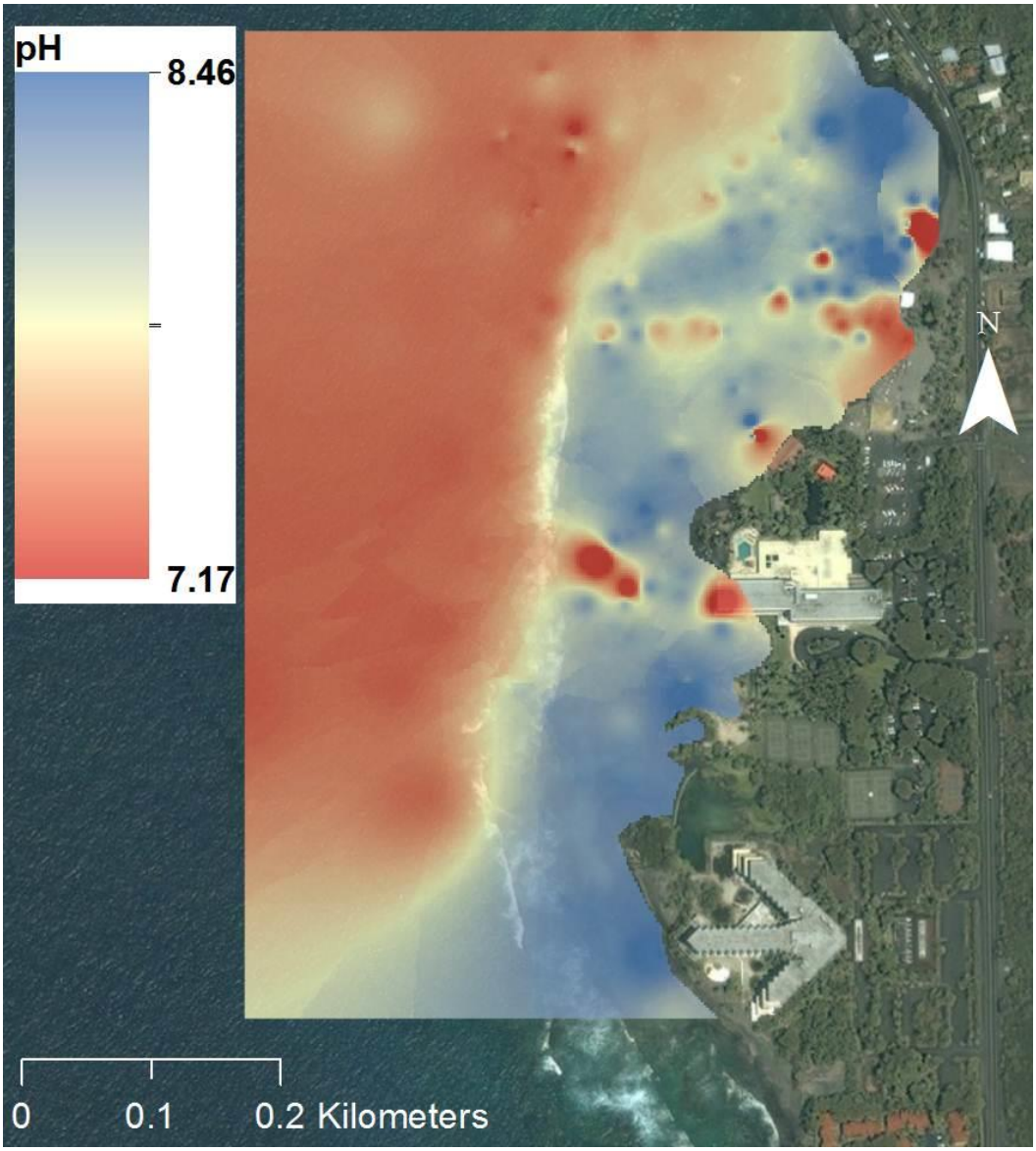

Figure 2.7. Daytime distribution of pH values in Kahalu‘u Bay.

2.3.1.6 Dissolved Oxygen

The mean dissolved oxygen (DO) for all survey stations is 120% and ranged from 104 – 169% (Table 2.1). The mean DO differed by location: inside (122%) and outside (115%) with ranges from 104 – 169% and 107 – 128% respectively (Table 2.2, Fig. 2.8).

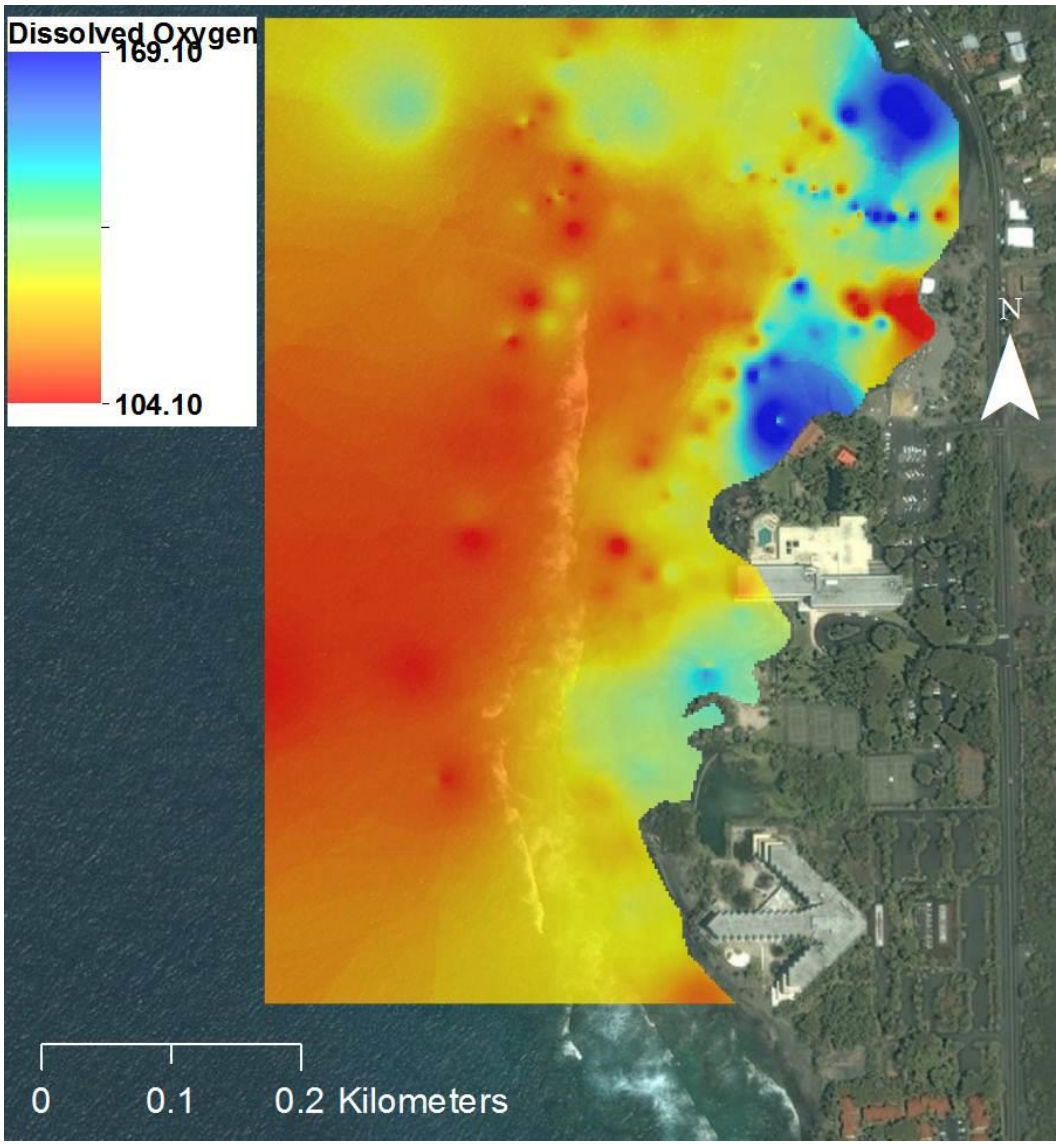

Figure 2.8. Daytime dissolved oxygen (% saturation) distribution in Kahalu‘u Bay

Table 2.2 Descriptive statistics of 202 surveyed stations by location.

Variable	LOCATION	Mean	SE Mean	Min	Median	Max
Depth MLLW (m)	I	0.91	0.04	0	0.96	2.04
	O	4.02	0.51	0.37	2.17	11.71
Temperature (°C)	I	25.62	0.06	23.61	25.48	28.3
	O	26.33	0.04	25.78	26.25	26.9
Salinity (ppt)	I	32.32	0.63	0.17	34.92	35.17
	O	34.26	0.71	5.18	34.95	35.09
Turbidity (ppt)	I	1.26	0.59	0	0	92.2
	O	0.18	0.15	0	0	6.2
pH	I	8.27	0.01	7.17	8.3	8.46
	O	8.16	0	8.1	8.16	8.21
Dissolved Oxygen (%)	I	121.77	0.84	104.1	120	169.1
	O	115.34	0.91	107.2	113.65	128

I=inside Bay, O=outside Bay

MLLW=Mean Low Low Water

2.3.1.7 Waves

Wave energy is a major physical factor controlling coral reef communities. Jokiel et al. (2004) surveyed sites throughout the MHI and showed that mean wave height had a positive relationship with species richness. However, waves can reach destructive levels that will damage corals and restrict species distribution patterns (Dollar 1982, Storlazzi et al. 2002). Mean wave direction (compass bearing) shows a negative relationship with coral cover and diversity (Jokiel et al. 2004) because major storm surf in Hawai‘i arrives along a gradient that roughly diminishes in a counter clockwise direction from the North (Moberly 1974, Jokiel 2006). The largest and most frequent storm surf arrives during the winter North Pacific Swell (bearing 315°) with the less frequent and less damaging storm waves during the summer from the South Swell (bearing 190°), Kona Storm

waves (bearing 201°) and the less severe Trade Wind Swell (bearing 45°). Maximum wave height is a major factor with a negative relationship with coral cover, diversity and species richness (Jokiel et al. 2004). Maximum wave height is a good index of destructive wave events that damage Hawaiian reefs. The reef at Kahaluʻu is partially shielded from the storm surf of the North Pacific Swell and completely from the Trade Wind Swell by the mass of the Island of Hawaiʻi. However, North Pacific Swell coming from the NW and South Swell from the SW and Kona Storm waves from the south will impact this location. Wave information on oceanic wave height and direction reaching Kahaluʻu Bay is not directly available. However, a wave-sensing buoy is operated by the Coastal Data Information Program (CDIP) at site number 146 (http://cdip.ucsd.edu) which is located approximately 1 km off Kaumalapau, Lānaʻi, HI at 20° 47.27' N 157° 0.59' W at a depth of 201 m. This buoy is located along a westward facing shoreline that blocks the North and Northwest swell. Kahaluʻu experiences a similar wave regime. Data are taken with a Datawell directional buoy that measures wave energy and wave direction. A complete exemplary data set exists for 2012 which can be used as a surrogate to describe general wave conditions at Kahaluʻu Bay over the course of one year (Figs. 2.9-2.11). Largest mean wave heights originated at North Pacific Swell from the west and occurred during the winter months of January and February (Fig. 2.9) with monthly mean wave heights exceeding 1 meter and coming from a compass direction of approximately 260° (Fig. 2.10). Mean wave height decreased during the spring and remained low during the summer months. May has the lowest recorded

mean wave height. Wave direction shifted from West to South West and South during this period. During the fall there is a steady increase in wave height that peaks in winter once again. Large storm events occurred throughout the year (Fig. 2.11) as the result of major North Pacific Swell in the winter (Dec.-Mar.) and South Pacific Swell and Kona storms in the summer (Jun-Aug). The largest recorded wave height, 2.2 m, occurred in February (North Pacific Swell). Thus at Kahalu‘u we would expect more wave activity in the winter months than in the summer months, but with large wave events occurring occasionally from the NW in the winter and from the SW in the summer.

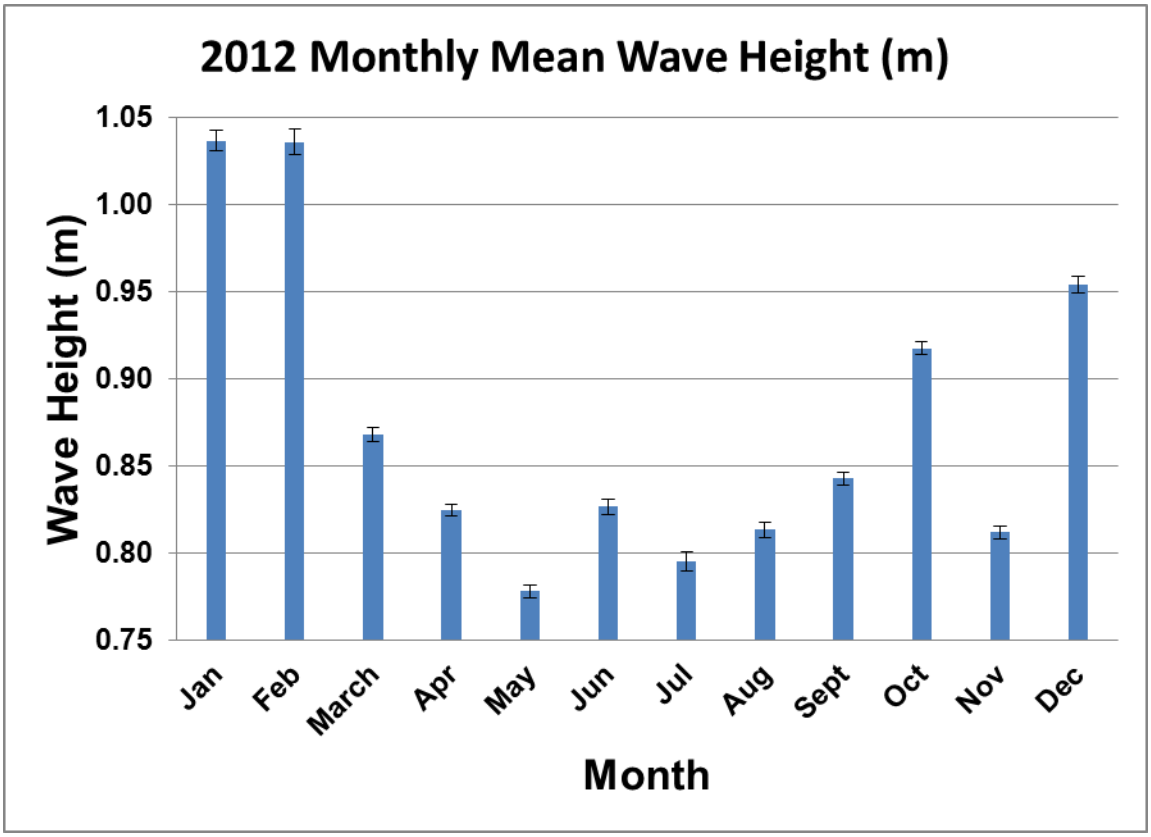

Figure 2.9. Monthly mean wave height (m) for 2012 at Kaumalapau, Lana´i. Data from Coastal Data Information Program (http://cdip.ucsd.edu).

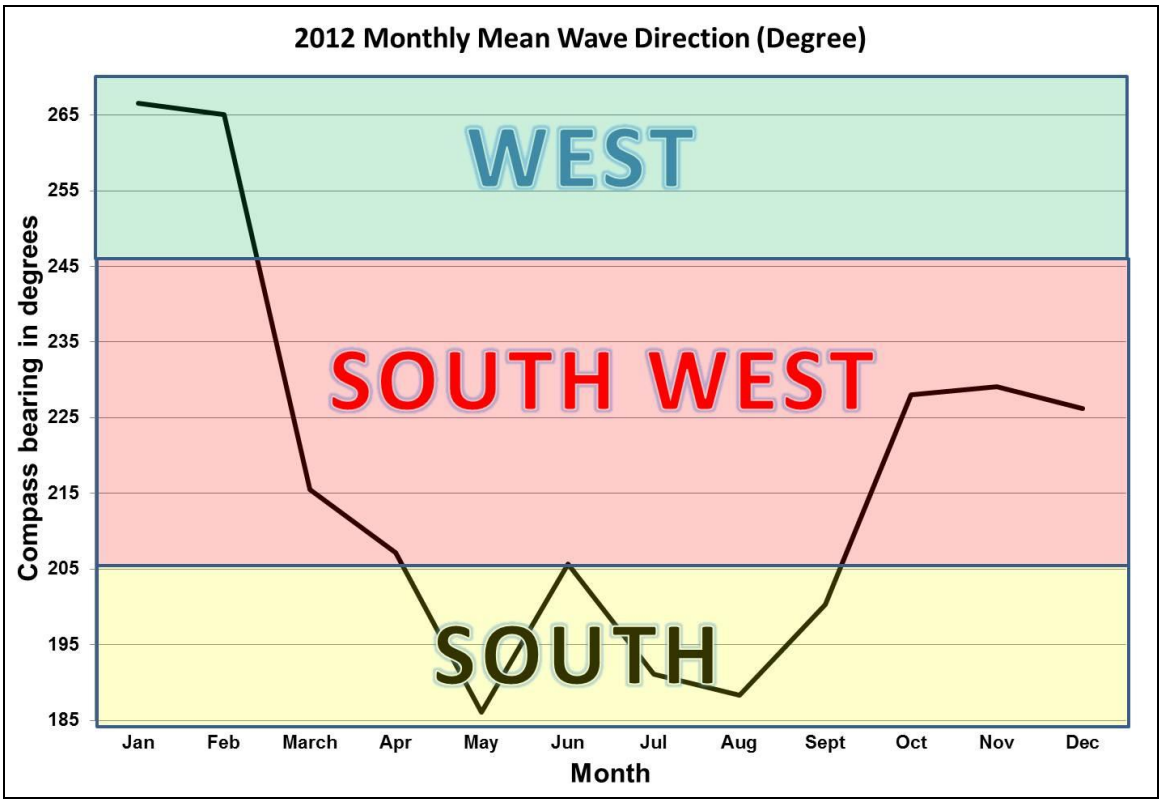

Figure 2.10. Monthly mean wave direction (degree) for 2012 at Kaumalapau, Lana´i. Data from Coastal Data Information Program (http://cdip.ucsd.edu).

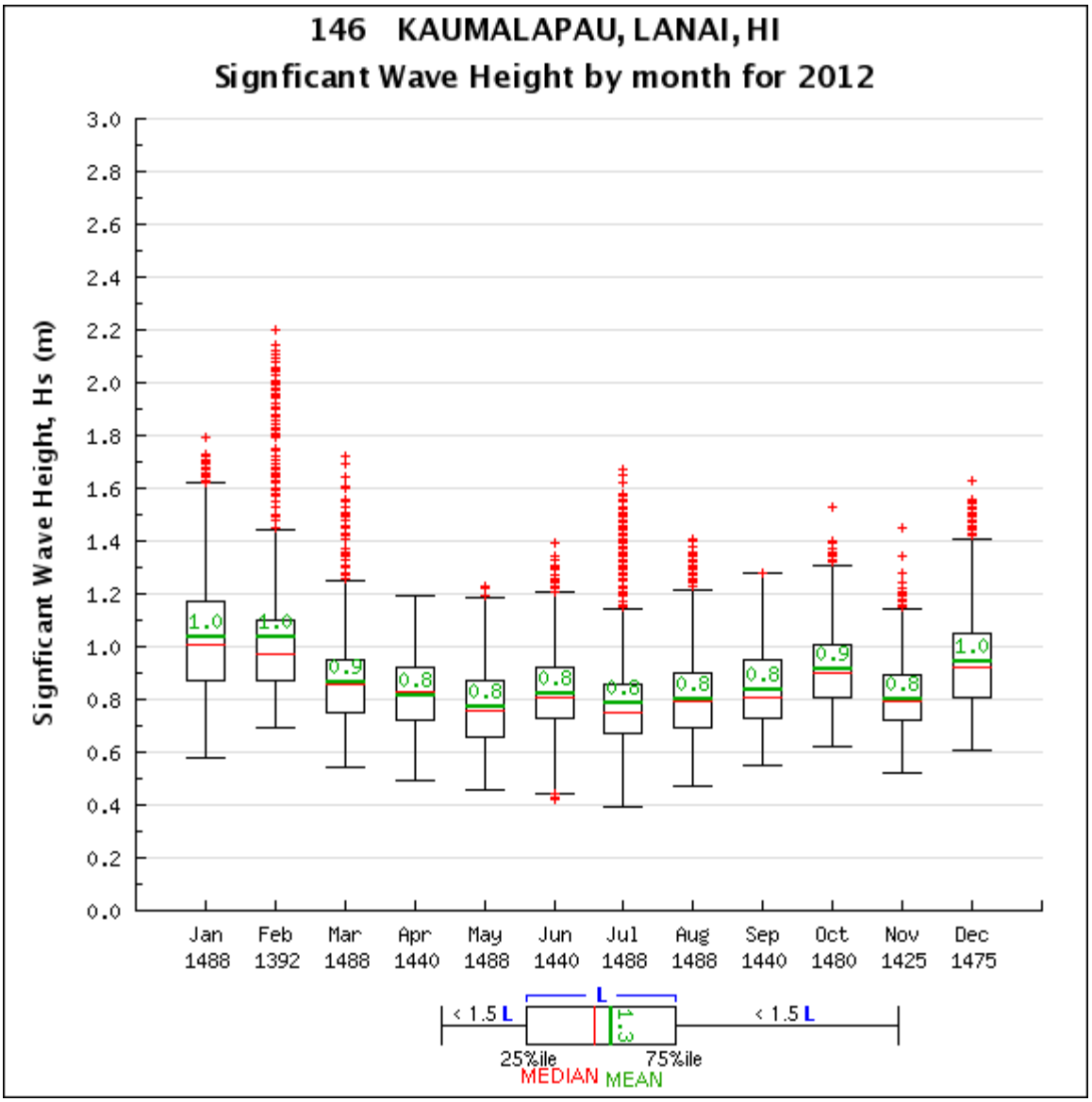

Figure 2.11. Monthly outlying wave heights (m) for 2012 at Kaumalapau, Lana´i. Data from Coastal Data Information Program (http://cdip.ucsd.edu).

2.3.1.8 Tides

Tides are changes in local sea level caused by the gravitational pull of the moon and the sun on the ocean that creates "bulges" of water on opposite sides of the earth. Kahalu‘u Bay passes through these bulges twice a day, resulting in a semi-diurnal (half daily) component to the tide (Fig. 2.12). The sun and the moon do not lie directly over the equator, so one of the bulges is larger than the other,

leading to a diurnal (daily) component. There is a modulation of the tidal range caused by the position of the moon relative to the sun. During full moon or new moon the sun and moon act together to produce larger "spring" tides. When the moon is in its first or last quarter the sun and moon gravitational pull do not reinforce each other and smaller "neap" tides occur. The cycle of spring to neap tides is half the 27-day period of the moon's revolution around the earth, and is known as the fortnightly cycle. The combination of diurnal, semi-diurnal and fortnightly cycles dominates variations in sea level at Kahalu‘u Bay as shown by the sample data from the nearest Kona Coast tide station at Kawaihae. (http://tidesandcurrents.noaa.gov). The measured tide differs slightly from the predicted tide due to influence of winds, mesoscale eddies, changes in regional mean sea level and other factors. The Diurnal Range (difference in height between mean higher high water and mean lower low water) at Kahalu‘u is 0.66 m (2.2 ft.). The Mean (difference in height between mean high water and mean low water) at Kahalu‘u is 0.45 m (1.5 ft). The extreme range is approximately 1 m (3.3 ft).

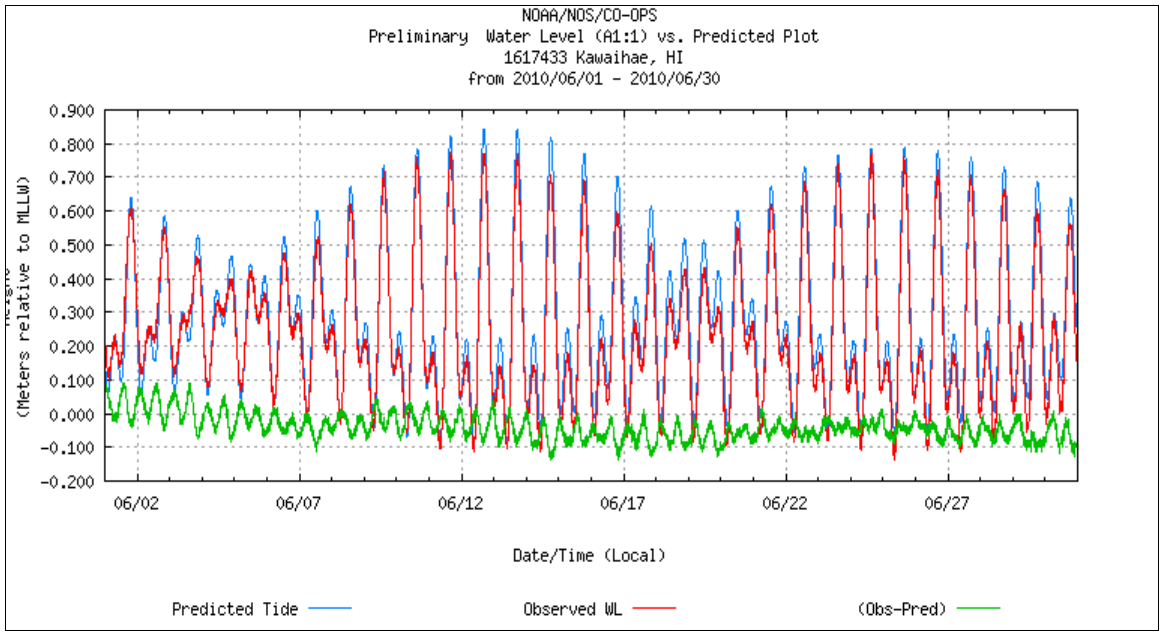

Figure 2.12. Kona coast tides during survey of June 2010 show the strong diurnal and semi-diurnal component. The measured tide is in blue, predicted tide in red and the difference between predicted and observed is in green.

2.3.1.9 Currents in Kahalu‘u Bay

Currents within Kahalu‘u Bay are controlled primarily by waves and tides. Wave height varies throughout the year (Fig. 2.9). The bathymetry of the area (Fig. 2.1) consists of a shallow basalt bench to the south that drops off sharply to depths of 10 m along the ocean margin and gradually into deeper water at the north end of the bay. Waves pile onto the shallow shelf to build a dynamic head of seawater which flows downhill to the north (Fig. 2.13). The velocity of the current is determined by interaction between wave height and tide height. As the tide level rises, more water is driven onto the shallow bench at the south end of the bay and flows to the south and exits through the deeper north channel. Surf beat has a major effect on current velocity. Large wave sets increase the dynamic head in the south with resulting rapid acceleration of current flowing to

the north. Acceleration of current by large wave sets creates a major hazard to swimmers who can be swept out to sea by such rip currents which accelerate rapidly and unexpectedly. This has also been noted by Mitchell Fujisaka in interviews. During times of flat calm the currents are weak and driven primarily by tidal exchange. However, some level of wave pumping is nearly always present.

Times of high wave energy and strong currents are very important to the ecology of the Kahalu‘u Bay ecosystem. Rapid flushing removes detritus and fine sediments from the system which benefits the coral communities and moderates conditions of temperature, salinity and nutrient levels throughout the area.

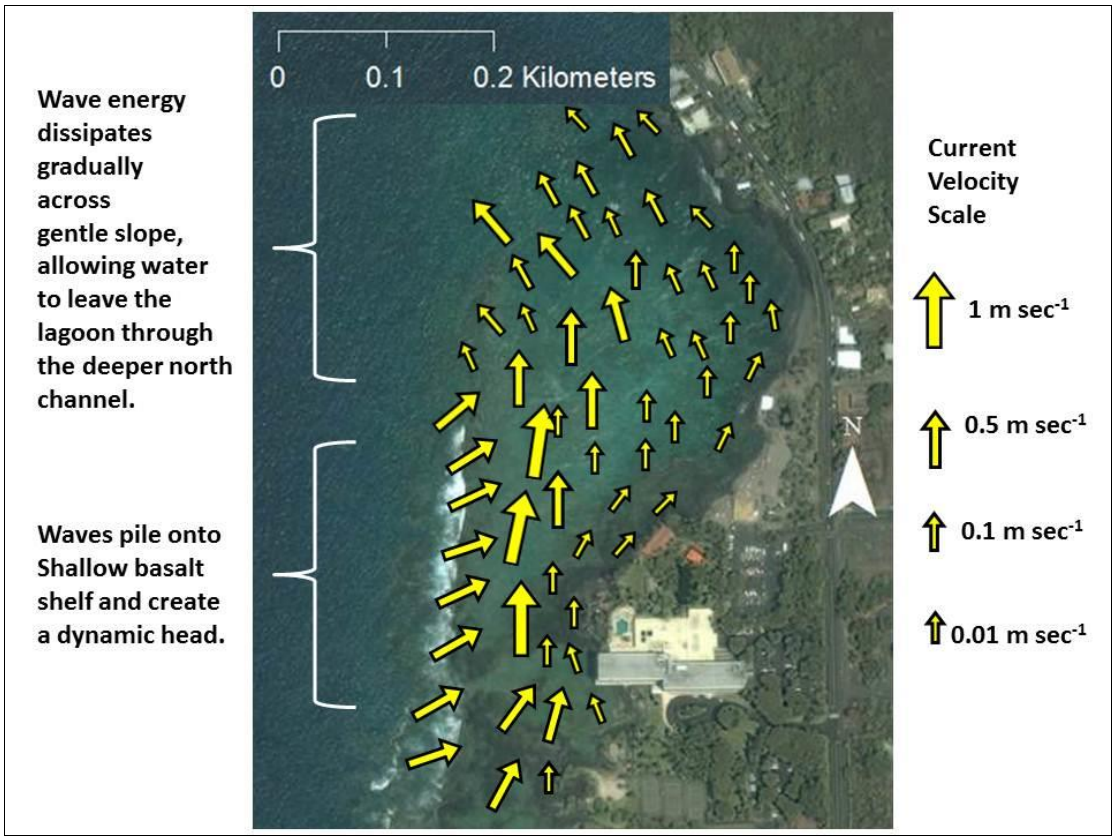

Figure 2.13. Generalized map of current flow within Kahalu‘u Bay during periods of high surf (figure produced by Jokiel).

2.3.2 Biotic Factors

2.3.2.1 Corals

The mean coral coverage of 202 stations is 21% (Table 2.3). Outside or ocean reef stations (35%) is nearly twice as much coral as inside or lagoon stations (18%).

Table 2.3 Mean coral coverage by location

Location	Mean ± [Minimum, Maximum]
Overall	21 ± 2 [0,90]
Lagoon	18 ± 2 [0,90]
Ocean Reef	35 ± 4 [10,90]

2.3.2.2 Fishes

The overall mean biomass and numerical abundance of fishes observed at Kahalu´u Bay was 2.4 (kg/stations) and 48 (no./ station) [Table 2.4]. Ocean reef or outside stations has a higher mean yield of fish biomass (5.2 kg/station) and numbers (84) than lagoon or inside stations (1.7 kg/station and 39 no./station).

Table 2.4 Mean fish biomass and numerical abundance by location

Location	Biomass (kg/station)	Numerical Abundance (No./station)
Overall	2.4 ± 0.2	48 ± 3
Lagoon	1.7 ± 0.2	39 ± 2
Ocean Reef	5.2 ± 0.5	84 ± 8

2.3.3 Abiotic Influence on Biological Structure

2.3.3.1 Coral

A multivariate regression analysis was conducted with the predictor variables: depth, temperature, salinity, turbidity, pH, and dissolved oxygen with total coral cover as the response variable. This is statistically significant with an R^2 of 0.298 ($p < 0.0005$). All predictor variables account for 29.8% of the variation in predicting total coral cover. Results from the multivariate regression indicate that depth ($p = 0.0001$) and salinity ($p = 0.007$) are statistically significant. Regression results are shown in table 2.5.

2.3.3.2 Fish Numerical Abundance and Biomass

<u>Total Number of Fishes and Biomass</u>

A multiple regression was conducted to determine if abiotic parameters (depth, temperature, salinity, turbidity, pH, and dissolved oxygen) measured in this study can predict the total number of fishes and biomass. The same factors were used in the successive regression models. The model was statistically significant or fish abundance ($p <0.0005$, $R^2 = 0.3409$) and biomass ($p <0.0005$, R^2 of 0.5364). In the multivariate regression, 34.09% of the variance for predicting total number of fishes and 53.64% for fish biomass is explained by the predictor variables. Two abiotic predictor variables were statistically significant (depth (p=0.004) and pH (p=0.0007)) for fish abundance and four factors (depth ($p <0.0005$), temperature ($p <0.0005$), salinity ($p <0.0005$), and pH ($p <0.0005$)) for fish biomass. Regression results are shown in table 2.5.

Herbivores Number and Biomass

The multivariate regression model is statistically significant for numbers of fishes ($p < 0.0005$, R^2=0.226) and fish biomass (p <0.0005, R^2=0.5051). A large portion of the variability in predicting the number of herbivores (22.63%) and biomass (50.51%) is explained by these variables. The three predictor variables that are statistically significant in predicting number of fishes are temperature (p<0.0005), salinity (p=0.006), and pH (p<0.0005). Depth (p =0.027), temperature (p <0.0005), salinity (p=0.002), and pH (p <0.0005) was statistically significant in predicting fish biomass. Regression results are shown in table 2.5.

Invertebrate Feeders Number and Biomass

A multiple regression was conducted to determine if the number of invertebrate feeders can be explained by any of the abiotic factors. The model was statistically significant for abundance of invertebrate feeders (p= 0.0005, R^2 0.1218) and for biomass (p<0.0005, R^2=0.3243). Predictor variables only accounted for 12.18% of the variation in predicting the abundance of invertebrate feeders and 32.43% for biomass. No abiotic factors were found to be statistically significant for number of invertebrate feeders. Depth (p =0.001), temperature (p =0.016), and salinity (p <0.0005) were statistically significant in explaining biomass. Regression results are shown in table 2.5.

Piscivores Number and Biomass

The multivariate regression model was not statistically significant (p=0.949) or any individual factor for piscivore numbers although the abiotic factors used in the model accounted for 18.97% of the variability. Piscivore biomass was statistically significant (p =0.0254, R^2=0.3095). Approximately 30.95% of the variation in was explained by the measured abiotic factors. Results from the regression indicate that salinity (p =0.027) and pH (p =0.033) are statistically significant in contributing to the variability in piscivore biomass. Refer to regression results shown in table 2.5.

Zooplanktivores Number and Biomass

This regression model was statistically significant for both zooplanktivore numbers (p=0.009, R^2= 0.2882) and biomass (p =0.006, R^2=0.2887). Predictor variables accounted for 28.82% of the variation in predicting total zooplanktivore abundance and 29% of biomass. Only pH (p =0.041) is statistically significant in explaining the variability in zooplanktivore numbers and no factors are significant in predicting biomass (table 2.5).

Table 2.5 Water quality parameters tested against biological variables of coral, fish numbers and fish biomass. Statistically significant values denoted by bold type and an asterisk (*).

Response Variable	**Water Quality Parameter**					
	Depth (m)	Temperature (^{o}C)	Salinity (ppt)	Turbidity (ntu)	pH	Dissolved Oxygen (%)
Coral	**0.017***	0.163	**<0.0005***	0.687	0.76	0.635
Fish Number	**0.004***	**<0.0005***	**0.018***	0.385	**0.0007***	0.31
(H) Number	0.539	**<0.0005***	**0.006***	0.616	**<0.0005***	0.286
(INV) Number	0.08	0.097	0.173	0.8	0.425	0.678
(P) Number	0.877	0.565	0.849	0.83	0.911	0.959
(Z) Number	0.108	0.398	0.229	0.901	**0.041***	0.986
Fish Biomass	**<0.0005***	**<0.0005***	**<0.0005***	0.901	**<0.0005***	0.857
(H) Biomass	**0.027***	**<0.0005***	**0.002***	0.477	**<0.0005***	0.833
(INV) Biomass	**0.001***	**0.016***	**<0.0005***	0.647	0.117	0.402
(P) Biomass	0.434	0.111	**0.027***	0.226	**0.033***	0.575
(Z) Biomass	0.361	0.128	0.51	0.131	0.184	0.795

H=Herbivore, INV=Invertebrate feeder, P=Piscivore, Z=Zooplankton feeder

2.3.4 Habitat Grouping

Four major habitat types were identified by observation in Kahalu‘u Bay (Fig. 2.14).

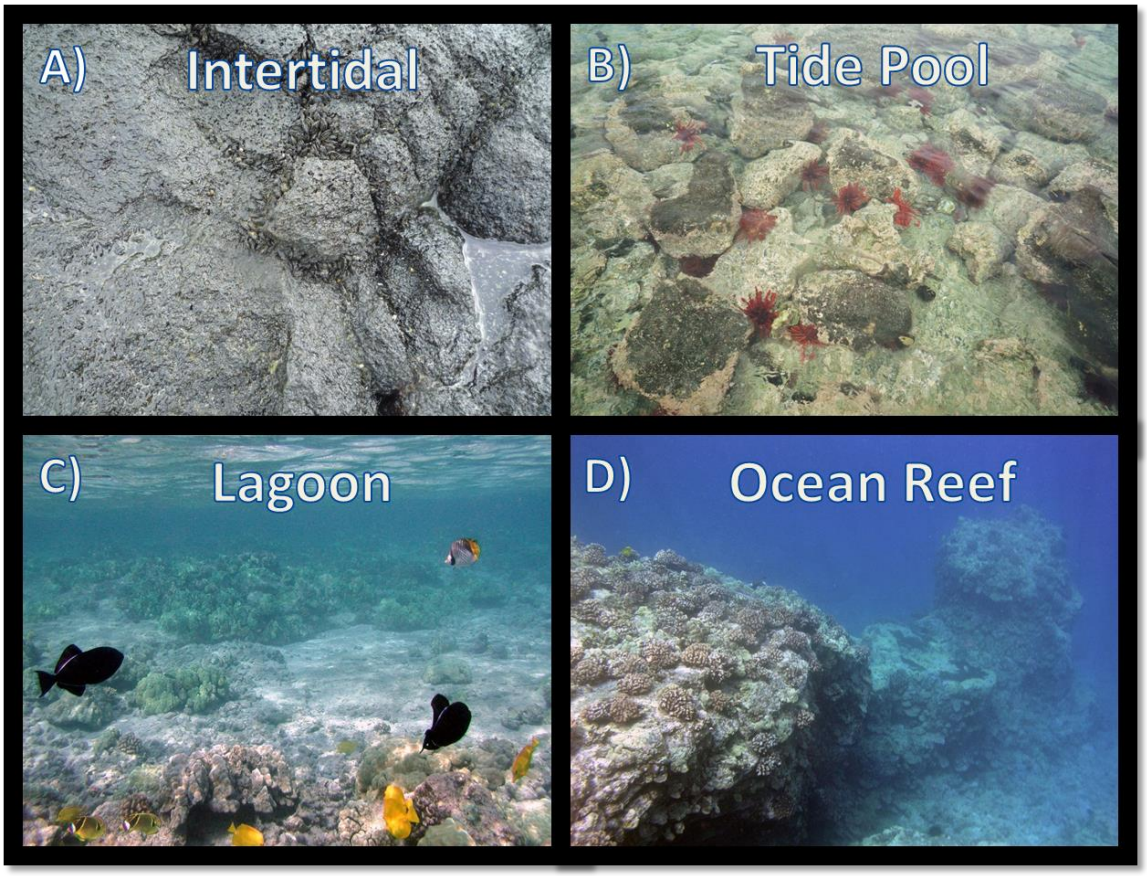

Figure 2.14. Representative images of the four major habitat types of Kahalu‘u Bay.

2.3.4.1 Principal Components Analysis (PCA)

A Principal Components Analysis (PCA) using eight variables including location, depth (m), rugosity, temperature (° C), salinity (ppt), total coral cover (%),fish biomass (g), and fish numerical abundance, reveal three distinctive groupings from 202 stations (Fig. 2.15). In the first three axes, 73.4% of the variability is accounted for by these factors.

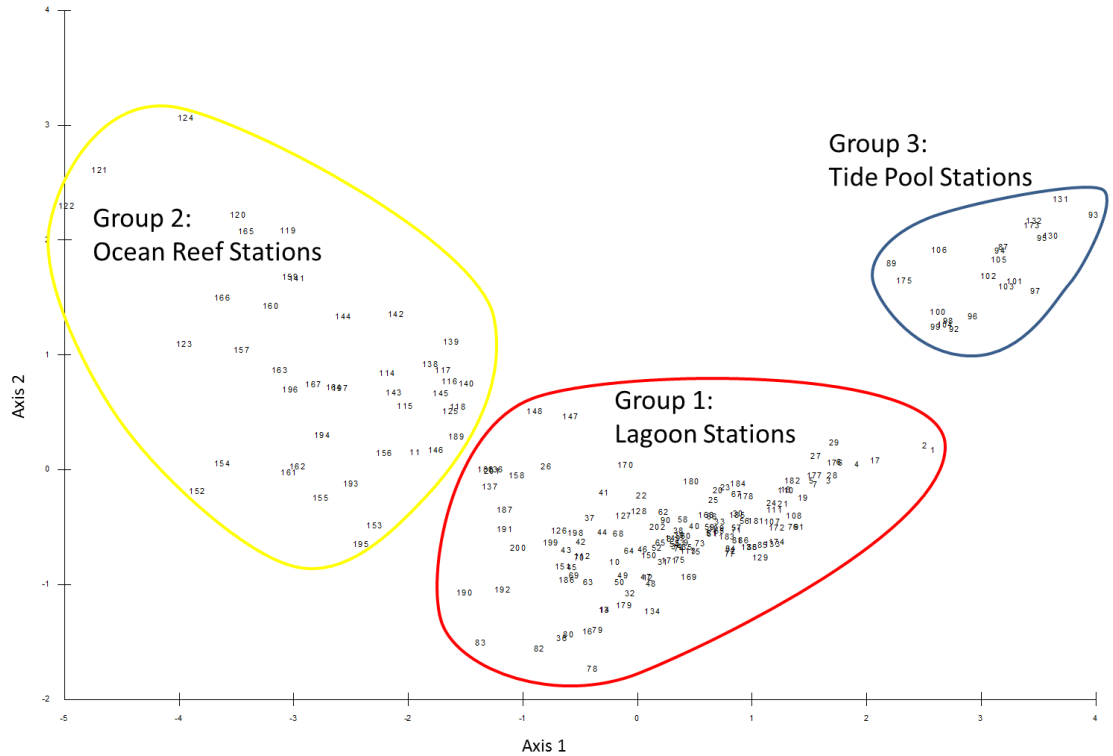

Figure 2.15. Results from the Principal Components Analysis (PCA) indicated three distinct groupings.

<u>Group 1: Lagoon Stations</u>

Separation in ordination space reveals the strong similarity within each grouping. The "red" cluster has the largest number of stations (Fig. 2.15). They are characterized by location on the inside of the breakwall, intermediate rugosity, water temperatures and salinities near ambient open ocean conditions, and moderate coral cover. Fish communities at these stations are modestly populated (numerical abundance and total biomass) as compared to the other clusters.

<u>Group 2: Open Reef Stations</u>

The second grouping, (the yellow cluster) are located outside the breakwall (Fig. 2.15). They are categorized by ambient open ocean temperatures and salinities,

high coral cover, and high vertical relief. High abundance and biomass of fishes are found within these stations as compared to the other groupings. The red and yellow clusters are closely related in spatial complexity, temperature, and salinity but differ in terms of location, total fish biomass and numerical abundances.

Group 3: Tidepool Stations

The final grouping (the blue cluster) of stations are the most dissimilar from the other two (Fig. 2.15). These stations located inside the breakwall are characterized as having low salinities, colder temperatures, lower rugosity, and lower coral cover. Fish communities are also lower at these stations in biomass and numbers compared to other groups. Although divergent from the other groups, group 3 is closest to group 1 in ordination space, with some overlap of station location. Both these groups possess lower fish abundance and biomass than stations in group 2.

2.3.4.2 Analysis of Similarities (ANOSIM)

An Analysis of Similarities (ANOSIM) was concurrently conducted with the Principal Components Analysis (PCA) in order to determine if the groupings are significantly different from each other. Prior to the analysis the variables location, depth (m), rugosity, temperature (° C), salinity (ppt), total coral cover (%), all fish biomass (g), and all fish number were used to generate a similarities plot (Fig. 2.16). Similar to PCA results three distinct groups were revealed. The groups of stations are located inside and outside the breakwall, the open ocean, and in the

tidepool areas (Fig. 2.17). Subsequently in PRIMER, an ANOSIM was conducted for pairwise comparisons between each grouping using the factor habitat type (inside or lagoon, outside or open reef, and tidepool areas). Statistical results from the ANOSIM indicate that all groups are significantly different, all *p*- values were less than 0.001. Congruent with the PCA inside and open ocean stations are more closely related than tidepool stations.

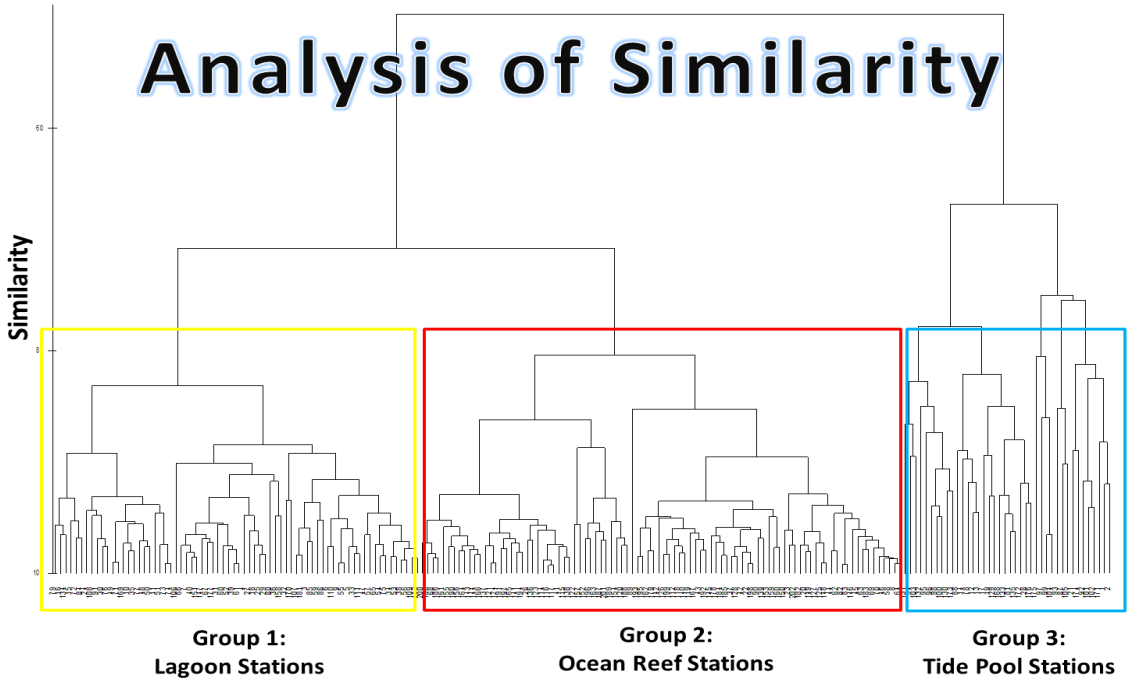

Figure 2.16. Similarity matrix showing relatedness of station locations.

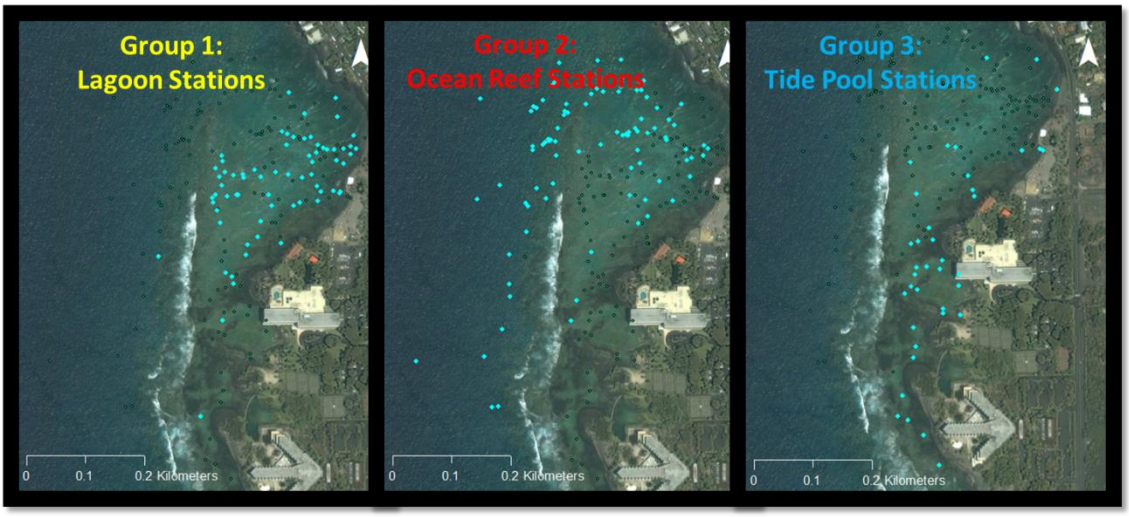

Figure 2.17. Map showing location of Groups 1-3 in similarity matrix.

2.3.5 CRAMP sites

Comparisons of Historical Benthic Habitat Monitoring

Resurveys of West Hawai‘i’s Coral Reef Assessment and Monitoring Program’s long-term monitoring sites were conducted in late March 2010 in collaboration with the State of Hawai‘i Division of Aquatic Resources (Jokiel et al. 2004). Analyses of these data show an increase in coral cover over the past decade from 2000-2010 at La‘aloa located 0.3 km north of Kahalu‘u Bay. Both 3m (28.4%) and 10m (27.2%) stations show a similar pattern of increase. Nenue located 6 km south of Kahalu’u Bay followed the same trend with an increase in coral cover of 125% in the past decade at the 5m station and 59.9% increase at the 10m station (Table 2.6).

Table 2.6 Decadal temporal change in coral cover at CRAMP sites adjacent to Kahalu‘u Bay

	Site/Year							
	HaNen 05m		**HaNen 10m**		**HaLaa 3m**		**HaLaa 10m**	
Species	**2000**	**2010**	**2000**	**2010**	**2000**	**2010**	**2000**	**2010**
Anthelia edmondsoni	0.00	0.06	0.00	0.00	0.00	0.00	0.56	1.10
Leptastrea purpurea	0.60	0.08	0.00	0.00	0.30	0.00	0.00	0.00
Montipora capitata	0.00	4.44	0.50	2.82	0.10	0.30	0.41	2.86
Montipora flabellate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Montipora patula	1.00	2.04	0.30	0.20	0.60	0.60	0.70	0.30
Montipora studeri	0.00	0.08	0.00	0.00	0.20	0.00	0.00	0.00
Pavona duerdeni	0.00	0.06	0.00	0.00	0.10	0.00	0.00	0.00
Pavona varians	0.00	0.00	0.00	0.02	0.10	0.00	0.06	0.00
Pocillopora meandrina	1.90	2.88	1.10	2.01	12.40	2.10	12.50	2.04
Porites compressa	0.10	0.04	2.30	3.49	0.00	1.70	0.00	3.02
Porites evermanni	0.00	0.08	1.40	0.75	0.00	0.00	0.00	0.74
Porites lobata	6.60	13.13	13.50	21.26	17.50	35.50	30.63	47.02
Total coral cover (%)	**10.2**	**22.9**	**19.1**	**30.6**	**31.3**	**40.2**	**44.9**	**57.1**
	12.7		11.5		8.9		12.2	
% increase	124.5		59.9		28.4		27.2	

When examining the more extensive coverage from the Division of Aquatic Resources (DAR) West Hawai‘i Aquarium Project (WHAP) data from 2003-2007 a similar pattern emerges where there are statistically significant increases in coral cover near the Kahalu’u area collaborating with the much smaller CRAMP data set (Tissot et al. 2003). On a larger scale you see declines in coral cover in the northern W. Hawai’i region and no statistically significant change in the south (Fig. 2.18).

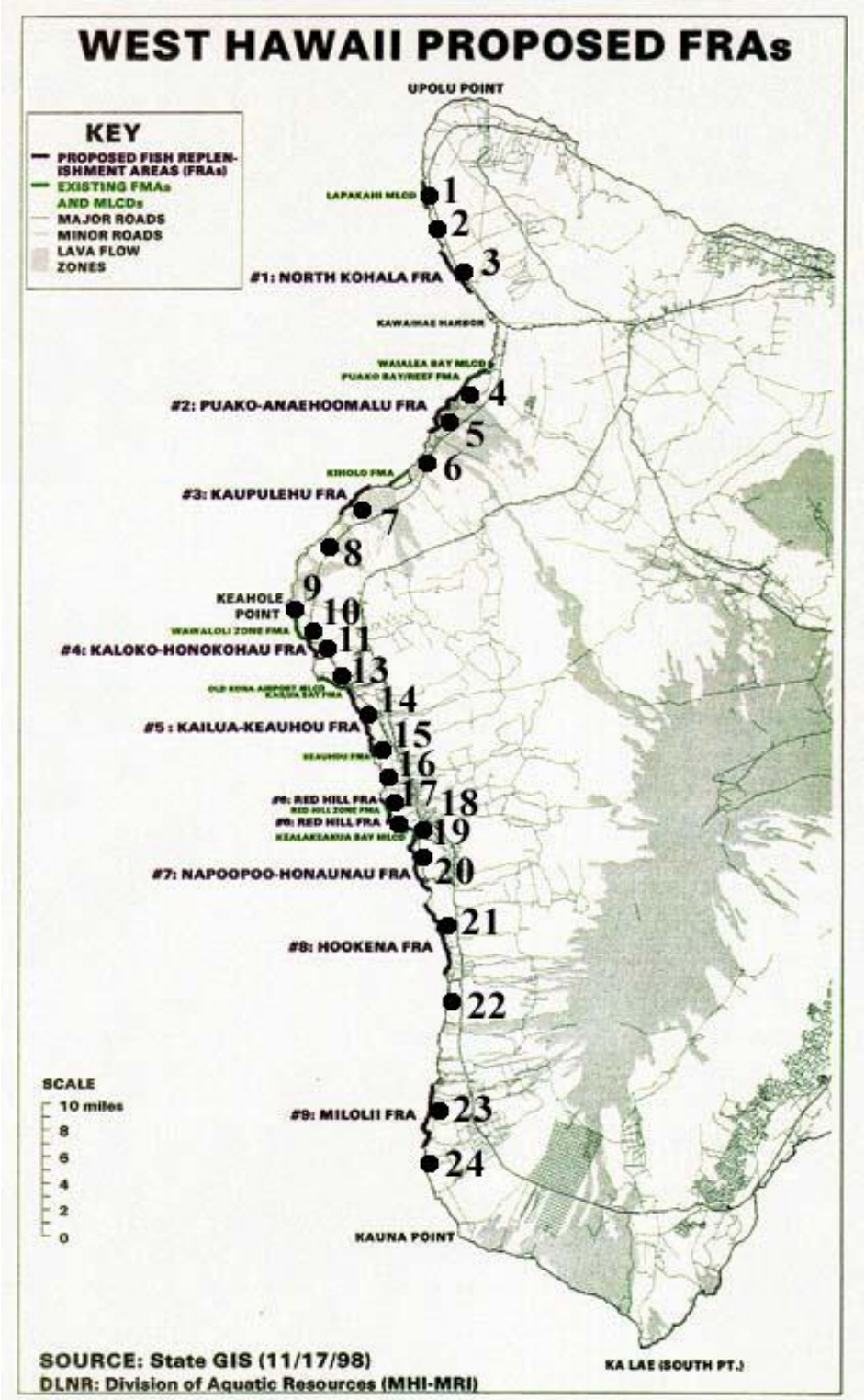

Figure 2.18. Division of Aquatic Resources (DAR) West Hawai‘i Aquarium Project (WHAP) sites in West Hawai‘i.

2.3.6 Trampling

The historical coral trampling study conducted at Kahalu‘u in 1999 was revisited in April 2010 (Rodgers 2001, Rodgers and Cox 2003). Three experimental sites located within the high human use impact zone and three control sites located outside the main impact area were resurveyed. Data on fish, corals, algae, and other invertebrates were recorded. Results show a 75% decline in coral cover in the high impact area with little change in the adjacent low impact area (3.4%). Invertebrate counts were also compared between years (1999 & 2010). A statistically significant decrease in the collector urchin, *Tripneustes gratilla* was seen at the high impact site from 1999 to 2010 (p=0.000) while a sharp increase in the red pencil urchin, *Heterocentrotus mammilatus* was observed (p=0.000). High variability, habitat heterogeneity, and a small sample size make temporal comparisons difficult. Since GPS coordinates were not taken in 1999 there was difficulty locating the exact original transects, increasing the level of error. An accurate baseline has been set with mapping the benthic habitat characterization stations. A subset of these stations can now be used for future comparisons and continued monitoring.

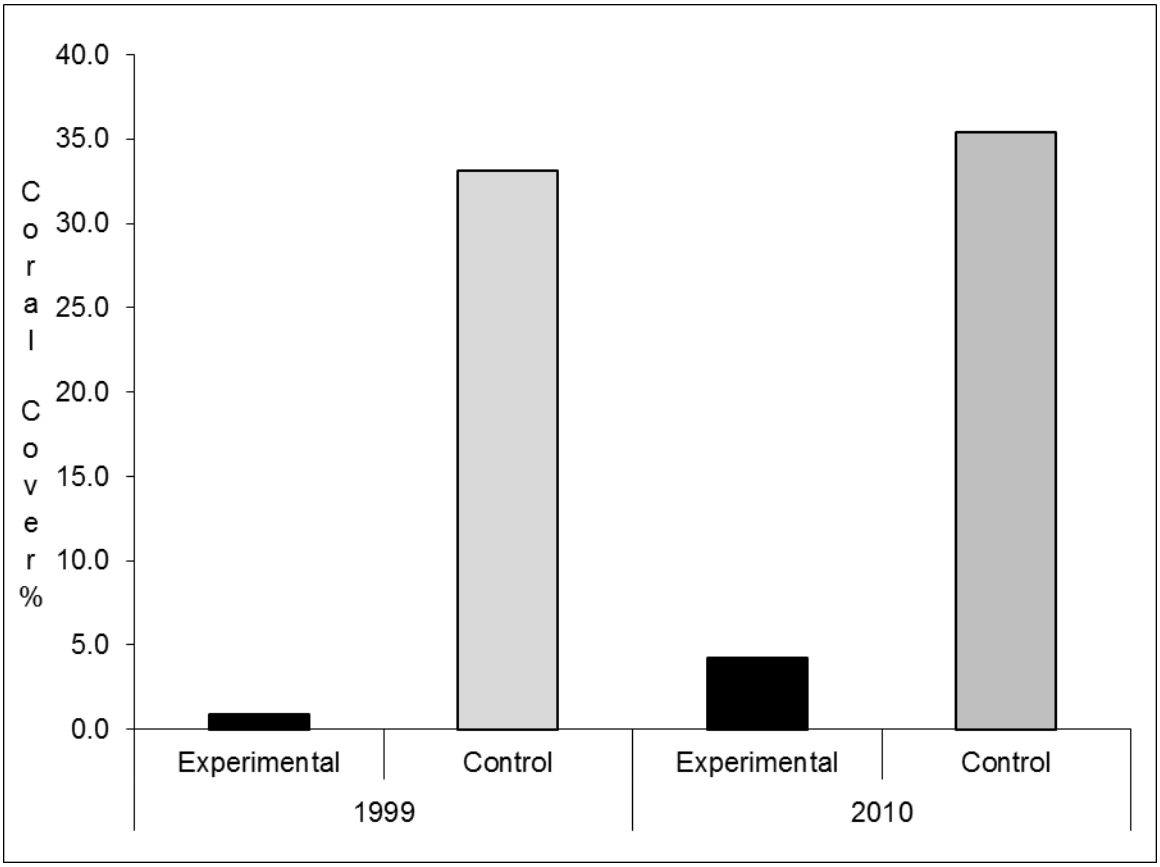

Figure 2.19. Resurvey (2010) of total coral cover from 1999 trampling sites in Kahalu‘u Bay, Hawai‘i (Rodgers 2001).

Results show a 75% decline in coral cover in the high impact area with little change in the adjacent low impact area (3.4%) (Fig. 2.19).

Invertebrate counts were also compared between years (1999 & 2010). A statistically significant decrease in the collector urchin, *Tripneustes gratilla* was seen at the high impact site from 1999 to 2010 (p=0.000) while a sharp increase in the red pencil urchin, *Heterocentrotus mammilatus* was observed (p=0.000).

2.4 Discussion/ Summary

2.4.1 Bathymetry/ Depth

Kahalu´u Bay is relatively shallow as most survey stations were approximately 1.5 m in depth at Mean Low Low Water (MLLW) (Fig. 2.1). No stations within the bay exceed 2 m. Shallow depths within the bay are attributed to high coral coverage, the presence of basalt shelves, boulders, and rubble. These structural components sit high in the water column thus reducing the space between the surface and seafloor. It is worthy to note that some areas are exposed during extreme low tides.

Outside locations are deeper with the exception of stations near the breakwall that are shallow because of the basalt shelf but within a short distance there is a steep and sudden drop off. By roughly 0.1 km away from the breakwall the depth drops to over 10 m.

2.4.2 Temperature

Typically sea surface temperatures (SST) become cooler as distance is increased from shore. This is attributed to reduced water movement and shallower depths. Kahalu´u Bay is atypical because stations within the boundaries of the breakwall are cooler than open ocean stations (Fig. 2.4). This unique temperature signature is a result of many freshwater springs that feed into the inshore section. In this study, freshwater sources that were located were mapped and are associated with locations that have the coolest temperature. Not all springs were located.

2.4.3 Salinity

The presence of many freshwater springs dictates the overall trends in salinities that were observed at the bay (Fig. 2.5). Stations located within the bay are lower in salinity than those outside. In addition, stations which are situated closer to the freshwater sources have the lowest salinity values. This supports the presence of freshwater in this area.

2.4.4 Turbidity

At most times the waters of Kahalu´u have good water visibility (Fig. 2.6). There is one area located near the new pavilion and lifeguard tower where turbidity levels are high. This is the most likely due to resuspension by ocean users of the large amount of sand found there.

2.4.5 pH

Most stations within the bay are more acidic than areas outside of the bay (Fig. 2.7). This is a consequence of the presence of freshwater that has lowered salinities inside the bay.

2.4.6 Dissolved Oxygen

Areas near springs have higher levels of dissolved oxygen because freshwater allows for greater up-take of oxygen (Fig. 2.8). All other stations have

decreased levels of oxygen because at these stations during the day, oxygen is being used by corals and algae for primary production.

2.4.7 Abiotic Influence on Corals

Corals

In this study, salinity and depth are shown to influence the abundance and distribution of coral. This is in concert with the primary literature that demonstrate these factors heavily influence coral growth (Rodgers 2005, Moberg et al. 1997).

Salinity stress can induce both lethal and sub-lethal effects in corals. There have been reductions in growth, reproduction, survivorship, respiration and photosynthetic rates reported (Muthiga and Szmant 1987, Coles and Jokiel 1992, Moberg et al. 1997, Ferrier-Pages et al. 1999). In France, photosynthesis and respiration decreased from small changes in salinity in *Stylophora pistillata* (Ferrier et al. 1999) with similar results in Thailand with *Porites lutea* and *Pocillopora damicornis* (Moberg et al. 1997). Tolerances to salinity for corals range from as low as 25 ppt to as high as 45 ppt although corals in Hawai‘i have been shown to have a much narrower salinity range with both upper and lower lethal limits (Edmonson 1928). Manipulative experiments have shown that tolerance of most corals to salinity is within 5 ppt of ambient salinities. Prolonged deviations from this established range will result in mortality.

The corals at Kahalu´u Bay are partially regulated by salinity supported by the sparse to absent distributions in areas of low salinity. This is confirmed in the

primary literature where mortality of most coral species occur when salinity levels are reduced to 15-20 ppt for the duration of 24 hours or longer (Edmondson 1928, Coles & Jokiel 1992, Jokiel et al.1993). Lowered salinities directly impact coral metabolic functions because there is a lack of osmoregulation (Muthiga & Szmant 1987).

In addition to salinity, corals at Kahalu´u Bay are also regulated by depth. A positive relationship exists between depth and coral coverage, where depth increases as coral cover increases. Depth is correlated with temperature and light levels. At shallower depths corals are exposed to higher temperatures and levels of irradiance (Jokiel 2004). This makes them more susceptible to bleaching events reducing their abundance and distribution in these areas. Depth can act as a buffer for anthropogenic impacts. Kahalu´u Bay is used by approximately 400,000 people annually. Most are visitors and have little or no experience snorkeling. These activities are usually limited to inside locations and few venture outside of the breakwall. Inside locations are shallower than outside ones and thus are much more vulnerable to trampling by snorkelers. Research results by Rodgers and Cox (2003) indicated that trampling can reduce coral coverage and associated fish populations. Deeper stations are unaffected by trampling as they are untouched by snorkelers even ones that are standing. There is high coral cover located just inside and parallel to the breakwall. Coral cover flourishes here because strong currents, extremely shallow waters, and proximity to the beach prevent most snorkelers from entering this area.

2.4.8 Abiotic Influence on Fisheries at Kahalu´u Bay.

Factors influencing fish distributions differed between numerical abundance and biomass. Both these variables are important and explain different aspects of the fish community. A community may have numerous small fishes or juveniles which will not be reflected in the biomass numbers. Conversely, a few extremely large fishes will greatly increase biomass numbers but not numerical abundance. Differences were also observed in trophic levels of fishes (herbivore, invertebrate feeder, piscivore, and zooplanktivore).

<u>Numerical Abundance</u>

All Fish (Number)

Statistical results indicate that depth, salinity, temperature and pH influence the distribution of the total number of fishes. All factors except for pH are positively related to the number of fishes. The numerical abundance of fish is inversely proportional to pH.

Similar to corals, the total numbers of fishes are influenced by depth (Pittman et al. 2009). Deeper stations are located outside the breakwall where human interactions are minimal, and water volume is greater (e.g. more available space). These conditions make it much more conducive for larger abundances of fish as there is a greater volume for which they can roam as well as feed from. Inside stations experience heavy human traffic (ex. snorkelers, swimmers, and surfers) and water column volume is minimal. Corresponding to reduced coral

populations, trampling has also been known to reduce fish populations (Rodgers and Cox 2003).

Fishes are also influenced by salinity (Sponaugle and Pinkard 2004). A majority of the fishes are found outside of the breakwall, where ambient salinities exist. Results from Boeuf and Payan (2001) support these findings as they have shown that lowered salinity impair fish development and growth. It is important to note that fish can adapt to short durations of lowered salinities as they have the ability to regulate osmotic pressure (McCormick 2001). In special cases, fishes such as *Kuhlia sandvicensis* have an affinity for freshwater sources (Tester and Trefz 1954).

Temperature levels are correlated with salinity and freshwater also controlling the distribution of fishes (Green and Fisher 2004). A greater number of fishes were found in areas that were close to ambient seawater salinities. Seawater is warmer than areas affected by freshwater. Reef fishes may prefer warmer locales that are close to ambient without breaching the upper threshold, as these areas are colder and may disrupt or impair spawning intensity (Danilowicz 1995). The distribution of fishes is also regulated by pH levels. Salinity dictates pH levels at the bay. Freshwater lowers the pH, whereas open ocean areas range from 7.9-8.3 or ambient ocean pH. Fishes at Kahalu´u Bay prefer ambient pH levels because of its relationship to salinity.

Trophic levels (Number)

When investigating trophic levels, only herbivore and zooplanktivore abundances were influenced by the measured abiotic factors. Herbivores were influenced by temperature, salinity, and pH. Similar to findings of numerical abundance of all fishes, the majority of herbivores are distributed in areas that are close to ambient open ocean salinity and pH levels. Herbivores account for the majority of the fishes (59.3%) found at Kahalu´u Bay. Herbivores depend on algal abundance which is influenced by nutrient availability. Of the factors examined, zooplanktivores were only influenced by pH and also found in locations that were close to ambient conditions. Data from invertebrate feeders and piscivores did not produce any significant findings. This may be the consequence of a small sample size for these trophic levels.

Biomass Abundance

All fish

Findings from the regression indicate that depth, temperature, salinity, and pH influence total fish biomass. Deeper depths reduce human impact and horizontally increase available area. The fishes at Kahalu´u Bay prefer oceanic conditions as impacts to growth, development, and reproduction are reduced from conditions subjected to freshwater.

Trophic Levels

Regression for each trophic level reported at least three significant factors that influence distribution. Herbivores are controlled by depth, temperature,

salinity, and pH. Invertebrate feeders are regulated by depth, temperature, and salinity. Piscivores are influenced by salinity and pH levels.

2.4.9 Summary

Below is a bulleted summary of the findings. Results have been compared, combined, and synthesized in fashion that best describes what factors influence fish distributions at Kahalu´u Bay.

Corals are influenced by depth and salinity. Deeper depths reduce impacts from humans and high temperatures. Lower salinities impair development and growth.

Regression results from both number and biomass indicate that depth, temperature, salinity, and pH influence the distribution of fishes.

Herbivore populations are regulated by temperature, salinity, and pH. This is integral to understand because herbivores account for the majority of fishes found at Kahalu´u Bay. These factors may also correlate with algal populations upon which herbivores are dependent.

CHAPTER 3 LINKAGES BETWEEN BENTHIC COMMUNTY COMPOSITION AND FISHERY CHARACTERISTICS

3.1 Introduction

Fish assemblages are regulated by a multitude of factors (Friedlander et al. 2003, Adjeroud et. al 1998, Walsh 1985). One factor, benthic composition, has extensively been shown in the primary literature to be integral in shaping fish communities (Brokovich et al. 2006, Almany 2004, Beukers and Jones 1997, Friedlander and Parrish 1998a, Jenkins and Wheatley 1998, Chabanet et al. 1997, Connell and Jones 1991, Bell and Galzin 1984). This chapter will focus on how, if, and what benthic characteristics regulate, shape and define fish communities at Kahalu´u Bay, Hawai´i.

The steps that I followed to attain these goals are as follows:

Amass existing background information from the primary literature concerning factors that influence fish assemblages.

Conduct ecological surveys in order to document and characterize benthic and fishery community at Kahalu´u Bay using methodologies developed by the Hawai´i Coral Reef Assessment and Monitoring Program (CRAMP).

Use multivariate analyses to determine which benthic characteristics influence the biomass or numerical abundance of fishes found at the bay.

3.2 Background Information

The temporal and spatial aggregation of reef fish can be attributed to and influenced by a variety factors (Anderson and Millar 2004, Steele 1999, Connell and Kingsford 1998, Jones 1991, Sale 1991). Influencing factors include but are not limited to: depth (Friedlander and Parrish 1998a), hydrodynamics (ex. currents, wave exposure, and water flow) [Fulton and Bellwood 2005, Friedlander et al. 2002, Friedlander and Parrish 1998b, Breitburg et al. 1995, McGehee 1994], quality of reef habitats (Syms and Jones 2000, Connell and Jones 1991), salinity (Jokiel et al. 1993), temperature (Nillson et al. 2008), and turbidity (Cheal et al. 2002). Among all factors, the quality of reef habitats are one of the most influential components driving the formation of fish communities (Almany 2004, Buekers and Jones 1997, Luckhurst and Luckhurst 1978).

Reef habitats provide numerous goods and services for a variety of marine organisms including reef fish (Nagelkerken et al. 2000b, Jones 1986, Friedlander and Parrish 1998b, Bell 1984). Along with other products, they provide include food and shelter for reef fishes. Reef structures serve as a source of food for some species such as *Chaetodon multicinctus,* obligate corallivores that only feed on corals (Crosby and Reese 2005). The presence and distribution of coral species highly influences their abundance and distributions (Friedlander and Parrish 1998a, Reese 1981). Reefs also provide shelter and protection for fishes (Walsh 1985). Most frequently these shelters allow fish to avoid predation while providing a place to rest when not feeding (Rickel and Genin 2005, Hixon and Beets 1993). These services are great incentives for fish species to recruit

to reef habitats that meet their basic living requirements and enhance species richness and abundance (Almany 2004, Bell and Galzin 1984).

The quality of a reef habitat to provide food and shelter is dependent on two main parameters: topographic complexity and benthic composition. Topographic complexity is the three dimensional structural arrangement of features over the seafloor and is often measured by rugosity (Friedlander and Parrish 1998a). A sandy area for example, is characterized as having low topographic complexity as structural features are lacking. Alternatively, an area with high topographic complexity has great spatial relief. Reef habitats are good examples of this as they are comprised of dynamic biogenic structures (Zawada 2010).

In the primary literature it is suggested that competition and predation are reduced as reef complexity increases (Almany 2004, Hixon 1991). Competition is lowered as resources like food and shelters are increased (MacArthur and Levins 1964). For example, complex reefs have larger surface areas and thus provide greater areas for feeding and holes for resting and hiding. In addition to competition, predation is reduced (Beukers and Jones 1997, Hixon 1991). A greater number of hiding areas increases the difficulty for predators to seek out their prey. Moreover, Murdock and Oaten (1975) noted that it was not only difficult for predators to catch prey species but encounter rates were also reduced.

Reef fishes benefit tremendously from habitats with greater benthic complexity. Studies have indicated that positive correlations exist between reef complexity and species diversity, as complexity increases diversity also increases (Johnson

et al. 2003, Talbot 1965). Increased rugosity has been shown to enhance species richness, abundance, and biomass of reef fishes (Friedlander et al. 2003, Friedlander and Parrish 1998a, Luckhurst and Luckhurst 1978, Talbot 1965).

Complementary to topographic complexity, the benthic composition or the nature of the benthic community is also influential in shaping the abundance and distribution of reef fish species (Chabanet et al. 1997). Components of a reef habitat can include: foundation material (carbonate or basalt), sand, boulder, rubbles, macroalgae (MA), crustose coralline algae (CCA), turf algae, and coral (live and dead). Inherently, the presence or absence of a structural component can dictate which fish species can recruit to reef habitats. For example, a reef habitat that consists mostly of sand or rubble will likely have low species diversity, number and biomass. Recall that sand and rubble, are low in rugosity and thus lack the three-dimensional structures it needs to foster larger abundances and biomass. Contrary to having low diversity certain fish families like Mullidae or goatfish might have an affinity for sandy areas with rubble. Research by Holland et al. (2003) indicated that the goatfish species, *Mulloides flavolineatus*, tend to reside in sandy areas with rubble. Sand patches are prime feeding grounds for goatfish as they sift through the sand and rubble for food with their barbels, which are their sensory appendages (Sazima et al. 2006). Similar to goatfish, *Chaetodon multicinctus* also has an affinity for a particular benthic component. This butterflyfish species is an obligate corallivore and thus acquires its nutrients from feeding on live coral polyps (Crosby and Reese 2005).

Consequently this species requires live coral to survive. Additional research has also shown that other fish characteristics are positively correlated with other benthic components, in particular live coral (Chabanet et al. 1997, Sano et al. 1984, Carpenter et al. 1981). Complementary to these findings, others have reported that benthic composition, in particular coral species, diversity, and abundance did not influence reef fish communities (i.e. abundance and/or biomass) [Ohman and Rajasuriya 1998, Chabanet et. all 1997, Luckhurst and Luckhurst 1978, Roberts and Ormand 1987]. This chapter will focus on determining if and what benthic composition parameters influences the abundance and distribution of fishes (total and trophic level) found at Kahalu´u Bay, Hawai´i.

3.3 Research Questions

General Hypotheses Being Tested

H_o = Benthic habitat characteristics do not influence the abundance and distribution of fish assemblages at Kahalu´u Bay.

H_a = Benthic habitat characteristics influence the abundance and distribution of fish assemblages at Kahalu´u Bay.

The general hypothesis embraces a series of more detailed analyses covering the relationship of fish number and biomass, trophic level (herbivores, invertebrate feeders, piscivores, zooplanktivores,) location, primary substrate,

(shelf, sand, boulder, rubble), and benthic biotic composition (macroalgae, CCA, turf algae, coral)

3.4 Methods

3.4.1 Benthic Habitat Characterization (BHC)

Benthic coverage at 202 stations was assessed using methods developed by National Oceanic and Atmospheric Administration (NOAA) for ground truthing of benthic habitats (Fig. 3.1). A Global Positioning System (GPS) point was taken at the central point of each surveyed circle (seven meter radius). Visual estimates were taken for the following parameters: Presence or absence (P/A) of shelf, sand, boulder, and rubble; percent macroalgae (MA), crustose coralline algae (CCA), turf algae (TA), total coral cover (TCC), and coral species; and invertebrate species abundance (m^{-2}) (table 3.1). Surveys were conducted between 1 April 2010 and 5 June 2010.

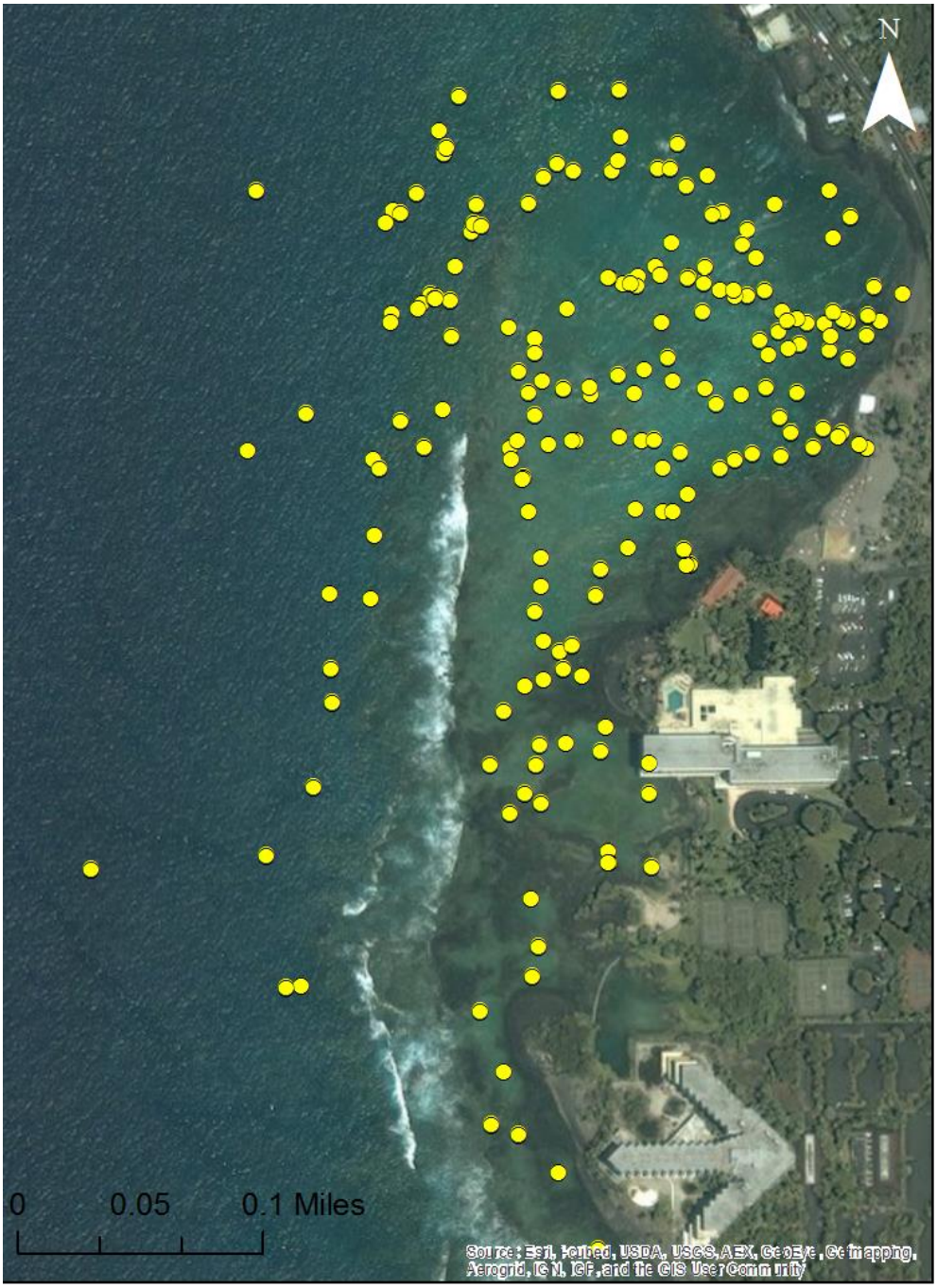

Figure 3.1. 202 Stations surveyed at Kahalu´u Bay, Hawai´i.

Table 3.1 List of benthic data collected

Benthic Data	Data Type
Location	Outside, Inside
Primary Substrate Composition	Carbonate or Basalt
Shelf	P/A
Sand	P/A
Boulder	P/A
Rubble	P/A
Macroalgae (MA)	P/A
Crustose Coralline Algae (CCA)	P/A
Turf Algae (TA)	P/A
Coral	P/A

P/A = Presence or Absence

3.4.2 Fish Abundances

Fish surveys were conducted at 202 stations shown in Fig. 3.1. Visual estimates of abundance, species, and length were recorded within a seven meter radius (Rodgers et al. 2005). Fishes were identified to the lowest taxonomic level possible and enumerated by length. Surveys were conducted between 1 April 2010 and 5 June 2012.

Biomass estimates were based on species type, abundance, and total fish length. These factors were inserted into known species specific biomass equations from FISHBASE (www.fishbase.org) to calculate biomass. Biomass estimates from each station were summed to acquire total biomass. Numeric abundance and species were summed to quantify the number of fishes and species present at each station.

3.4.3 Statistical Analysis

A multifactorial Analysis of Variance (ANOVA) was used to determine if a relationship exists between response variables: fish abundance (total number per station), fish total biomass per station, and trophic level (by abundance and biomass) and the categorical predictor variables: location, primary substrate, shelf, sand, boulder, rubble, macroalgae, crustose coralline algae, turf algae, and coral. A square root transformation was used on the variables fish abundance and fish biomass to meet the assumption of normality.

Tukey range tests were performed in each multifactor ANOVA in order to determine if any of the means between each categorical variable were significantly different from each other. A 95% confidence level was used in this test.

3.5 Results

3.5.1 Descriptive Results

3.5.1.1 Benthic Habitat Characterization (BHC)

Surveys were conducted both on the inside (n= 162) and outside (n= 40) of the bay. Stations outside the bay are located on the *makai* (seaward) side of the breakwall (Pāokamenehune). The foundation or primary substrate at each station is predominantly made of basalt (n = 198) in origin, with few carbonate sites (n= 4). Most stations are situated on a shelf (n= 141). Only 61 of the 202 stations were not on top of a shelf. Sand (n= 79) is found at about a third of all stations. Conversely, 123 stations lack the presence of sand. Boulders are

found at 71 stations and are absent at 131. Most stations do not have rubble (n = 122) though rubble is found at numerous stations (n= 80). Macroalgae is rarely observed but is present at four stations. Of the 202 stations, 124 have crustose coralline algae. Although macroalgae is lacking, turf algae is prevalent at Kahalu´u Bay and is found at 134 stations. Coral is observed at the vast majority of the stations (n= 172).

3.5.1.2 Fish Surveys: Numerical Abundance and Biomass

The most abundant species at this site is *Acanthurus triostegus* (*manini*) comprising 16.2% of all individuals (Fig. 3.2) and 8.9% of the biomass (Fig. 3.3). Seven of the species with the highest abundance were also found to be in the top ten species with the highest biomass. Two other fishes in the family *Acanthuidae* were also found in high abundance, *Acanthurus nigrofuscus* (*mā´i´i´i*) making up 12.8% of the individuals and 9.2% of biomass and *Zebrasoma flavescens* (*lau´ipala*) with 11.9% of individuals 17.2% of biomass. *Z. flavescens* are found on 65.2% of all transects, the highest frequency of any species and the highest biomass of fishes. *Z. flavescens* are the number one aquarium fish collected in West Hawai‘i. *Melichthys niger* (*humuhumueleele*) had the second highest biomass (10.0).

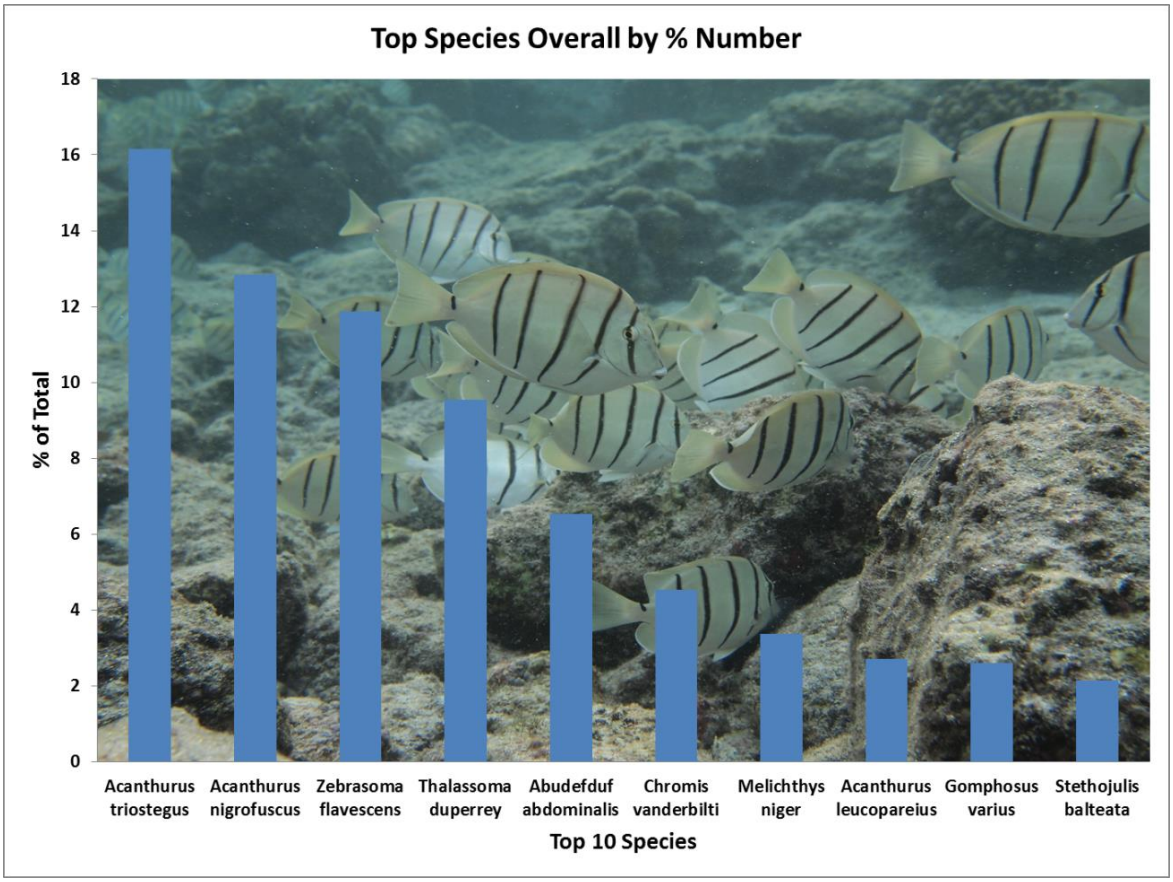

Figure 3.2. Fish densities: Top ten species by numerical abundance.

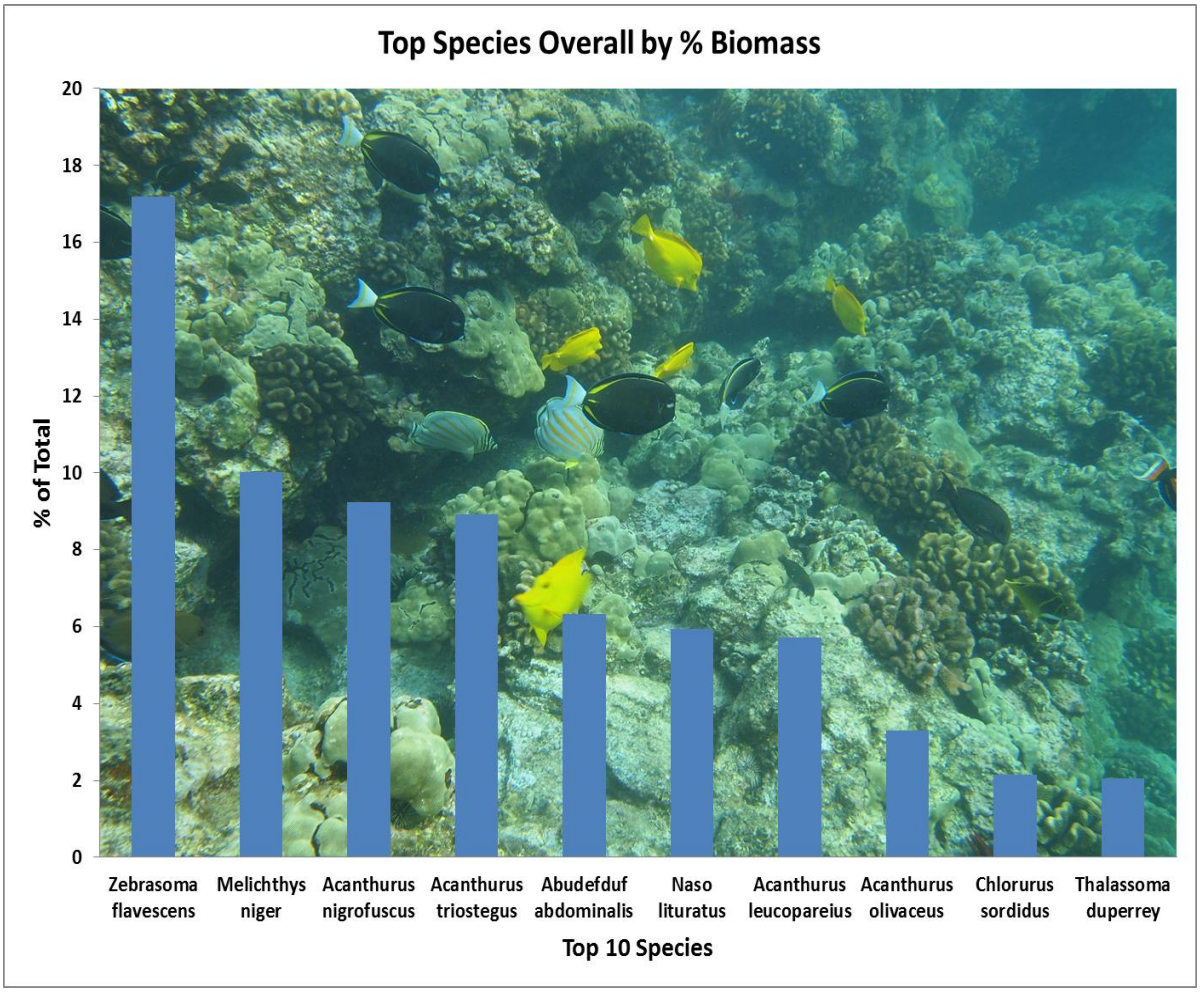

Figure 3.3. Fish densities: Top ten species by biomass.

3.5.1.3 Fish Surveys: Trophic Levels

Herbivores are the dominant trophic group in both numerical abundance and biomass, while piscivores are scarce. This is an artifact of fishing pressure. Large numbers of piscivores are found in the Northwestern Hawaiian Islands (NWHI). Large apex predators encompass over half the total biomass in the NWHI (54%), but are only a minor component in the main Hawaiian Islands (3%) (Friedlander and DeMartini 2002). At Kahalu´u Bay piscivores constitute only 1.7% of the total biomass and 0.7% of the number of individuals. Of the piscivores, the peacock grouper *Cephalopholis argus* (*roi*) an introduction in 1956 by the Hawai‘i Fish and

Game for commercial reasons from Moorea, French Polynesia, is the most prominent making up 45.3% of the biomass and 33.3% of the individuals. Large biomass percentages are due to the large size of this species. *C. argus* comprises a large percentage of the numerical abundance in this feeding guild because there are few other piscivores (10 species) present as compared to herbivores (35 species). Zooplanktivores and invertebrate feeders make up 7.3% and 17.4% of the total biomass respectively with a larger proportion represented in numerical abundance (12.7%) and (27.4%). The zooplanktivore population is primarily comprised by *A. abdomimalis* (*mamo*) constituting 86.7% of the biomass and 51.7% of the individuals. The invertebrate feeders are driven by *T. duperrey* (*hinalea*) that constitutes 11.8% of the biomass and 34.9% of the individuals. The largest trophic group by far for both biomass (73.6%) and number of individuals (59.3%) are the herbivores. The herbivores are driven mainly by *Z. flavescens* (*lau'ipala*) which make up 23.4% of the biomass and 27.8% of the individual fish counts (Figs. 3.4 and 3.5). Refer to Appendix I and II for top overall species by numerical abundance and biomass. Refer to Appendix III through X for top trophic level by species for numerical abundance and biomass.

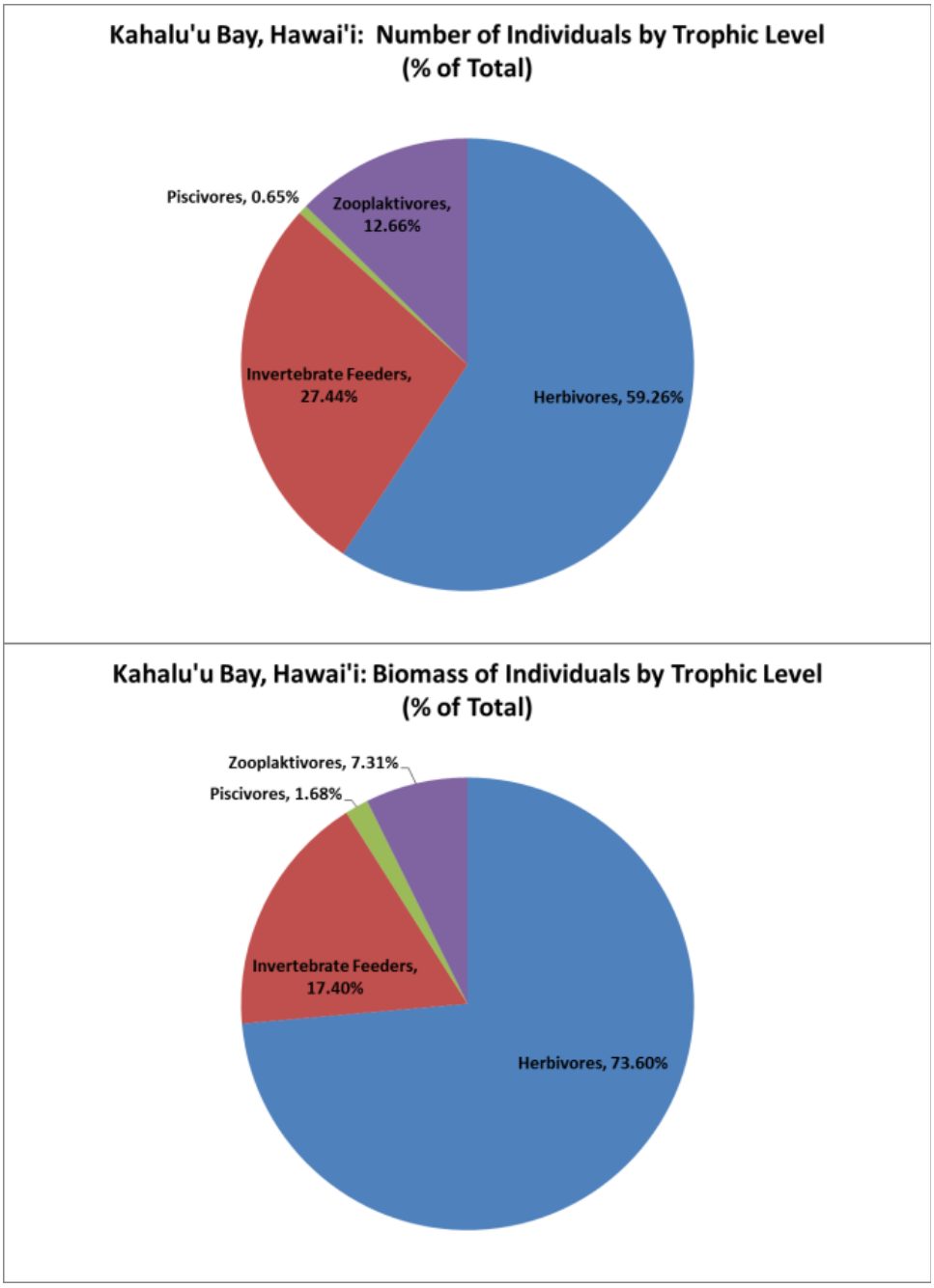

Figure 3.4. Mean numerical abundance and biomass by trophic level.

3.5.1.4 Fish Status

At Kahalu´u endemic fishes comprise 19.8 % of the biomass and 36.6% of the individuals which is consistent with statewide values of 11.6% of the biomass and 22.9% of numerical abundance. There are a total of 17 endemic species present

at this location. The endemic fish population is driven primarily by *Acanthurus triostegus* (*manini*) making up nearly half of the biomass (45.1%). Other species that make up a significant portion of the endemic population include *Abudefduf abdomimalis* (*mamo*) and *Thalassoma duperrey* (*hinālea*) (Appendix XI). The majority of the fish population at Kahalu´u is indigenous with 79.1% of the total biomass and 62.9% of the number of fishes. These species have large distributions throughout the Pacific Ocean. *Zebrasoma flavescens* (*lau'ipala*) constitutes a significant portion of the indigenous fishes with 21.7% of the biomass and 18.9 % of the individuals (Appendix XII). There are three introduced species present at this site, all of which were introduced intentionally by Hawaii Fish and Game in the 1950s as stock enhancement. This includes *Cephalopholis argus* (Tahitian name *roi*) which makes up the highest biomass and largest number of individuals (70.4% and 44.7% respectively). The other two species are both snappers, *Lutjanus fulvus* (Tahitian name *to´au*) and *Lutjanus kasmira* (Tahitian name *ta´ape*) (Appendix XIII).

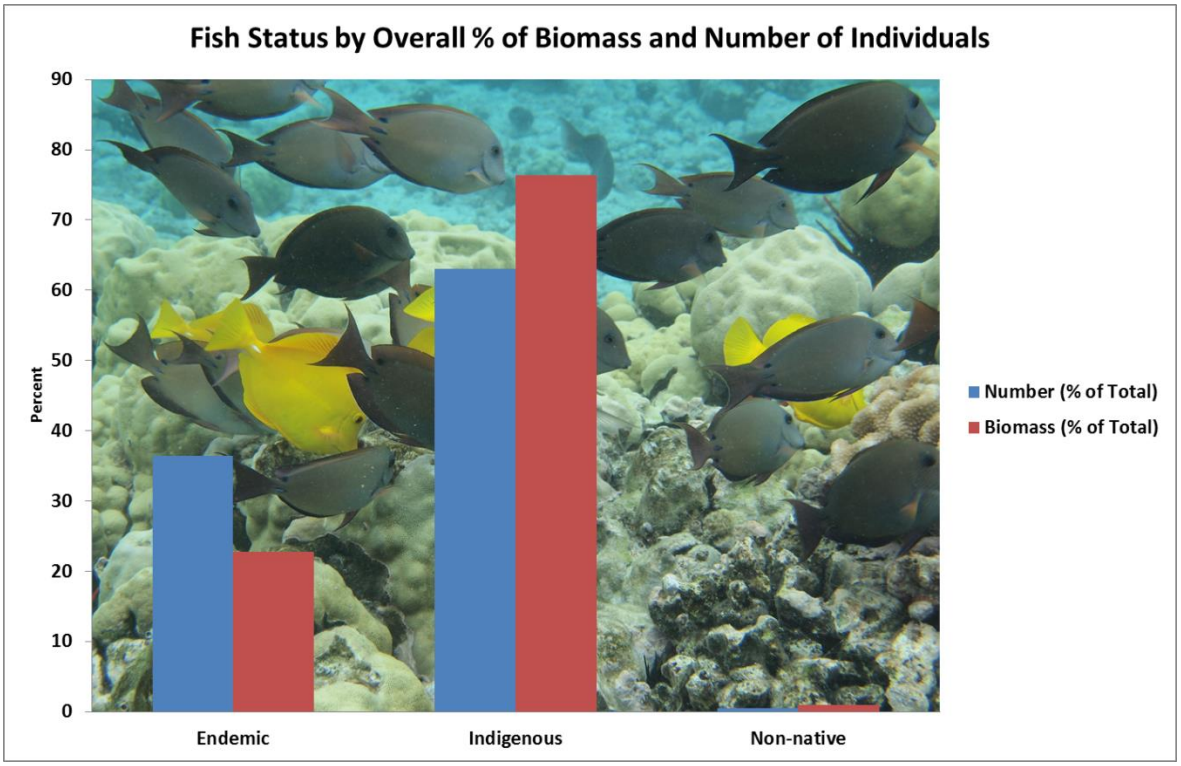

Figure 3.5. Endemism by biomass and numerical abundance.

3.5.2 Statistical Results

3.5.2.1 Fish Numerical Abundance and Biomass

<u>All Fish</u>

The multifactor ANOVA is not significant (R=0.3595) however, the categorical variables in this model explain 36.0% of the variation in predicting the total number of fishes. Statistically significant categorical variables are location (p<0.0005), shelf (p=0.005), sand (p=0.042), macroalgae (p=0l014) and coral (p<0.0005), influencing the overall abundance of fishes observed at Kahalu´u Bay. Primary substrate (p=0.916), boulder (p=0.869), rubble (p=0.064), crustose coralline algae (p=0.511), and turf (p=0.274) are not found to be statistically significant (table 3.2).

Categorical variables account for 49.25% of the variation in predicting the biomass of all observed fishes (R^2=0.4925). Location (p<0.0005), shelf (p<0.0005), rubble (p<0.0005), and coral (p<0.0005) are statistically significant. All other varaibles used in the model are not statistically significant (table 3.2). Results from Tukey's test for numerical abundance and biomass report similar statistical findings to the ANOVA. Both indicate that location, shelf, sand, and coral significantly explain the abundance and biomass of fishes surveyed. Numerically and by biomass, there were a greater amount of fishes on the outside of the bay (mean=5.8 fishes, 40.8 g of fishes per station) than inside the breakwall (3.9 fishes and 17.8 g of fishes per station).

For benthic composition, the numerical abundance and fish biomass are lower at stations that have a shelf, sand, and coral. In the absence of a shelf, the mean number of fishes is 5.4 and 35.7 g per station, which is significantly greater than fishes found at a shelf (μ=4.3 fish and 22.8 g per station), sand (μ=4.5 fish and 26.5 g per station), or coral (μ=5.9 fish and 41.6 g per station). Coral is one of the driving factors that influence fish communities. Conversely, when coral is absent numbers of fishes (μ=3.8 fish) and biomass (μ=16.9) are greatly reduced. Slight differences are also noted between numerical abundance and biomass. Macroalgae is shown to influence the mean number of fishes. Macroalgae reduced the number of fishes (μ=3.4 fishes per station) as compared to 6.3 fishes in its absence. Rubble is important in influencing the mean biomass. Without rubble the mean biomass is 36.7 g per station, while stations with rubble the mean is lower (21.8 g).

Table 3.2. Presence/absence of benthic habitat features tested against biological variables. Statistically significant values are denoted by an asterisk.

Response Variable	Benthic Habitat (Presence or Absence)									
	Location	Primary Substrate	Shelf	Sand	Boulder	Rubble	Macroalgae	CCA	Turf	Coral
Fish Number	**<0.0005**	0.916	**0.005***	**0.042***	0.869	0.064	**0.014***	0.511	0.274	**<0.0005***
(H) Number	**0.010***	0.408	0.082	0.17	0.935	0.447	0.094	0.549	**0.016***	**<0.0005***
(INV) Number	0.487	0.975	**<0.0005***	**0.028***	0.284	**0.019***	**0.048***	0.355	0.87	**<0.0005***
(P) Number	**0.006***	**0.033***	0.252	0.621	0.491	0.659	0.53	0.566	0.804	0.258
(Z) Number	**<0.0005***	0.076	0.432	0.358	0.067	0.49	0.344	0.747	**0.024***	0.172
Fish Biomass	**<0.0005***	0.994	**<0.0005***	0.086	0.299	**<0.0005***	0.06	0.517	0.166	**<0.0005***
(H) Biomass	**<0.0005***	0.699	**0.001***	0.136	0.202	**<0.0005***	0.124	0.867	**0.028***	**<0.0005***
(INV) Biomass	0.092	0.615	**<0.0005***	0.068	0.353	**<0.0005***	0.096	0.316	0.451	**<0.0005***
(P) Biomass	**0.001***	**0.002***	0.336	0.253	0.349	0.227	0.848	0.149	0.72	0.265
(Z) Biomass	**<0.0005***	0.149	0.404	0.404	0.423	0.664	0.863	0.806	0.618	0.835

H=Herbivore, INV=Invertebrate Feeder, P=Piscivore, Z=Zooplanktivore

Trophic Level

Herbivores

The categorical variables in this model account for 23.3% of the variance in predicting the number of herbivores (R^2=0.233). Only three of the variables are statistically significant: location (*p*=0.010), turf (*p*=0.016), and coral (*p*<0.0005). All other variables are not statistically significant: primary substrate (*p*=0.408), shelf (*p*=0.082), sand (*p*=0.170), boulder (*p*=0.935), rubble (*p*=0.447), macroalgae (*p*=0.094), and crustose coralline algae (*p*=0.549) (table 3.2). Categorical variables used in the model account for 44.07% of the variance in predicting the biomass of herbivores (R^2=0.4407). The categorical variables: location (*p*<0.0005), shelf (*p*=0.001), rubble (*p*<0.0005), turf (*p*=0.028), and coral

(p<0.0005) were statistically significant. All other are not statistically significant (table 3.2).

The categorical variables from the multifactor ANOVA for biomass explained in greater detail which benthic component influences herbivore biomass. In the presence of a shelf herbivore biomass was lowered (20.8 g per station) as compared to its absence (30.7 g of herbivores per station). Similar results are reported for rubble, stations without rubble (31.8 g per station) yielded higher biomasses than those which included rubble (19.7 herbivores per station). Results from Tukey's test for both the numerical abundance and biomass of herbivores reported similar statistical findings. Both indicated that location, turf, and coral significantly explain the abundance and biomass of surveyed herbivores. Location was significant at predicting the abundance and biomass of all fish species. Numerically and by biomass there are a greater amount of fishes at stations outside the bay (μ=4.6 fish and μ=34.9 g of fishes per station) than at stations inside the breakwall (μ=3.5 fishes and μ=16.6 g of fishes per station). The numerical abundance and fish biomass are also increased in the presence of turf algae and coral. Turf algae increases the presence of fishes (μ=4.4 fish and μ=29 g per station). In the absence of turf algae the mean number (3.6 fishes) and biomass (22.5 g) per station are lower. Coral is one of the influencing factors that frive fish communities. In the presence of coral there is a mean of 4.9 fishes and 37.1 g per station. When coral is absent fish numbers (μ=3.2 fish) and biomass (μ=14.4) are greatly reduced.

Invertebrate Feeders

ANOVA results are not statislically significant (R^2=0.2434) with the categorical variables in this model explaining 24.34% of the variation in predicting the number of invertebrate feeders. Half of the variables are significant (shelf (p<0.0005), sand (p=0.028), rubble (p=0.019), macroalgae (p=0.048), and coral (p<0.0005)). Location (p=0.487), primary substrate (p=0.975), boulder (p=0.284), crustose coralline algae (p=0.355), and turf (p=0.870) are not statistically significant. Refer to table 3.2.

The R^2 value from a multifactor ANOVA (0.280) explains 28% of the variation in predicting the biomass of invertebrate feeders. The majority of the variables were not significant: location (p=0.092), primary substrate (p=0.615), sand (p=0.068), boulder (p=0.353), macroalgae (p=0.096), crustose coralline algae (p=0.316), and turf (p=0.451). Only three variables were significant: shelf (p<0.0005), rubble (p<0.0005), and coral (p<0.0005) (table 3.2).

The categorical variables from the multifactor ANOVA for numerical abundance explained in greater detail which benthic component influences invertebrate feeder number. In the presence of sand, invertebrate abundance was lowered (μ=1.4 fishes per station) as compared to its absence (μ=1.9 invertebrate feeders per station). Similar results are reported for macroalgae, stations without macroalgae (μ=2.5 fishes per station) yielded higher abundances than those which included rubble (μ=0.8 invertebrate feeders per station).

Results from Tukey's test for both the numerical abundance and biomass of invertebrate feeders reported similar statistical findings. Both indicate that shelf, rubble, and coral statistically explain the abundance and biomass of

surveyed invertebrate feeders. Stations found at a shelf are significant at predicting the abundance and biomass of all fish species. Numerical abundance and biomass of invertebrate feeders is lower in the presence of a shelf (μ=1.2 fishes and 4.7 g of invertebrate feeders per station) as compared to stations without a shelf (μ=2.1 fishes, μ=11.7 g per station). In the presence of rubble (μ=1.3 fishes, μ=4.7 g of invertebrate feeders per station) the abundance and biomass of invertebrate feeders are also decreased as opposed to its absence (μ=2.0 fishes, μ=11.7 g per station). Unlike both shelf and rubble, the presence of coral promotes fishes (μ= 2.5 fishes μ=12.6 g of fishes per station). In the absence of coral there is a mean of 0.8 fishes and 3.8 g of fishes per station.

Piscivores

Categorical variables in this model only accounted for a small portion (12.45%) of variance in predicting the number of piscivores (R=0.1245). Location (p=0.006) and primary substrate (p=0.033) were statistically significant. The majority of the variables are not statistically significant (table 3.2)

The categorical variables described 18.93% of the variance for predicting the biomass of piscivores. The R^2 value for this multifactor ANOVA was 0.1893. Two of ten variables were significant: location (p=0.001) and primary substrate (p=0.002). All other variables are not statistically significant (table 3.2). Results from Tukey's test for both the numerical abundance and biomass of piscivores report identical statistical findings. Both indicate that location and primary substrate significantly explain the abundance and biomass of surveyed

piscivores. Location is significant in predicting the abundance and biomass of all fish species. Numbers and biomass show a greater amount of fishes on the outside of the bay (μ=0.6 fishes, μ=9 g of fishes per station) than stations located on the inside of the breakwall (μ=0.3 fishes, μ=5.1 g of fishes per station). Numerical abundance and fish biomass are also influence by primary substrate. Where the foundational component is carbonate there are greater fish populations (μ=0.8 fishes, μ=11.4 g of fishes per stations). Conversely, if the foundational component is basalt, piscivore biomass (μ=2.6 g) and abundance (μ=0.2 fishes) are lowered.

Zooplanktivores

Variables examined account for 41.31% of the variance in predicting the number of zooplanktivores (R^2=0.413). Only two variables are significant: location (p<0.0005) and turf (p=0.024). All others are not significant (table 3.2).

The categorical variables explain 28.17% of the variation in predicting the biomass of zooplanktivores (R^2=0.282). Location was the only statistically significant variable (p< 0.0005). All other variables were not significant (table 3.2).

Results from Tukey's test for both the numerical abundance and biomass of herbivores reported similar statistical findings. Both indicate that location significantly explains the abundance and biomass of surveyed zooplanktivores. Location is significant in predicting the abundance and biomass of all fish species. Numerical abundance and biomass are greater outside the bay (μ=2.4

fishes, μ=11.5 g of fishes per station) than inside the breakwall (μ=0.5 fishes, μ=3.1 g of fishes per station).

3.6 Discussion

3.6.1 All Fish

Statistical tests indicate that location, sand, and coral significantly influence the numerical abundance and biomass of all fishes at Kahalu´u bay. These variables contribute to shaping these fish communities because they influence shelter availability and food.

Station location impacts fishes. A greater number and biomass of fishes are found outside, on the ocean (*makai*) side of the breakwall than in stations located within the bay. This can be explained by the increased depth of the outside locations and greater coral cover then inside stations. Outside locations also have greater spatial relief providing more area for shelter from predators and food consumption. Supporting evidence also shows areas with higher spatial complexity have a greater diversity, fish number, and biomass (Friedlander et. al 2003, Friedlander and Parrish 1998a, Luckhurst and Luckhurst 1978, Talbot 1965).

Rugosity is a strong factor that influences fish assemblages (Friedlander and Parrish 1998a). One of the significant benthic components of this study is sand. Results indicate that fish number and biomass are reduced in the presence of sand. This can be explained by the low spatial relief of sand lacking complex structural components. As a result, shelter and food are limited in this area and hinder most fish species from assembling in sandy areas. Research by

Johnson et al. (2003) support this finding of areas with low spatial complexities not favoring the presence of fish communities as compared to highly complex areas. Unlike sand, coral enhanced fish communities, where greater abundances and biomass are associated with the presence of coral. Coral provides greater areas of shelter and food for reef fishes (MacArthur and Levins 1984) and reduced predation (Beukers and Jones 1997, Hixon 1991). Similar findings have been reported by other researchers where coral increased fish abundances and biomass (Chabanet et. al 1997, Sano et. al 1984, Carpenter et. al 1981).

3.6.2 Trophic Levels

Herbivores

Herbivores accounted for a majority of the biomass (73.60%) and numerical abundance (59.26%) of fishes observed at the bay. Consequently there were similarities between the significant variables from all fishes. Like all fishes, findings from multifactor ANOVAs indicate that location and coral significantly impact the abundance and distribution of herbivores. Outside locations are deeper and have greater coral cover. As a result these sites have greater spatial complexities or rugosity and have greater abundance and biomass than stations located within the bay. This is similar to findings by Friedlander and Parrish (1998a), which indicated higher herbivore biomass and abundance are positively related to the rugosity of the substratum. They further state that habitats which are complex provide space or shelter for fishes

supporting the findings in this study. Along with location and corals, the presence of turf algae enhance herbivore biomass and abundance. This is also supported by Friedlander and Parrish (1998a). In the presence of turf algae abundance and distribution increase because this is a primary food resource (Friedlander and Parrish 1998a).

External research concerning the top herbivores found at Kahalu´u Bay support the findings of this study. *Acanthurus triostegus* (manini) account for approximately 27% of the number and 23% of the bimass in herbivores. This species requires cover in order to settle and recruit to an area. Sale (1969) indicates that juveniles do not select areas in the absences of cover and reports that cover, in particular coral coverage, influences the distribution of *A. triostegus* in the field. The results in this study are supported by these research findings. As coral and location increase their abundance and biomass increase.

Acanthurus nigrofuscus (*mā´i´i´i*) is the second most abundant by number (21.65%) and biomass (13.60%). Research by Montgomery (1989) indicates that the distance from shelter and feeding sites were highly correlated. Moreover, *A. nigrofuscus* were found in close proximity to their shelters. This finding supports the results in this study where *A. nigrofuscus* were greater in areas that provided them greater amount of shelter (outside and coral) and food (presence of turf algae).

Zebrasoma flavescens (*lau´īpala*) account for 20.0% of the number and 12.5% of the biomass. Similar to other herbivores, research has reported that

this species resides in coral rich habitats and requires turf algae (Claisse et. al 2009). Coral provides shelter, while turf algae provides food for *Z. flavescens*. These three species combined account for approximately 68% of the number and about half of the herbivore biomass.

Invertebrate Feeders

Similar findings from multifactor ANOVAs indicate that shelf rubble and coral influences their abundance and distribution. In the absence of shelf and rubble the abundance of invertebrates feeders are greater numerically and by biomass. Conversely in the presence of coral, invertebrate feeders were enhanced, meaning greater biomass and numerical abundance. Wrasses [*Thalassoma duperrey* (*hīnālea*), *Gomphosus varius* (*hīnālea ´i´iwi*), and *stethojulis balteata* (*´omaka*)] account for over half of the numerical abundance and a third of the biomass of invertebrate feeders. Research by Friedlander and Parrish (1998a) indicate that wrasses are most abundant in habitats that are characterized as having spur and grooves. They also note that these habitats provide shelter due to the abundance of interstitial spaces. These wrasses prefer to be in highly rugose areas such as coral habitats. Moreover they avoid areas that are characterized as having low rugosities (e.g. shelf and rubble). Butterflyfishes are the second most common invertebrate feeder. Chaetodontids are often corallivores and use coral as a source of food and shelter (Crosby and Reese 2005). Findings in the primary literature indicate that there is a positive correlationship between coral and their numerical abundance (Bouchon-Navaro

and Bouchon 1989, Bell et al. 1985, Bell and Glazin 1984). Other research show that a disturbed reef habitat may negatively impact chaetodonid abundances (Russ and Alcala 1989, Sano et al. 1987, Sano et al. 1984). These findings support the results of this study where benthic components which lowered rugosity were not favored (e.g. shelf and rubble) while highly rugose coral habitat enhances the abundance of invertebrate feeders.

Piscivores

The abundance, by number and biomass, of piscivores are significantly influenced by only two variables: location and primary substrate. Piscivores are more abundant on the outside and where carbonate is the primary substrate or foundation component. This is similar to findings by Friedlander and Parrish (1998a) in which they note a positive relationship between depth and the abundance of Piscivores. Friedlander and Parrish (1998a) also note that foraging occurs near the reef edge but an affinity with the substratum is lacking. Outside locations are shallow near the breakwall and sharply drop off and represent the reef edge. In addition the reef edge is primary composed of coral and possibly piscivores are found near carbonate dominated sites that lack high coral coverage.

Zooplanktivores

The findings from multifactor ANOVAs indicate that location is the only variable that influences their abundance and distribution. These findings are supported by the primary literature. Zooplanktivore abundance is positively related to depth, where as depth increases abundance increases (Friedlander and Parrish 1998a). They are found in deeper locations because their food, transient zooplankton, aggregate in the water column near areas of higher water motion (Hobson 1991). Observed zooplanktivores abundances seem to be influenced by their feeding behavior. This may change during the night because they are diurnal feeders.

3.6.3 Summary

Fish communities at Kahalu´u Bay are shaped by the composition of the benthic environment. Fish assemblages are enhanced by benthic components that increase spatial complexity. Rugosity determines the availability of space or shelter and abundance of food. As structural components which favor a higher spatial complexity increases so does the abundance and biomass of fishes present. The presence of benthic components such as sand, rubble, and shelf coupled with location within the bay reduces the abundance and distribution of fishes (numerically and by biomass). The presence of corals combined with outside locations provides greater rugosity and areas for shelter and food and thus promotes the presence of fishes. In conclusion, benthic composition and

spatial complexity are integral to understanding how fish communities are shaped.

CHAPTER 4 BRIDGING HAWAIIAN CULTURAL KNOWLEDGE AND WESTERN SCIENCE

4.1 Introduction

Traditional cultural knowledge and Western science have operated autonomously over past centuries, which have created a perceived divide between the two bodies of information. However, we know that independent contributions by each system have produced insights concerning the natural environment. Although both forms of knowledge are represented in Hawai‘i, Western scientific research and findings often dominate decisions concerning marine resource management while cultural knowledge is given little importance. Cultural knowledge may be included as historic footnotes or colorful stories, but often is not seen as being of value or importance in making environmental decisions. This is problematic as indigenous people are knowledgeable about the environment they occupy and can provide information that could facilitate sound management decisions. Furthermore practitioners can also benefit from scientific data that pertains to their fields of practice and which may be beyond their reach.

Indigenous people are keepers of a body of knowledge about the land and sea which is regularly referred to as Traditional Environmental Knowledge (TEK) (Lowe 2004). As in the case of other facets of culture it is seldom integrated with science. In fact, this knowledge has often been disregarded because the people holding this information do not have educational degrees, nor have their observations been tested according to Western scientific protocols.

Recently, there has been an expansion and integration of TEK and culture into Western science and management programs (Poepoe 2003). As a result, there is increasing acceptance and recognition of Hawaiian TEK and cultural values. This forward movement will likely continue to influence my field of study (marine biology) in coming years. The overarching purposes of my study was to determine if TEK obtained from long-term residents (*kama'aina*) of Kahalu´u Bay, Hawai´i could provide insights into local marine ecology. On the other hand, I wanted to know if Western scientific methods can provide new insights into cultural practices and TEK. Finally, I wanted to determine if integration of knowledge from both systems can be used to create "best holistic management practices" (BHMPs) that could facilitate protection of Hawai´i's natural resources.

<u>The steps that I followed to attain these goals are as follows</u>:

1. Gather historical scientific information on coral reef resources of Kahalu'u Bay using published sources, reports and unpublished data produced by scientists.

2. Gather available TEK through interviews of local individuals who are knowledgeable about this region, and/or other published and unpublished information including cultural practices, legends, chants, or songs.

3. Conduct a thorough scientific ecological study of Kahalu'u Bay using modern scientific procedures developed by the Hawaii Coral Reef Assessment and Monitoring Program (CRAMP).

4. Compare available TEK with the scientific results to determine if there is mutual complimentary common ground between the two sources of information that can lead to bridging the perceived gap between the disciplines, with each source of knowledge enhancing the other.

4.2 Ka Nohona Pili I Ka ´Āina

Life and survival in these islands differs substantially from ancient times. Presently residents are reliant on the external shipment of goods for their everyday needs. It is estimated that 85-95% of Hawai´i's foods are imported. Moreover, 85% of Hawai´i's energy originates from petroleum based products. Consequently, Hawai´i would be greatly impacted if shipping routes were disrupted. With this in mind, it is useful to understand how the Hawaiians were able to maintain populations that may have been comparable to today's figures, yet did not rely on outside sources for their survival. Pre-censal data ranges from Cook's accounts of 200,000 to 300,000, to King's accounts of 400,000 to Stannard's estimate of 800,000 to 1 million Hawaiians (Dye and Komori 1992). Stannard (1989) based the prior low numbers on apologists for diseases that wanted to keep the Hawaiians from knowing the true population decline. It is currently believed that King's and Stannard's estimates were too high.

Kirch (1984) suggested population controls were density dependent with limited food and agricultural lands. Some of the density control mechanisms included infanticide, celibacy, abortion, war and sea voyaging. Earle (1979)

believed that population controls were density independent. His hypothesis of cultural change was based on political competition not population pressure since social stratification was important in early Hawai'i.

1000 AD Population expansion

1650 AD (160,000) Population peak

1778 AD (200,000-1 million) Capt. Cook: first Western arrival

1830 AD (130,000) First census: missionaries

Archeological timelines tell a similar story (Dye and Komori 1992). The first archeological evidence of human habitation was around 300 AD in Waimānalo. Other ahupua'a were not inhabited until much later such as upper Kāne'ohe in 1200 AD. (Dye 1994).

300-500 AD Site O18 Bellows

400-600 AD Kahana, Kāne'ohe, Kailua, Waimānalo

500-700 AD First evidence of pond cultivation Luluku

800 AD Earliest coring evidence Uko'a Pond

1000 AD Kapunahala

1200 AD Upper Kāne'ohe and Maunawili Valley

Methods used in determining these timelines includes:

Volcanic glass- used as tools, found in house sites and dated to obtain census of permanent and temporary habitations

Radiocarbon dating

Sediment cores- pollen and spores, charcoal, bones

Archeological digs and sites- middens, bones, shells

Oral and written accounts- census, ships, songs and chants (*mele*/*oli*)

4.2.1 Allocation of Land Resources

Prior to Western contact and exploitation, the ancient Hawaiians believed they were an "integral part of nature" and existed harmoniously with the environment (Jokiel et al. 2011, Kawaharada 2006, Maly and Maly 2004, Maly and Maly 2002, Valerio 1985). The Western concept of private property did not exist. The Hawaiians lived on and tended the *´āina* (land) which was subdivided into smaller segments. Each subsequent parcel allowed for land tenure (*kuleana*) and stewardship but not ownership of land or resources.

The largest land division was the *mokupuni* (island), which was further parceled out into *moku* or districts. Each *moku* was divided into *ahupua´a* or divisions of land that stretched from *mauka-to-makai* (ridge-to-reef). Each included a complete watershed(s) and all adjacent coastal marine resources with few exceptions (Jokiel et. al 2011, Burrows 1989, Kirch 1985). *Ahupua´a* were then

further divided into two to three smaller segments called *´il*[1]*i*. These strips of land were perpetually maintained by the same families for generations. There were two types of *´ili: ´ili pa´a and ´ili lele*. *´Ili pa´a* were smaller contiguous *mauka-to-makai* strips of land. *´Ili lele* were a series of disjointed segments of land which included a mountain, valley, and near shore land segments. These were often established in areas where it was difficult to have a single parcel of land which stretched from *mauka-to-makai* but still allowed families to access resources from the land and sea (Kirch 1985, Burrows 1989).

The ´āina provided many essential goods and services for the Hawaiian people and therefore its management was important. The *ali´i* (chiefly class) assumed peripheral control over the lands they ruled, yet they limited their involvement. The *konohiki* (overseer) was assigned to an *ahupua´a* and was the resource manager. Rules and regulations were created and modified under the guidance and input of the *kahuna* (priest and specialized experts), *kūpuna* (elders), and *hoa´āina* (native inhabitants) and allowed for a combination of top-down and bottom-up control of resource use. Ultimately, the *konohiki* made informed decisions concerning that area's resources (MacKenzie 1991).

The ability for the common person to play an active role in management was significant. They were allowed to involve themselves in this process as they were immensely knowledgeable about the resources of their *ahupua´a*. This level of understanding was required because their survival was dependent on the

[1] Physical descriptors and additionally, *´ili ´āina* (owned by the *ali´i*) and *´ili kūpono* (owned by *konohiki*) were designations of economic/political relations of the *´ili* – affecting control of use and receipt of produce.

preservation of natural resources that provided them with medicine, food, supplies, and water.

4.2.2 Allocation of Marine Resources

Prior to Western contact, the *ali´i* (chiefs) controlled the near shore resources for the lands they ruled. However far removed from most areas, the *ali´i* bestowed power on to the *konohiki* (land managers) of each *ahupua´a*, who oversaw the distribution of these resources. Through the guidance of the elders and expert practitioners these *konohiki* made informed decisions in order to set harvesting prohibitions on certain marine resources. Often referred to as *kapu*, these resource restrictions were set during specific times and places for a multitude of reasons which included: resource depletion prevention; offerings to the *akua* (gods) or higher ranking officials (*konohiki – ali´i*); and gender dietary restrictions. It is important to note that the *hoa´āina* (native inhabitants) were granted collection rights for sustenance and tribute, while abiding by the *kapu* set in place. Additionally, harvesting was not based on quotas, instead times and places were selected in order to prevent the disruption of natural rhythm while also ensuring the sustainability of these resources.

Offshore marine resources were managed differently than those found along the shore. Natives were free to fish the deep sea as they wished, as long as *kapu* were not in place. Although there were few if any *kapu*, restrictions still existed as fisher knowledge was required to catch target fish species. In the days of old, knowledgeable fishers knew of secret *ko´a* (fishing grounds). There

were different *ko´a* for different species. This knowledge was not widely spread and was responsibly passed down to the fisher's protégé. This knowledge was integral to acquiring offshore marine resources.

4.3 Traditional Environmental Knowledge

4.3.1 What is Traditional Environmental Knowledge (TEK)?

Indigenous people have built and retained knowledge about the natural world for generations. They understood its importance because knowledge ensured their survival. Conversely early Western researchers did not appreciate nor accept this knowledge as having any validity (Moller et al. 2009). This all changed by the late 1970s as there was growing scientific interest in indigenous knowledge, especially in the marine field (Grant and Miller 2004). It was then that scientists coined the term Traditional Environmental Knowledge (TEK).

TEK has been incorporated into many Western disciples as evident by the numerous times it is referenced in the primary literature. TEK has aliases which include but are not limited to: Traditional Ecological Knowledge, Ecological Knowledge, Indigenous Ecological Knowledge, Indigenous Environmental Knowledge, and Indigenous Knowledge. They all have the same underlying meaning. As defined by Johnson (1992), TEK is a "body of knowledge built up by a group of people through generations of living in close contact with nature. It includes a system of classification, a set of empirical observations about the environment and a system of self-management that governs resource use." In Hawai´i, this knowledge has been perpetuated in cultural practices, legends,

chants, songs, and documented in Hawaiian language newspapers, books and other publications.

There is a congruency between the definition of TEK and Hawaiian knowledge of the environment. Hawaiians have lived in close contact with the land and sea environments for centuries. In addition, they possessed a system of classification. For example, *limu* (algae) have names based on their morphological features as well as the habitats where they are found. Each *limu* possesses a two part name: The first name of the *limu* groups all *limu* together, whereas the second name denotes the particular type of *limu* (Huisman et al. 2007). This is similar to the binomial nomenclature naming system in science for which there is a genus and species name for each organism. Moreover, the Hawaiians perpetuated a tremendous amount of environmental information. This is evident in their moon calendars which indicated which nights were favorable for planting and fishing and which were not. Finally, resource management schemes (such as closed areas, gear restrictions and size limits) have been used by the Hawaiians centuries before being implemented by Western nations (Jokiel et al. 2011). It is plain to see that the Hawaiians were an integral part of the environment and recognized the need for sustainable practices in order to perpetuate their people.

4.3.2 Examples of TEK from the Primary Literature

TEK is not unique to Hawai´i. For centuries other indigenous cultures have possessed place-based knowledge of the natural environment (Rocha 2005,

Donovan and Puri 2004, Grant and Miller 2004). This information is poorly understood by the Western world. In particular, TEK related to marine organisms often draws skepticism from the scientific community if originating from an anecdotal indigenous source. In recent years, these oral records are more readily accepted by scientists when they are confirmed by reputable researchers. Below are examples of TEK from the primary literature.

4.3.2.1 Seabirds the Natural Fish Finder (Johannes 1981)

Under optimal conditions (for example clear and calm days) fishermen are able to locate schooling fish. This ability, however, is greatly reduced under conditions of wind, rain and overcast, when it is difficult to visually detect fishes. For many generations, fishers of Oceania, such as the Palauans, have depended on seabirds as an aid in locating fishes under a variety of weather conditions. Through their observations they learned a great deal about seabird behavior which provided insights into locating the fishes. These insights include: which fishes are present, what the prey fish is, and what fishing method is to be used. As quoted by Johannes (1981), “about one-half of what he (master fisherman) told me about Palau’s seabirds can be found scattered in the scientific literature. In no instance did his observations contradict those already published by ornithologists.”

An example of the immense knowledge held by the Palauan fishermen includes their understanding of how three bird species can co-exist while feeding on the schooling fish. When he asked how that was possible and why one species

would not monopolize the resource a master fisher replied without hesitation. The fisher noted that the white terns hunt early in the morning before the others. They also arrive at the schools faster because of their great cruising altitudes. The noddies on the other hand are the most aggressive and the largest of these bird species. When they arrive they dominate the feeding grounds. Their drawback is that they tend to feed closer to shore. Audubon's shearwaters feed on smaller prey and can dive to catch their prey. The fish they catch are inaccessible to the other species.

4.3.2.2. Bonefish (*Albula glossodonta*) Migration Routes [Johannes et al. 2000]

This fishery is important in Tawara, an atoll of Kiribati. Tawara fishers have caught these fishes for generations and have learned much about their reproduction and migration patterns. Catala (1957) reported that bonefish were caught on or close to full moon nights as they would congregate in large schools at specific locations within Tawara lagoon. They would then migrate from the lagoon to shallow reef flat and ultimately head over the outer reef edge. Within a few days of spawning they would return to sites within the lagoon. Since the 1960s, Tawara fishers saw the demise of the fishery when causeways were built between islands blocking or destroying migration routes. Overfishing with the use of gillnets depleted schools. In the 1990s this failing fishery drew concern from the government which attempted to gather information from fishers through questionnaires. Their efforts were fruitless because the random selection of fishers yielded only young fishers, who lived near the center of Tawara and

possessed little if any knowledge about this fishery. In addition, the written questions were not appropriate for those who were experts on the fishery. At the same time, Johannes and Yeeting (2000) conducted oral interviews with expert fishers and learned about the migration routes that had been blocked. They were able to locate the last known migration route, which was found in North Tawara, far from the center of the atoll. Without official sanction from the fisheries department the North Tawara villagers protected the spawning route. This community based management scheme proved to be successful as catch-per-unit-effort (CPUE) and mean bonefish size appeared to increase in 1999.

4.3.2.3. Larval Fish Behavior (Johannes 1981, Haggan et al. 2007)

In the 1970s, Tobian fishers shared their knowledge about larval behavior of at least five reef fish species with Johannes. Based on their observations they noted that larvae congregate on drift material in the open ocean that gave them protection from predators. As they drifted closer to the island they swam directly towards reefs that were still a great distance away. Eventually these small fish reached these reefs and recruited into the population. For more than 15 years this knowledge was unused and led scientist to falsely believe that larvae were completely controlled by ocean current, which was the only factor influencing its abundance and distribution. This knowledge led to critical errors in understanding fish stocks and management (Leis and Carson-Ewart 2000). In the 1990s researchers (Stobutzki and Bellwood 1998) documented the larval

dispersal mechanisms that were previously known by Tobian fishers for generations.

4.3.2.4 Sea Turtles (Carr 1972)

Hunters vouched for generations that green turtles (*Chelonia mydas*) returned to the same locations year after year. They could differentiate between them based on distinctive wounds and marks. Such anecdotal knowledge was neglected for many years as biologists conducted turtle research. In the 1950s, Archie Carr (1972) realized the importance of this information and tested its validity. Results from his research demonstrated that the turtle hunters' claims were indeed true. Other TEK included information on growth rates, longevity, reproduction, and nesting frequency. Recent genetic techniques have further supported this claim and acknowledge female turtles return to lay eggs at the same location of their birth.

4.3.2.5 Timing of Flora and Fauna Reproduction (Veitayaki 2002)

The people of Fiji, like other indigenous cultures, understood the natural processes of the surrounding flora and fauna. Knowledge based on oral transmissions from the elders and their own observations allowed them to predict when specific species would reproduce. The Fijians also linked the reproductions of plants with the birthing of marine organisms. It was believed that when a particular species found on land was reproductive so too was its marine counterpart:

"January was associated with the abundance of spinefoot and rabbit fish (nuqa), shellfish and bivalves (kaikoso), and trochus (vivili). This month was also when the land crabs (lairo) spawn in the sea and breadfruit trees bear fruit (Veitayaki 2002)."

4.3.3 Application of TEK in Modern Times

4.3.3.1 Cultural

From a cultural perspective the importance of TEK use lies in preserving ones culture. Some benefits are listed below:

The documentation of TEK can preserve cultural aspects (such as rituals and values) through a variety of media: audio, visual, and text.

TEK can provide insights concerning cultural ideals, ways of living, and cultural practices employed by the source at a specific time and place. These insights allow for comparisons between places. For example, in Hawai´i there were similar and contrasting fishing techniques used among *ahupua´a*.

The immense TEK place-based knowledge can enrich our daily lives.

TEK is useful in development planning. If agencies accurately use this information to make informed decisions during the planning process, the community buy in may be greater as there is a level of community involvement and cultural sensitivity.

4.3.3.2 Scientific

Traditional Environmental Knowledge provides numerous benefits to the scientific community if collected, translated, and implemented correctly. In 1986 the IUCN (International Union for Conservation of Nature) outlined some of these discernible benefits:

TEK can provide novel insights useful for understanding biological and ecological phenomena that have previously gone unexplained.

TEK can provide insights concerning resource management. Indigenous people have been managing their natural resources for generations using sustainable practices. Consequently they have implemented the same or similar “novel management schemes”, as termed by Westerners, centuries before them.

Cultural involvement, can lead to community investment and ultimately resource protection.

TEK can be used to establish protected areas and provide the basis for conservation education. Protected areas can enhance an area while maintaining cultural rights and responsibilities. In addition, the TEK of indigenous people is of interest to others outside of the local community. Values such as conservation and sustainable management practices can be taught and learned from a TEK point of view.

TEK can be useful for the ongoing monitoring and assessment of the environment. Intimate knowledge of resources can provide qualitative estimates of resources in the past.

4.3.4 Detriment of TEK Use

4.3.4.1 Cultural

Cultures can be heavily impacted by the permissible or non-permissible use of TEK. Some detrimental impacts include:

The use of TEK can reveal knowledge that was meant to be kept private. Publicized knowledge can lead to over extraction of goods and services. For example, when *ko´a* (sacred fishing sites) are revealed some fishermen quickly raid the area for fish leaving these generations-old sites fruitless.

Generally TEK involves sacred rituals, practices, and/or sites. The availability of this knowledge can lead to the exploitation or desecration of one's culture or sites. For example, during the construction of the Waikoloa area, the King's Trail, an ancient footpath, was marked and allowed for public access. It includes numerous sacred sites among which is an area with rock engravings or petroglyphs. Over the years this area has been decimated by heavy foot traffic and blemished by individuals who tried to create their own petroglyphs or desecrate existing ones.

TEK can easily be misinterpreted or misconstrued. When non-indigenous people extract information from an indigenous source they might take everything literally which sometimes leads to the wrong assumptions or faulty explanations of phenomena. Information is "lost in translation" because subtle aspects of TEK are sometimes not understood by other cultures.

4.3.4.2 Scientific

There are potential negative aspects of TEK.

Western researchers sometimes lack the ability to translate traditional knowledge. They poorly understand the culture's nuances and thus make assumptions based on their knowledge about what is being conveyed or completely disregarding the shared information.

Some Western researchers who use TEK can be considered thieves as they exploit ideas and knowledge (especially environmental) from indigenous people and present this information for personal gain.

Some Western researchers extract information from indigenous sources based on claims of benefiting indigenous people, but have alternative motives. For example, companies for years have used the TEK of tribal people to learn more about their plants and medicinal uses. In turn, these companies use this knowledge and extract pharmaceutical components which are sold to the world. These companies profit off this knowledge without fair compensation to the indigenous people.

4.4 Comparison Between TEK and Western Science

Fundamental differences exist between TEK and Western Science (Table 4.1). These differences are explained in detail below:

4.4.1 Information Dissemination

Indigenous people disseminate information orally and on a local basis. This information is either shared vertically meaning that an elder, which is not necessarily blood related, to an underling individual or the information can be shared horizontally (elder to elder, fisherman to fisherman). In general this is different from Western Science which is widely disseminated through peer reviewed articles or other publications and various types of media including the internet.

4.4.2 Acquisition of Knowledge

In the indigenous realm knowledge was acquired through observations. The harvesting of fishes was based on their observations about the lunar cycle as well as the timing of fish reproduction. The planting of flora were based on the lunar cycle, the presence of precipitation, and ample sunlight. Western research is based on quantification and analysis of observational data from the environment. Testable hypotheses are developed based on initial observations. Subsequent research builds on a foundation of findings that have been globally disseminated in the literature.

4.4.3 System Approach

Indigenous people have a holistic view of the environment. Their decisions were based on the entire system. For example, the Hawaiians viewed the sky, land, and sea as one unit. This is evident through their land divisions or *ahupua´a* which stretched from the tops of the mountain and extended to the

outer reef crest. Fishing related decisions were based on input from not only fishermen but also from the *mahi´ai* or farmers from the uplands. In the past, Western scientists often have been reductionists. When investigating systems like the ocean these scientists often study one small component. However, marine science is rapidly moving toward the holistic view of indigenous people. There has been major expansion of the Integrated Ecosystem Assessment (Levin et al. 2009) in contemporary science, which involves complete analysis of all aspects of the physical, chemical and biological environment.

4.4.4 Way of Thinking

The way of thinking differed between indigenous cultures and western scientists. Indigenous people are intuitive in their way of thinking and often hold onto ideas passed on to them as absolute. These ideas are not readily questioned. They based their thinking on anecdotal observations and oral histories. Alternatively, scientists base their thinking on analysis of observational data and all conclusions are wide open to challenge and revision. No ideas are held as absolute and all ideas are constantly under scrutiny.

4.4.5 Mode of Information Collection

Indigenous people collect information qualitatively. *Lawai´a* or fishermen would compare the size, weight, or amount of catch to something similar. For example, the fish was larger than an adze. Western scientists on the other hand are quantitative. Like the *lawai´a* they could make comparisons to other things

but numeric values would distinguish between the two. For example, the fish was a meter in fork length and equal to a meter stick.

4.4.6 Information Generator

In the indigenous world the information generator was the resource user. The resource user was considered to be the one who frequently interacted with the resource of interest on a regular basis. For example *lawai´a* were focal to information concerning anything to do with going *holoholo*. Literally *holoholo* means to go out for a walk, ride or sail, to go out for pleasure, promenade (Pukui and Elbert 1986) but in this circumstance it means to “go fishing”. In the old days *lawai´a* would not dare say they are going fishing as they believed the fish would hear them and their activities of that day would prove fruitless (Maly and Maly 1987). Alternatively in the Western science world the information generators are the experts or specialists in the field of interest. For example, you would go to see a coral disease specialist if you were interested in learning about coral disease.

4.4.7 Area and Length of Data Collection

Indigenous people have usually collected qualitative information for a single area over a long period of time. Their breadth of knowledge encompasses the entire *ahupua´a* system and was passed down orally from generation to generation. In some cases this knowledge can be centuries old. Western scientists on the other hand often have collected data over large areas over a

shorter period of time. For example, the Coral Reef Assessment and Monitoring Program (CRAMP) have studied the health of coral reef systems throughout the entire Hawaiian archipelago for over a decade (Brown et al. 2004).

4.4.8 Management/ Decision Making

Indigenous peoples have made management decisions concerning their natural resources based on the information provided from all resource users. The *Konohiki* or the land manager would be advised from the *kahuna* or high priest as well as the heads of each occupation, and in some cases the people, to decide if their management decisions will benefit the people of that particular place. Input would be provided from all (Kahāʻulelio 2006, Kamakau 1976). In Western science laws and theories based on evidence provided by researchers are the driving force behind the establishment and implementation of management decisions.

Table 4.1 Summary of Differences Between TEK and Western Science (Based on Jokiel et al. 2011 and Brodnig and Mayer-Schönberger 2000).		
Component	**TEK**	**Western Science**
Information Dissemination	Oral Transmission	Written Tradition (i.e. publications)
Acquisition of Knowledge	Through Observations	Through Context
Systems Approach	Holistic	Reductionist
Way of Thinking	Intuitive	Analytical
Mode of Information Collection	Qualitative	Quantitative
Information Generator	Resource User	Experts and Specialist
Length of Data Collection	Long Term Over a Single Area	Short Term Over a Large Area
Management/ Decision Making	Based on Summary of Collected Information	Laws and Theories

4.5 Bridging Culture and Science in Hawai´i

Bridging the gap between culture and science through the use of TEK is important to adding clarity to how marine resources are managed in Hawai´i. "Bridging the gap" does not mean that one is integrated into another discipline (i.e. culture incorporated into science), which would be the foundational element; instead together disciplines contribute to the understanding of both. Bridging this gap is crucially important to making sound decisions concerning future natural resource management.

4.5.1 Examples of Bridging Culture and Science in Hawai´i

Efforts have been taken to bridge the gap between culture and science in Hawai'i. This section highlights the most significant examples contributing to both the *Lāhui* (Hawaiian nation) and Western Science.

4.5.1.1 Mo´omomi Bay

The community of Mo´omomi Bay, located on the northwest coast of Moloka´i, provides a pertinent example of how gaps can be bridged between the traditional cultural approach to resource management and science. This community relies greatly on coastal marine resources, and thus resource sustainability is important to their survival. Community members hold a vast amount of place-based knowledge about their resources. This knowledge includes information about fishery dynamics, fish behavior, fish reproduction and harvesting of various other near shore resources. The community based management scheme currently employed anecdotally is more effective than the current centralized governing management schemes employed elsewhere. This community has taken management of coastal resources back into their own hands with the help of western scientists. It is noteworthy that cultural practitioners have worked side by side with scientists to achieve one goal: resource sustainability. Furthermore, scientific studies which included the examination of gonads or fish reproductive organs and/or ossicles or fish auditory bones provided key information pertaining to the timing of reproduction and fish growth rates. Collaborative contributions by both parties afforded this system to serve as a possible model for other communities (Friedlander 2002). However, this management scheme operates in a small isolated Hawaiian community and might not work in other places with a large and culturally diverse population.

4.5.1.2 Papahānaumokuākea National Marine Monument

The Papahānaumokuākea National Marine Monument is the largest designated conservation area within the United States, and is also one of the largest marine protected areas in the world. Its extent encompasses 362,073 km^2 and is part of the Hawaiian archipelago located within the Pacific Ocean. This monument was established on June 15, 2006 by Presidential Proclamation 8031 under the authority of the Antiquities Act (16 U.S.C 431-433) and was formed in order to perpetuate and protect its significant cultural and natural resources (more than 7,000 marine species). In 2010, the monument was deemed a World Heritage Site by the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Complementary to its scientific importance, Papahānaumokuākea is significantly important to the native Hawaiian culture and is evident by the archeological cultural sites found on Nihoa and Mokumanamana (Kikiloi 2012).

The name Papahānaumokuākea originated from Hawaiian genealogy and creation and was selected to give homage and respect to the people of this place. Papahānaumoku is “earth mother” and Wākea, or Ākea is “father sky”.

The monument staff which is a blend of both cultural practitioners and scientists are continually working on projects to use the Hawaiian knowledge system as the basis for learning not only about culture practices and rights but also about how this knowledge system can be foundational in implementing management schemes (Papahānaumokuākea National Marine Monument 2008).

4.5.1.3 “Hawaiian Language Translation” Project

A partnership between the University of Hawai´i Sea Grant College Program (UH Sea Grant) and Dr. Marvin “Puakea” Nogelmeier, an associate professor of Hawaiian Language at the University of Hawai´i at Mānoa Hawai´inuiāke School of Hawaiian Knowledge, was initiated after UH Sea Grant expressed their interest in the gathering and translation of Hawaiian language newspaper articles which included theme such as: traditional and modern fishing practices, climate change, and other ocean related topics. Through this collaborative effort a pilot project was initiated and resulted in the production of a number of historical documents titled related to marine resources. The project report included the translation of twenty-two articles from the 1900’s, one that has been published, titled “Saving the fish” with the remainder of selected translations being available online. These articles covered a broad range of topics which included reef access and traditional knowledge concerning types of nets. This project indicated the need for both disciplines to be integrated as these articles provided insights for past resource baselines.

4.5.1.4 Creation of New ´Ike Through Scientific Observation and Monitoring

It is important to recognize that the sharing of knowledge is a two-way street. Significant contributions can be incorporated into both scientific discipline and cultural. The examples above focused on the cultural contributions to science. This following subsection focuses on scientific contributions to the Hawaiian culture.

A collaborative partnership between Kehaunani Tom Springer (Conservation International's Hawai´i Fish Trust), Pelika Bertelmann (Co-founder of Nā maka o Papahānaumokuākea: Non-profit that is a strong proponent for community based marine management), and the University of Hawa´i at Hilo (UHH) was developed in order to gather information about the nature world (*lani* – sky, *honua* – land, and *kai* – sea), its associated resources as well as to integrate Western Science with culture. As a result they conducted observation as well as quantitative monitoring surveys based on cultural and Western Science protocols along West Hawai´i. Through their monitoring surveys they were able to gather information concerning coastal resources. Using their data which was collected using Western science techniques they were able to add new *´ike* (knowledge) to existing bodies of practitioner insights. In one example they were able to create modern *´ōlelo no´eau* (proverb) based on their data concerning wave action, seasonality, and *limu* (algae) growth to predict the presence of young limpets. The proverb is as followed:

"Hāli´i ´ia ka pōhaku i ka limu, ´ākoakoa mai nā pua ´opihi I ke kau kai ko´o."

Translated: "As the rocks are covered in a blanket of limu, baby ´opihi are found on the rock in this season of rough seas."

This is a pertinent example that identifies the importance of both disciplines for which contributions can be made to both. An old proverb best captivates this concepter, "*E a´o kāua.*" "Let's learn together." This proverb denotes that as one teaches, they also learn.

4.6 Examples of Bridging Culture and Science through TEK Use at Kahalu´u Bay

Past and present *lawai´a* or fishers have always been intimately connected to marine ecosystems and as a result possess immense knowledge that is specific to their fishing sites. Through oral history dissemination and/or observations they have come to understand the abundance and distribution of species based on spatio-temporal variances; behavior and feeding difference between organisms; and changes in weather and ocean patterns throughout the year. Such information is known as traditional environmental knowledge (TEK) and can provide understanding and historical information to the field of marine ecology. Like many other traditional fishers, the *lawai´a* of Kahalu´u Bay are now aged but as kūpuna are still the keepers of place-based knowledge. Detailed below are some examples of the knowledge they have shared with me either in interviews or personal conversation. It is with great gratitude and responsibility that this information was shared with me in a way that I can contribute to the *Lāhui* and bridge the gaps that exist between culture and science.

4.6.1 Obtaining and Recording TEK

The purpose of this study was to evaluate the relationship between Western scientific method and TEK. The first step of this process is to record TEK in an objective manner using appropriate interview techniques.

This case study used the interview technique in order to document TEK of Kahalu´u Bay, Hawai´i. In the initial stage, the Kohala Center (TKC) identified

key individuals that hold TEK about the Kahalu´u *ahupua´a*. TKC is a non-profit organization that has worked in this region since 2001 and has developed an intimate relationship with the residents of Kahalu´u.

Once identified, these individuals (known as "*kūpuna*" or elders), were then formally introduced to me. Subsequently, informal "talk story sessions" or *kama´ilio* were scheduled. In the Hawaiian culture it is formal protocol that an intimate relationship be developed before any "personal or privately held information" is shared. In these informal gatherings, information about one's life (i.e. where you are from, where you grew up) is shared. In addition, these meetings were pivotal in fulfilling an aspect of the Hawaiian culture: "*kulikuli kou waha, a ho'olohe kou pepeiao*" or "close your mouth, and listen with your ears". It was necessary to listen first because often the questions one might have are answered in the listening process. The initial process of listening to the *kūpuna* can lead to insights and to further questions. These initial meetings were informal and meant to build trust, so the early discussions were not recorded. Once the introductory period passed, which lasted for approximately three years, these individuals were asked if they would be willing to participate in a recorded formal interview. This period was based on own protocol and not a designated one. Interviews conducted as part of University of Hawai'i research is contingent upon full review and approval from the Institutional Review Board of the Committee of Human Studies (www.hawaii.edu/irb). Official authorization of questions to be asked was acquired and interview protocol was followed. Refer to Appendix XIV for the letter of project approval from the Committee on Human

Studies (CHS). Upon agreement of interviewees, an interview time and place was scheduled. Questions for the interview were provided ahead of time in order to prepare the interviewee (Appendix XV). On the day of the interview, each participant was consulted one last time. Prior to being interviewed each interviewee was asked to read an agreement to participate form (Appendix XVI) and sign a letter of consent (Appendix XVII), which describing project details. All interviews were recorded using a Canon EOS Rebel T2i camera. Two interviews were conducted, each approximately one hour long. The interview started with foundation questions which built the credentials for each interviewee. Subsequently, these individuals were asked a series of questions about the bay and coral reef resources. At the conclusion of the interview each participant was given the opportunity to ask any questions. In addition, they were asked if the content documented can be used and distributed in the manner described in the letter of consent.

During the post-interview stage the interview footage was reviewed and responses transcribed. When necessary the interview footage was edited. Edits were only made to improve quality of footage and not to exclude detail unless under the direction of the interviewee. After post-editing, interviewees were asked again to review footage and sign a Transcript/ Video Released form (Appendix XVIII), which indicated their approval of content. Responses from the interview were used to generate hypotheses concerning coral reef resources that were tested according to Western science protocols. Currently copies of the interviews will also be given to the interviewees (for personal use and for family

record), will be submitted to the UH library for archival purposes, will be posted on the UH/TKC portal website (http://portals.intelesense.net/tkc/), and excerpts included in this doctoral dissertation.

4.6.1.1 Brief Descriptions of Interviewees

Mitchell M. Fujisaka

Mitchell Fujisaka was born into a fishing family in 1936. He was raised in the *ahupua´a* of Kahalu´u. He spent a great deal of time fishing at Kahalu´u Bay. As a child he helped Henry E.P. Kekahuna, a renowned archeologist, map cultural sites within Kahalu´u. He holds historical accounts of the Kahalu´u Bay area and noted changes throughout time.

Ray "Chikao" Kunitake

Ray "*Chikao*" Kunitake or Chick was born on a coffee farm in Holualoa in 1937. As a child, Chick would walk from the Holualoa farm down to Kahalu´u Bay to fish and swim. Although Chick does not drive he still frequents Kahalu´u Bay and has noted changes that have occurred there. As a result of living 900' up in Holualoa, Chick has noted larger scale changes along West Hawai´i including the Kahalu´u Bay area. Uncle Chick provides a *makai* (ocean) and *mauka* (upland) perspective of Kahalu´u.

4.6.2 Comparison of TEK and Scientific Findings.

Like many other traditional fishers, the *lawai´a* of Kahalu´u Bay are now aged but as *kūpuna* are still the keepers of place-based knowledge. TEK is simply part of the culture and passed on to the next generation as truth. In contrast, scientific knowledge is obtained through a process of forming a hypothesis and testing the hypothesis by quantitative methods and statistics. These results are always subjected to further testing. Detailed below are three examples of the knowledge that the *lawai´a* shared as TEK and how this knowledge was compared to knowledge obtained by the scientific method. It is with great gratitude and responsibility that I undertook this study as a way to contribute to the *Lāhui* and bridge the gaps that exist between TEK and scientific knowledge.

4.6.2.1 Rugosity and Fish Abundance/Biomass

<u>TEK</u>

When questioned about what were some of the most significant changes over the years, *kūpuna* Fujisaka responded that “there is too much corals these days and not enough fish”. I then followed up with additional questions. For example, where were the fish found? If they were not among the corals, then where were they found? Kūpuna Fujisaka quickly responded, “inside the bay”. He indicated away from the reef. When questioned further he explained what he meant by this in detail. He said that back in his days they would build “houses” for the fish. These houses were constructed with basalt rocks. He noted that

they (the houses) looked similar to the rock piles made after using an *imu* (underground oven). Its dimensions were approximately 2m x 2m x 1.5 m. He continued to explain that these houses were built for multiple reasons. The first reason is that rock piles provided a place for the fish to live. He said that if you look at the reef there aren't many places where the fish could hide or live as the reef was flat and did not have a lot of *pukas* (holes) in them. Moreover he said that there wasn't much food there for the fish. By food he was referring to algae (*limu*). He said the *limu* would grow on the piled basalt rocks and the fish would come to these houses to feed. His final reason was that these houses made it much easier for them to collect fish. The fish congregated in these houses. The little fish drew in the larger fish. When they wanted to harvest the fish they surrounded the entire structure with a net and either chased the fish into the net or removed the rocks one by one until they could close their net. In summary, TEK tells us that the fish prefer these structures as they would house and feed them. The coral was not preferred as it did not have high enough relief nor did it support the growth of *limu*.

Western Science

The Western science literature shows a positive correlation between the fishes and coral cover (Friedlander and Parish 1998a, 1998b). As coral cover increases the number and biomass of fishes increases as well. Thus, there is an

apparent conflict between TEK and the scientific literature. The TEK report from *kūpuna* Fujisaka is that “too much coral” means less fish. The scientific reports show that there are more fishes in high coral locations. So how can this apparent conflict be resolved? Scientists understand that rugosity, or bottom complexity, is a major factor controlling fish abundance and biomass. Coral cover in natural environments creates higher rugosity, so coral cover is correlated with rugosity or topographical relief. The “rock piles” reported by *kūpuna* Fujisaka greatly increase bottom complexity, but the term rugosity is foreign to TEK practitioners. Thus, we need to test the relationship between fishes and rugosity.

Hypothesis Tested

H_o = The predictor variable rugosity is not associated with the response variable, the number of fishes.

H_1 = The predictor variable rugosity is associated with the response variable, the number of fishes.

Rugosity is a relative index of topographic relief or spatial complexity that can be derived in various ways. The Coral Reef Assessment and Monitoring Program (CRAMP) utilizes a chain and tape method (McCormick 1994) in which a light brass chain marked off in 1-m intervals is spooled out over the bottom along the length of a transect tape that is stretched tightly over a 10 m distance .

The amount of chain necessary to follow the contour over the 10 m horizontal distance is divided by the straight-line tape measurement to generate an index of rugosity. For example, on a sand bottom only 10 m of chain will be needed to follow the bottom along a stretched 10 m transect line resulting in a rugosity of 10 m/10 m = 1.0. On a complex surface it might take 20 m of chain to follow the bottom over the 10 m transect line for a rugosity of 20 m/10 m=2.0. Rugosity can also be defined using the variance in depth at a given site. Another accepted method to estimate rugosity is visually by a trained observer (Analytical Laboratories 2001, Coyne et al. 2003), which is the desirable alternative at Kahalu´u because the fishes and benthic data at each of the 202 stations was taken within a circle with a 7 m diameter (Fig. 4.1) that was visually estimated. Scaled vertical and oblique photos were taken at each location. Rugosity was later estimated in the lab by expert opinion using the photo images and criteria shown in Fig. 4.1 to rank rugosity based on a scale from 1.0 to 2.0. Based on this the set of criteria, sand is given a rugosity index of 1.0 (Fig. 4.1 A), rubble, 1.2 (Fig. 4.1 B), boulder/ low coral cover, 1.4 (Fig. 4.1 C), moderate coral cover, 1.6 (Fig. 4.1 D), high coral cover, 1.8 (Fig. 4.1 E) and high vertical relief of corals was given the highest rugosity index level of 2.0 (Fig. 4.1 F). Rugosity assessment was completed by two observers (Kaipo Perez and Dr. Paul Jokiel) in a single viewing to insure uniformity and reduced observer variability.

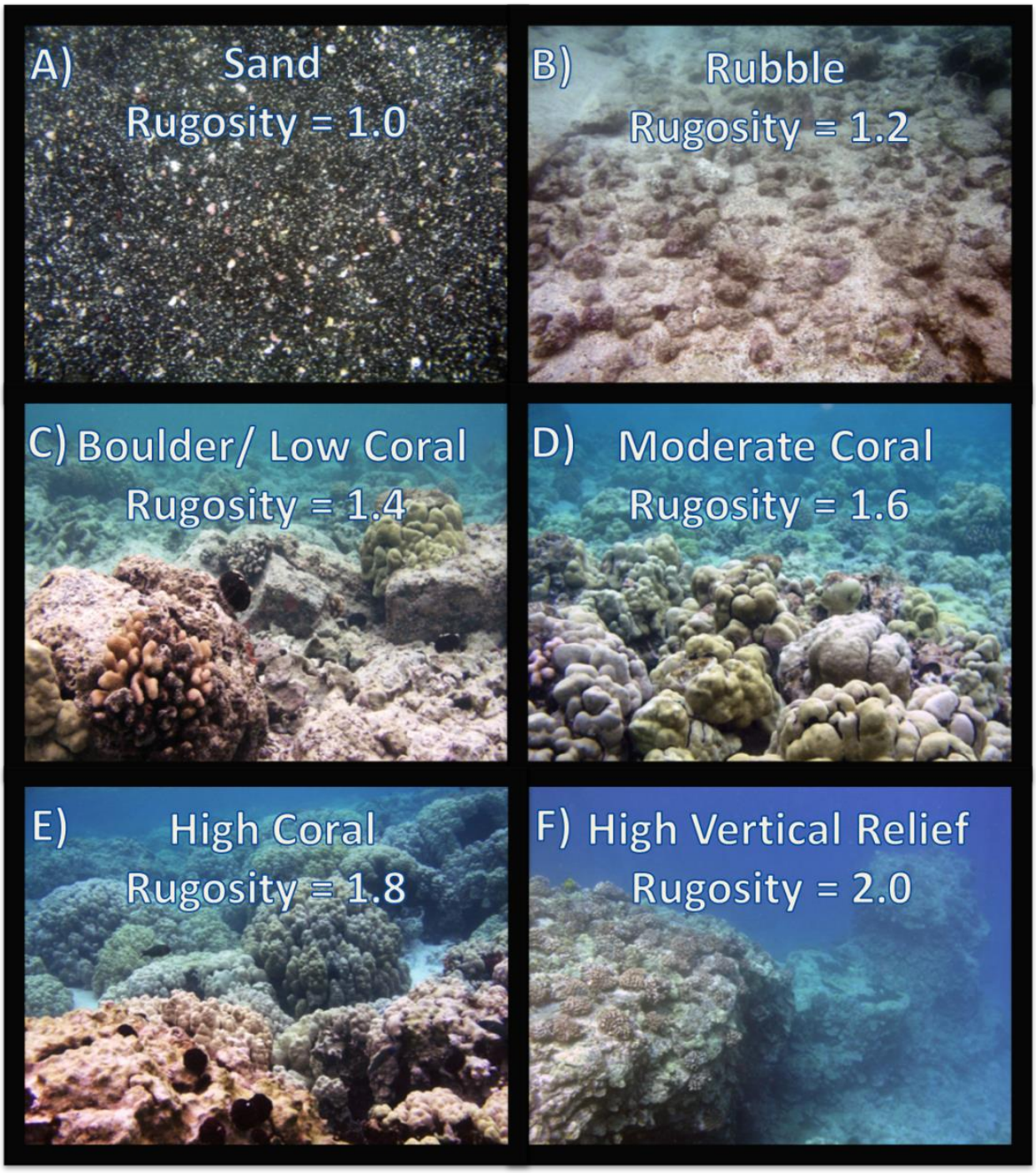

Figure 4.1. Scoring criteria for rugosity ranging from 1.0 for sand to 2.0 for areas of high vertical relief.

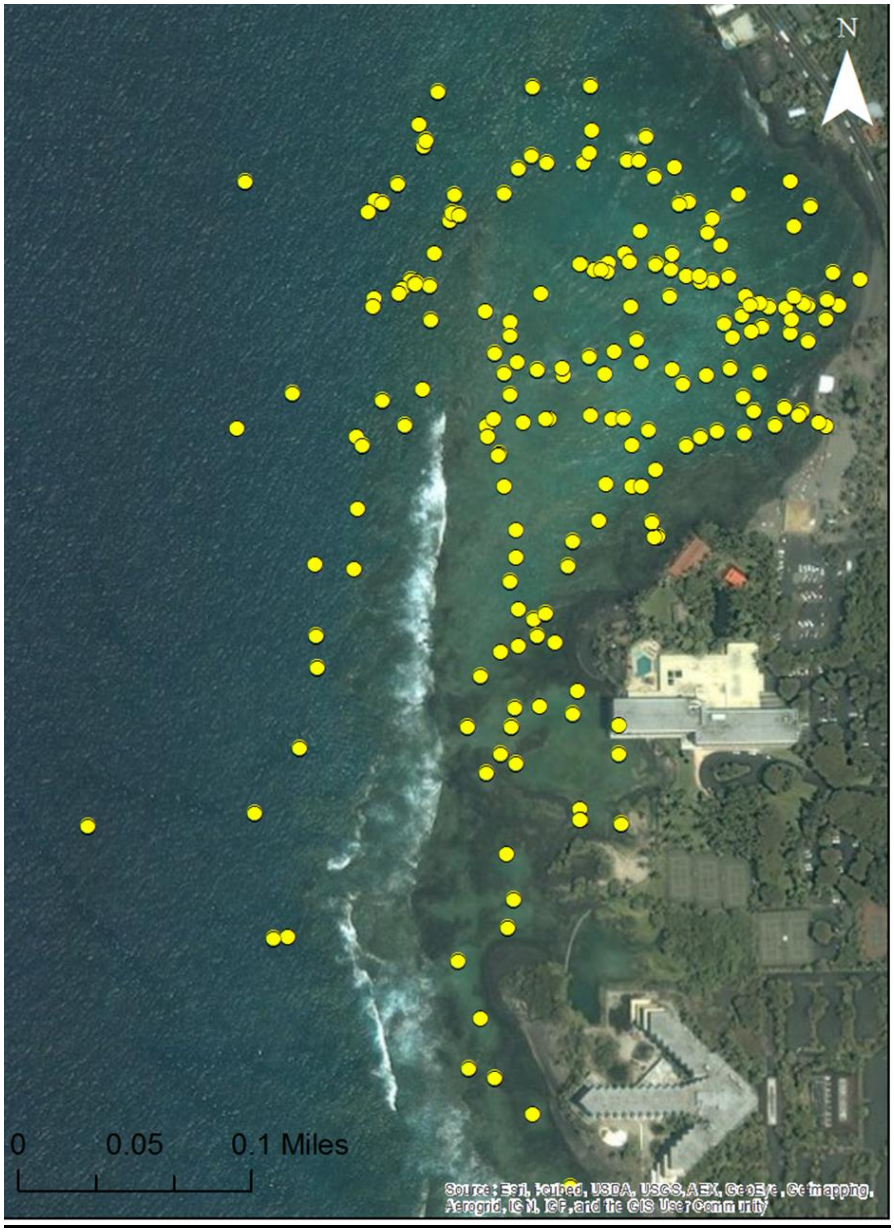

Figure 4.2. Stations surveyed at Kahalu´u Bay, Hawai´i. n=202

Fish Abundances

Fish surveys were conducted at 202 stations shown in Fig. 4.2. Visual estimates of abundance, species, and length were recorded within a seven meter

radius (Rodgers et al. 2005). Fishes were identified to the lowest taxonomic level possible and enumerated by length. Surveys were conducted between 1 April 2010 and 5 June 2012.

Biomass estimates were based on species type, abundance, and fish length. These factors were inserted into known species specific biomass equations from FISHBASE (www.fishbase.org) to calculate biomass. Biomass estimates from each station were summed to acquire total biomass. Numeric abundance and species were summed to quantify the number of fishes and species present at each station.

Statistical Analysis

General linear regression models were used to determine a relationship between response variables, fish abundance (total number per station), fish total biomass per station, and richness (number of fish species per station) and the rugosity of the benthic environment. A square root transformation was used on the variables fish abundance and fish biomass to meet the assumption of normality.

Results

Fish Abundance

A positive correlation exists between rugosity and numerical abundance (p=<0.0005, α=0.1). A p-value of < 0.05 supports the alternative hypothesis that

rugosity is associated with the number of fishes. Rugosity accounted for a significant portion (23%) of the variability in the numerical abundance of fishes.

Fish Biomass

A positive correlation was found between rugosity and fish biomass (p=<0.0005, α=0.1) supporting the alternative hypothesis that rugosity is associated with fish biomass. A large portion of the variability in fish biomass (26%) was accounted for by rugosity.

Fish Species (richness)

A statistically significant correlation was found between rugosity and richness (p=<0.0005, α=0.1) supporting the alternative hypothesis that rugosity is correlated with the number of species of fishes with 21% of the variability explained by rugosity.

Discussion

Results of this investigation demonstrate how apparent contradictions between the Western science method and TEK can be resolved. The problem was one of communication. The observation that "there is too much corals these days and not enough fish" runs counter to the scientific observation that there is a positive relationship between fish number/biomass and coral cover. The wisdom from this *kūpuna* is that basalt rock piles provided cover for the fishes and was a better substrate for development of food (*limu*) for the preferred target species.

The error in understanding what *mana´o* (wisdom) this *kūpuna* shared was a consequence of misinterpretation. TEK was that rock piles have higher rugosity and are a better food source for the desirable fish species (herbivores) than corals. The TEK was lost in translation. He was explaining that the coral reef system at Kahalu´u Bay did not have great spatial complexity and as such was not suitable for housing fish. After exploring the details, his thought became evident.

The Western science data and the statistical result from this study are congruent with the TEK shared by *kūpuna* Fujisaka. This is evidence to show that traditional knowledge can provide significant insights to marine ecology. From the cultural perspective this study has shown that the wisdom of the *kūpuna* can be important and some basic concepts were understood decades before explored by Western scientists. Moreover, though this knowledge is site specific per conversation with *kanaka* from other locations they have indicated that their *kūpuna* have employed similar methods for drawing fish closer to shore in areas where there is little spatial complexity. From a scientific perspective this study has refined our understanding of how fish communities are structured at Kahalu´u Bay. The TEK method of creating rock piles to increase fish number/biomass is used today by contemporary scientists who increase rugosity in areas of low spatial complexity with the use of artificial reefs (Carr and Hixon 1997, Walsh 1985) in order to increase fish populations.

4.6.2.2 Fish Association *Kuhlia sandvicensus (Āholehole*) and *Mugil* spp. (*´Ama´Ama*) With Fresh to Brackish Water

TEK

Fishermen are cognizant of the physical and biological environment for which specific species of fish are found. They rely heavily on cues like substrate type (e.g. coral, sand, and rubble), moon phases, and tides to determine where and what fish are found at a particular location. This section captures the shared *mana´o* or TEK of some of the *kūpuna* of Kahalu´u about certain fish associations with fresh and brackish water. These associations were selected because *wai* (water) is an important concept of the Hawaiian culture. It is the root component for many disciplines including *kānāwai* (law). More significantly it means to be wealthy (*waiwai*). Historically the greater the amount of water the land could provide for drinking and growing food and trees, the wealthier it was.

When questioned about fresh and brackish water and if there are any fishes that are associated with it, the kūpuna independently acknowledged that certain fishes are often associated with these conditions. They went on to explain that these fish species include but are not limited to *āholehole* (*Kuhlia sanvicensis*) and *´ama´ama* (*Mugil cephalus*). One *kūpuna* explained that these fish (*āholehole and ´ama´ama)* have an affinity for fresh and brackish water when they are young (<15.2 cm (6 inches). Once they grow beyond this size they head out to where there is whitewash, areas characterized by heavy wave action.

The overall meaning from these *kūpuna* was that certain fishes, especially the smaller silvered bodied ones, are associated with areas of fresh and brackish water. They suggest that areas of low salinity are where these fishes are found.

Western Science

In the scientific literature there are examples of fish species that are highly correlated with the physical and biological environments they inhabit (Wilson et. al 2008, Kingsford 1993, Sale 1977). Whether based on water quality, benthic and/or abiotic characteristics, these factors are known to regulate their abundance and distribution. In some cases, certain abiotic and biotic criteria are a crucial requirement in their life history (Boehlert and Mundy 1988, Chesson and Huntly 1988). It is not surprising that the kūpuna of this area have come to understand and know which fishes are associated with fresh and brackish water.

Hypotheses Tested

Kulia sandvicensus: Hawaiian Flagtail *Āholehole*

Analysis of Variance (ANOVA)

H_o = The predictor variable, water type (Fresh water + brackish water) is not associated with the response variable or the presence of fish species (*Āholehole*).

H_1 = The predictor variable, water type (Fresh water + brackish water) is associated with the response variable or the presence of fish species

(*Āholehole*).

Contingency Table

H_o = Water type (Fresh water + Brackish Water and Salt Water) and fish species (*Āholehole*) are independent of each other, and the observed degree of association is no stronger than we would expect by chance or random sampling.

H_1 = Water type (Fresh water + Brackish Water and Salt Water) and fish species (*Āholehole*) are dependent on each other, and the observed degree of association is stronger than we would expect by chance or random sampling.

<u>Mugil spp.: Mullet *´Ama´ama*</u>

ANOVA

H_o = The predictor variable, water type (Fresh water + brackish water) is not associated with the response variable or the presence of fish species (*´Ama´ama*).

H_1 = The predictor variable, water type (Fresh water + brackish water) is associated with the response variable or the presence of fish species (*´Ama´ama*).

Contingency Table

H_o = Water type (Fresh water + Brackish Water and Salt Water) and fish species (*´Ama´ama*) are independent of each other, and the observed degree of association is no stronger than we would expect by chance or random sampling.

H_1 = Water type (Fresh water + Brackish Water and Salt Water) and fish species (*´Ama´ama*) are dependent on each other, and the observed degree of association is stronger than we would expect by chance or random sampling.

Methods

Salinity Measurements

A YSI 6920V2-2 S Multiparameter Water Quality Logger equipped with four probes was used to measure salinity at 202 stations. A 6560 conductivity probe with accuracy of ±0.5% of reading plus 0.001 mS/cm, with a range of 0 to 100 mS/cm was used to calculate salinity (ppt) based on algorithms from American Public Health Association (1989). All probes were calibrated according to protocol in the YSI 6-series multiparameter water quality sonde user manual. Two-hundred and one stations in and around the bay were surveyed between 10 March, 2011 and 25 July, 2011.

Āholehole and *´Ama´ama* Abundances

Fish surveys were conducted at 202 stations shown in Fig 4.2. The presence or absence of *Kuhlia sandvicensis (Āholehole) and Mugil spp.*

(´Ama´ama) were noted at each seven meter diameter survey station. The presence of each species was noted by "1" and their absence was denoted by "0". Surveys were conducted between 1 April 2010 and 5 June 2012.

Statistical Analysis

Two statistical approaches were used to test these hypotheses: Analysis of Variance (ANOVA) was performed in PRIMER5 and a chi-square test was performed in MINITAB14. Two tests were selected for validation to oppose or support the hypotheses being tested. For the ANOVA, the categorical variable water type was used with two categories: combined water types (freshwater and brackish waters) and saltwater. Both water types (fresh and brackish water) were combined to see if these fish species have an affinity for hyposaline water.

A chi-square test or contingency table was used for validation of the ANOVA. Combined water types (fresh and brackish water) and presence or absence of each fish species were the categorical variables used in the analysis.

Results

Āholehole and´Ama´ama

ANOVA:

A general linear regression model using the categorical variable water type (fresh+brackish water and saltwater) was statistically significant for *āholehole* ($p=0.012$, $\alpha=0.05$) and *´ama´ama* ($p<0.0005$, $\alpha=0.05$).

Chi-square Test:

Similar results from the chi-square test using the variables, presence and absence and the water type (fresh+brackish water and salt water) was statistically significant (p= 0.0118) for *āholehole* and for *´ama´ama* (p<0.0005, α=0.05).

The statistical results from the ANOVA and chi-square with p-values < 0.05 indicate the following:

Āholehole and´Ama´ama

ANOVA: The predictor variable, water type (fresh water + brackish water) is associated with the response variable (presence of fish species).

Chi-square: Water type (Fresh water + Brackish Water and Salt Water) and Fish species (*āholehole*) are dependent on each other, and the observed degree of association is stronger than we would expect by chance or random sampling.

Discussion

The statistical findings from the ANOVA and chi-square test supports the TEK report that these species, *āholehole* and *´ama´ama*, have an affinity for fresh and brackish water. The kūpuna's knowledge is congruent to findings which used Western science methodologies. The results show that TEK can provide insights concerning marine ecology. TEK is site specific but this knowledge is well known by local fishermen throughout Hawai´i. Fishermen learn at a young age that

fishes like *āholehole* and *´ama´ama* are usually found in areas of lower salinity. I was personally taught by my kūpuna that if I see the water shimmering or cloudy it indicates that a freshwater source is near. If that is the case, small fish such as *āholehole* and *´ama´ama* will be found in this area as long as the environment is healthy. From a scientific perspective, these findings can support ideas already published in the primary literature that speak of the relationship between fishes and freshwater sources (Benson and Fitzsimons 2002, Jordan and Tanaka 1927). Moreover, these results signify the biological importance of fresh and brackish water habitats as an integral part of these species life histories. Consequently, if populations are diminished, these areas can be protected to insure the sustainability of these vital fisheries which not only are biologically important but also hold cultural significance.

4.6.2.3 *Association of Parupeneus/Mulloidichthys (*Goatfish *spp)* with Sand

TEK

Fishermen have observed fishes and their behavior for centuries. Young and old alike hold knowledge that may be generations old. They depend on this knowledge to succeed at catching fishes. Their intimacy with the environment has allowed them to identify key features that will indicate the habitat of certain species as in the example of freshwater being indicative of the presence of *āholehole* and *´ama´ama*. This section will focus on *kūpuna* knowledge about the sand and its relationship with goatfish.

What did the *kūpuna* know about where goatfish could be found? The *kūpuna* explained that goatfish are found in areas where sand is present. Furthermore, they were adamant that if you did see them somewhere other than on the sand it was because they were moving from one sand patch to another. Once they swept over a sand patch for food they would swim to another location to feed. This observation can be tested using the data collected on goatfish to see if they were indeed found in sandy areas.

Western Science

Scientific literature has shown that certain fish species have a greater affinity for certain habitats based on factors such as benthic structure and/or abiotic characteristics (Nagelkerken et al. 2000, Ohman and Rajasuriya 1998, Luckhurst and Luckhurst 1978). These affinities exist for a variety of reasons which include source of food, shelter, and mating location (Friedlander and Parrish 1998a). Management actions for a given species are often focused on these areas labeled as “critical habitats”.

Hypotheses Tested

The hypothesis being tested asks if there is a relationship between sand and goatfish species (combined and individual species).

Combined Goatfish spp

H_o = Sand and Combined goatfish spp [*Mulloidichthys flavolineatus* (square-spot goatfish and *weke´ā*), *Mulloidichthys vanicolensis* (yellowfin goatfish and *weke´ula*), *Parupeneus bifasciatus* (doublebar goatfish and *munu*), *Parupeneus cyclostomus* (blue goatfish and *moano ukali ulua*), *Parupeneus multifasciatus* (manybar goatfish and *moano*), and *Parupeneus pleurostigma* (sidespot goatfish and *moano*)] are independent of each other, and the observed degree of association is no stronger than we would expect by chance or random sampling.

H_1 = Sand and combined goatfish spp [*Mulloidichthys flavolineatus* (square-spot goatfish and *weke´ā*), *Mulloidichthys vanicolensis* (yellowfin goatfish and *weke´ula*), *Parupeneus bifasciatus* (doublebar goatfish and *munu*), *Parupeneus cyclostomus* (blue goatfish and *moano ukali ulua*), *Parupeneus multifasciatus* (manybar goatfish and *moano*), and *Parupeneus pleurostigma* (sidespot goatfish and *moano*)] are not independent of each other, and the observed degree of association is stronger than we would expect by chance or random sampling.

Mulloidichthys flavolineatus (square-spot goatfish and *weke´ā*)

H_o = Sand and *Mulloidichthys flavolineatus* (square-spot goatfish and *weke´ā*) are independent of each other, and the observed degree of association is no stronger than we would expect by chance or random sampling.

H_1 = Sand and *Mulloidichthys flavolineatus* (square-spot goatfish and *weke´ā*) are not independent of each other, and the observed degree of association is stronger than we would expect by chance or random sampling.

<u>*Mulloidichthys vanicolensis* (yellowfin goatfish and *weke´ula*)</u>

H_o = Sand and *Mulloidichthys vanicolensis* (yellowfin goatfish and *weke´ula*) are independent of each other, and the observed degree of association is no stronger than we would expect by chance or random sampling.

H_1 = Sand and *Mulloidichthys vanicolensis* (yellowfin goatfish and *weke´ula* are not independent of each other, and the observed degree of association is stronger than we would expect by chance or random sampling.

<u>*Parupeneus bifasciatus* (doublebar goatfish and *munu*)</u>

H_o = Sand and *Parupeneus bifasciatus* (doublebar goatfish and *munu*) are independent of each other, and the observed degree of association is no stronger than we would expect by chance or random sampling.

H_1 = Sand and *Parupeneus bifasciatus* (doublebar goatfish and *munu*) are not independent of each other, and the observed degree of association is stronger than we would expect by chance or random sampling.

Parupeneus cyclostomus (blue goatfish and *moano ukali ulua*)

H_o = Sand and *Parupeneus cyclostomus* (aka blue goatfish and *moano ukali ulua*) are independent of each other, and the observed degree of association is no stronger than we would expect by chance or random sampling.

H_1 = Sand and *Parupeneus cyclostomus* (blue goatfish and *moano ukali ulua*) are not independent of each other, and the observed degree of association is stronger than we would expect by chance or random sampling.

Parupeneus multifasciatus (manybar goatfish and *moano*)

H_o = Sand and *Parupeneus multifasciatus* (manybar goatfish and *moano*) are independent of each other, and the observed degree of association is no stronger than we would expect by chance or random sampling.

H_1 = Sand and *Parupeneus multifasciatus* (manybar goatfish and *moano*) are not independent of each other, and the observed degree of association is stronger than we would expect by chance or random sampling.

Parupeneus pleurostigma (sidespot goatfish and *moano*)

H_o = Sand and *Parupeneus pleurostigma* (sidespot goatfish and *moano*) are independent of each other, and the observed degree of association is no stronger than we would expect by chance or random sampling.

H_1 = Sand and *Parupeneus pleurostigma* (sidespot goatfish and *moano*) are not independent of each other, and the observed degree of association is stronger than we would expect by chance or random sampling.

Methods

Benthic Habitat Characterization (BHC)

Benthic coverage at the 202 stations was assessed using methods developed by National Oceanic and Atmospheric Administration (NOAA) for ground truthing of benthic habitats (Analytical Laboratories 2001, Coyne et al. 2003) (Table 4.1). A Global Positioning System (GPS) point was taken at the central point of each surveyed circle (seven m radius). Visual estimates were taken for the following parameters: Presence or absence (P/A) of shelf, sand, boulder, and rubble; Percent macroalgae (MA), crustose coralline algae (CCA), turf algae (TA), total coral cover (TCC), and coral species; invertebrate species abundance (m^{-2}). Surveys were conducted between 1 April 2010 and 5 June 2010.

Table 4.2 List of benthic habitats and benthic data collected within each habitat

Benthic Data	Data Type
Location	Inside or Outside
Primary Substrate Composition	Carbonate or Basalt
Shelf	P/A
Sand	P/A
Boulder	P/A
Rubble	P/A
Macroalgae (MA)	Percent Cover
Crustose Coralline Algae (CCA)	Percent Cover
Turf Algae (TA)	Percent Cover
Total Coral Cover (TCC)	Percent Cover
Coral Species	Percent Cover
Invertebrate Species	No. per m^2

P/A = Presence or Absence

Goatfish Abundances

Fish surveys were conducted at 202 stations shown in Fig. 4.2. The presence or absence of goatfish species [*Mulloidichthys flavolineatus* (square-spot goatfish and *weke´ā*), *Mulloidichthys vanicolensis* (yellowfin goatfish and *weke´ula*), *Parupeneus bifasciatus* (doublebar goatfish and *munu*), *Parupeneus cyclostomus* (blue goatfish and *moano ukali ulua*), *Parupeneus multifasciatus* (manybar goatfish and *moano*), and *Parupeneus pleurostigma* (sidespot goatfish and *moano*)] were noted at each survey station. The presence of each species

was noted by “1” and their absence was noted by “0”. Surveys were conducted between 1 April 2010 and 5 June 2012.

Statistical Analysis

A chi-square test or contingency table in the statistical program MINITAB14 was used to see if any correlation exists between the presence of goatfish species and the presence or absence of sand. This test used the categorical variables presence/absence of sand and presence/absence of goatfish species.

Results

The chi-square test including all goatfish species was not statistically significant (p= 0.085). Individually, species also showed no statistical relationship between *Mulloidichthys flavolineatus* (p=0.973), *Parupeneus cyclostomus* (p=0.780), *Parupeneus multifasciatus* (p=0.456) and sand with the exception of *Mulloidichthys vanicolensis* (p=0.048). *P*-values were not generated for *Parupeneus bifasciatus* and *Parupeneus pleurostigma*. The statistical program indicated that no *p*-value will be given as two cells possessed expected counts less than one and would result in a chi-square approximation that would be invalid.

Discussion

A majority of the findings fail to reject the null hypothesis that relationships observed between the benthic characteristic, sand, and goatfish are independent of each other. *Mulloidichthys vanicolensis* (yellowfin goatfish and *weke´ula*) ($p=0.048$, $\alpha=0.05$) was the only species to agree with the TEK indicating that sand and this goatfish species are not independent of each other, and the observed degree of association is stronger than we would expect by chance or random sampling.

This example of TEK and science integration both opposes and supports TEK provided by the *kūpuna*. This can be explained by the following. It was already recognized by the *kūpuna* that these fishes were usually found in areas where sand is present. At Kahalu´u Bay sandy patches are uncommon these days. In order to get to these sandy areas the goatfish have to traverse frequently through areas that are absent of sand. Historically, greater amounts of sand were notably found in the Kahalu´u Bay area (Fujisaka pers. com). Testimony from the *kūpuna* indicates that the entire basalt flat exposed today was covered with sand. The *kūpuna* mentioned that when the man-made breakwall was built to protect the old pavilion, the sand was carried out of the bay area. In addition to the absence of sand, the fish count data at each station may reflect where these goatfish are found when they are moving but not necessarily their primary feeding grounds. It is important to note that the TEK shared by the *kūpuna* only indicated their knowledge about goatfish distribution based solely on feeding behavior. If similar studies are to be conducted in the future I would

suggest that the person(s) note the fish behavior (e.g. swimming, sleeping, and feeding).

Previous research by Holland et al. (1993) indicated a strong affinity between goatfish species and sand. Their findings included that the goatfish would hide in holes during the day and would traverse sandy areas and coral rubble habitats at night. These findings could explain why most of the goatfish species in this study were not found to be associated with sand substrates. Conversely, findings from this study also support the one species that was found to be highly associated with sandy environments.

In conclusion, this example does note that the TEK of this area may not be accurate today. This is not saying that the *kūpuna* were wrong or untruthful but merely indicating that this knowledge was accurate at one time but as the environment changed the *mana´o* (knowledge) may have indeed changed as well. This is supported by the fact that the *kūpuna* noted that tremendous amounts of sand disappeared from Kahalu´u Bay over the years. These same sentiments are also noted by Mac Poepoe, a *kūpuna* of Mo´omomi, who is quoted as saying “TEK is not static, rigid, or non-changing” (Poepoe et al. 2007). TEK is not always in concert with western science or modern knowledge but we may be able to learn from the TEK and use it to understand how the environmental baseline has shifted historically.

4.7 Summary/Conclusion

The three examples above provide insights into how to bridge the gap between TEK and Western science. There are large areas of agreement between the knowledge base developed by the two approaches, and each system can learn from the other. TEK can and has already provided significant insights into the field of marine ecology (Hamilton et al. 2012, Richmond et al. 2007, Menzies 2006, Drew 2005, Aswani and Hamilton 2004, Veitayaki 2004, Johannes and Yeeting 2001, Pierotti and Wildcat 2000, Zaan 1985, Johannes 1981).

The examples which have supported the *mana´*o of the *kūpuna* and have been verified by Western methodologies can contribute significantly to the Hawaiian culture. It can bring pride to the *lāhui* (Hawaiian nation) showing the significances of TEK from *kūpuna* and other cultural practitioners. It is noteworthy that the Hawaiian ancestors from the not so distant past understood the importance of this knowledge. This is evident in the Hawaiian language newspaper, *Ka Nupepa Kuokoa*, when the editor, D. Kanewanui, in 1902 wrote: "*O ka ike i loaa i na kūpuna o kakou ke nalowale loa aku nei a he mea maikai e paa kekahi o ia mau ike, a me kea no o ka lakou kii ana i na i´a o ka āina…",* which translates to, "the knowledge of our ancestors is disappearing completely and it is worthwhile to secure some of that information and the ways they caught fish of this land…" This quotation points out the importance of the written language given to the Hawaiians as a means of recording TEK along with other cultural and historical information so that it will be preserved. If TEK is to be preserved, we must follow the wisdom of Western science in producing and

maintaining an accessible written system of TEK information using contemporary scientific tools such as the internet and electronic access libraries.

The TEK shared in the sections above are generations old in the Hawaiian realm and are only now being recognized in the Western world. Furthermore, looking towards the future there is a need to incorporate TEK into the management of Hawai´i's natural resources. TEK needs to be embedded into management schemes. The examples of TEK that were not confirmed still provide insights concerning marine ecology. Perhaps these TEK were accurate at one time and changed for various reasons. For example at Kahalu´u Bay the sand disappeared when a sea wall was built, and this may have changed the observational behavior of goatfish. It is important that we learn from TEK to understand shifting baselines.

This chapter presents a method to bridge apparent gaps between TEK and science through the integration of both. Both systems have worked to understand basic concepts in marine ecology. In summary, there is a need for complete integration of both culture and Western science as they are necessary in making sound management decisions in the future. Both disciplines are like an eye glass lens. They add clarity to the picture of sustainable resource management. There should be a "co-production of knowledge" (Moller et al. 2009).

CHAPTER 5 SOCIAL SCIENCE: COMMUNITY INTERACTION AND ORAL HISTORIES COLLECTION

5.1 Introduction

The area of Kahalu´u is one of the historic land divisions or *ahupua´a* on the Kona or west side of Hawai´i Island. Akin to other *ahupua´*a, it includes an upland, coastal, and ocean component. Today this area is one in which cultural knowledge and historical sites have been passed on and restored. These efforts have afforded the community the opportunity to enhance their knowledge, awareness, and understanding (*´ike*) of the rich cultural history of this area as well as how it can influence future management decision making concerning their natural resources. For the purpose of this oral history project, I will focus on Kahalu´u Bay and its associated coastal and marine resources.

Kahalu´u Bay is presently owned by the County of Hawai´i. It was originally leased by the Estate of Bernice Pauahi Bishop to the County of Hawai´i and in 1953 officially became a county park. In September 1966, Richard Lyman, a former Bishop Estate trustee, released the property to the County of Hawai´i and they have remained the landowner ever since. In addition to the County, neighboring coastal land owners include Kamehameha Schools and other private home owners. Moreover, the larger public community which includes long and short-term residents, cultural practitioners, and tourists frequently engage in activities that affect the natural resources at the bay. Consequently, voices within the community are concerned about the sustainability of resources at

Kahalu´u Bay as well as the longevity and retention of oral histories from this area.

This chapter is comprised of the following: methodology for community interaction/ involvement; methodology of oral histories collection; biographical sketch of interviewees. This social science/oral histories project was conducted under the direction of Mr. Kaipo Perez III of the Zoology Department from the University of Hawai´i at Mānoa for the purposes of: 1) amassing information about the coral reef resources (past and present) at Kahalu´u Bay held by key individuals; 2) documenting the Traditional Ecological Knowledge (TEK) held by the interviewees; 3) using acquired TEK to formulate and test hypotheses concerning reef resources; 4) bridging the gap between science and culture by demonstrating the important connectivity between the two; 5) archiving this privately held knowledge for future reference.

5.2 Background

Kahalu´u Bay is the ocean component of a larger *ahupua´a* called Kahalu´u. It is located in central Kona along the west side of Hawai´i Island.

The *ahupua´a* of Kahalu´u was reportedly named after a high ranked chiefess, who was the wife of Keolonāhihi, and mother of Mākole´ā. Its boundaries stretch from Hualalai (~1,500 m elevation) and extend to the outer reef crest at Kahalu'u Bay. It is approximately 7,770 hectares (19,200 acres). The Kahalu´u *ahupua´a* is located within the Wai´aha watershed. The perennial stream in this watershed the Wai´aha River is partially fed by rainfall with minimum and maximum

precipitation within this watershed of 250 mm (9.8 inches) and 2000 mm (78.7 inches) respectively.

The land tenure of this area is as follows: Victoria Kamāmalu, granddaughter of Kamehameha I acquired the Kahalu´u, and the Keauhou I *ahupua´a*, on January 27, 1848. It was from Kamāmalu that Chiefess Bernice Pauahi Bishop inherited these lands. It later became part of the estate of Bernice Pauahi Bishop whose trust supports the Kamehameha Schools. The acquisition of this land by Kamāmalu by higher chiefs, the *hoa´āina* (native tenants) were allowed to make claims on *kuleana* (right or privilege) holdings. Many applied but only 53 claims were actually awarded. As reported by Kumu Pono Associated LLC, Kepā Maly (2004) notes these numbers may be incomplete. Following the Māhele ´Āina, in 1862, a Commission of Boundaries was established within the Kingdom to set the boundaries of all *ahupua´a*. The commission was established as rapid globalization occurred, calling for a fee-simple land base property system. Boundary descriptions were based upon information provided by native residents. The modern boundary exists between Paniau Point and Keahio‘olo Heiau. As noted in research conducted by Maly (2004), the rest of Kahalu´u can be divided into sections which include: the beach strip; *pāhoehoe* (smooth lava) and *a‘a* (rough lava) flow south of Kahalu´u; an overgrown older flow in the north and middle of Kahalu´u; coffee plantation and *ohi‘a* (Metrosideros polymorpha) growth in the mauka section.

Kahalu´u Bay is within the ocean component of the Kahalu´u *ahupua´a*. It is roughly two hectares (4.94 acres). It has always been an important site for the

community or the *´ohana nui* of this area. For generations and even to this day, many of the *´ohana* (families) who reside there have used the bay for various activities including skin diving, fishing, swimming, and family gatherings.

This bay is a popular snorkeling location for locals and tourists alike. It has been reported that there are approximately 400,000 visitors who visit the bay each year (The Kohala Center 2008). With a large number of resource users there is the potential that human interaction can adversely affect marine resources (Selkoe et al. 2009, Bruno 2007).

Marine flora and fauna found along West Hawai´i has and continues to be impacted by many resource users including those from the public and commercial sectors (Asoh 2004, Tissot et al. 2004). In the years prior to the late 1990s there was considerable growth in the number of tropical fishes being harvested by the aquarium trade along West Hawai´i. This drew concern from resource users and conflict developed between tropical fish collectors and recreational divers. It was for these reasons that in July of 1998, the legislative body of the State of Hawai´i signed into law ACT 306 (HRS Ch. 188F). As a result of this law, the West Hawai´i Regional Fishery Management Area (WHR-FMA) was created to include the coastline area from Upolu Point to Ka Lae (Fig. 1.3). Kahalu´u Bay is located within this Kailua-Keauhou Fish Replenishment Area (FRA) (Friedlander and Cesar 2004). Regulations for this area as set by the Division of Aquatic Resources are as follows: “There will be no commercial or non-commercial collection of fish for aquarium purposes; feeding of fish are prohibited.”

In recent years there has been a renewed effort to restore and revitalize cultural sites within the *ahupua´a.* Moreover as a result of direct and indirect human impacts, including overuse, the community has developed growing concerns about resource sustainability. This has also renewed the efforts of the community to understand Kahalu´u Bay's marine resources in the past and how this information can drive sound management decisions in the future. Many in the community believe this knowledge is based with the kūpuna.

5.3 Methodology

In December 2009, The Kohala Center[2] (TKC), including Dr. Mathew Hamabata and Ms. Cindi Punihaole, contacted all parties[3] involved in the EPSCoR (Experimental Program to Stimulate Competitive Research) Track II project[4] funded by the National Science Foundation (NSF). They wanted to arrange conference meetings in order to ensure that all granting parties were on the same page. In these initial calls TKC requested that all researchers involved, organize meetings with the Kahalu´u community in order to receive their approval for the project and to seek their comments concerning our proposed study. Once we, the marine contingent, understood their requests, we worked swiftly to list the objectives of this project and how it would benefit the community. It was through this process that a document (Appendix XIX) (which included acknowledgements, my autobiography, cultural/ community perspective benefit

[2] TKC is a non-profit organization that is embedded in the Kahalu´u community and served as their voice.
[3] Parties included: TKC, Center for Conservation and Research Training (CCRT) led by Dr. Kenneth Kaneshiro and Mr. Mike Kido, Kamehameha Schools Keauhou-Kahalu´u Education Group (KKEG).
[4] This project was designed for Kahalu´u to serve as a "model system" to demonstrate how improved capacity and infrastructure could lead to the mitigation of climate change impacts on water resources on watersheds. Mr. Kaipo Perez III and others from the Hawai´i Institute of Marine Biology (HIMB) were the

section, and a scientific perspective/benefit section) was developed in collaboration with the contributions of other key community groups: TKC and the Keauhou-Kahalu´u Education Group (KKEG) from the Kamehameha Schools. This document was crucial to our initial interactions with the Kahalu´u community as we sought to make our intentions and goals transparent before we began this project.

In early January 2010, we met with a variety of interest groups and community members over the course of a week. These groups included: Local schools [Kealakehe Middle and High School, West Hawai´i Explorations Academy (WHEA)], The Kohala Center (ReefTeach, Citizen's Science, and others), University of Hawai´i Sea Grant Extension, Keauhou-Kahalu´u Education Group (KKEG) of the Kamehameha Schools, Kamehameha Investment Corporation, National Parks Service, Divison of Aquatic Resources (DAR) Kona of the Department of Land and Natural Resources (DLNR), Department of Water Supply, Hawai´i County Parks and Recreation, Kahalu´u community members (long-term and short-term residents, kūpuna, and others). In these open meetings we presented our proposed research, distributed the information document and how we anticipated it would benefit the community. In addition we sought their comments and blessings. At one of these meetings we were told by Dr. Gregory Chun of the KKEG that "we should let questions and/or comments from the community drive our research rather than our research drive questions and/or comments from the community". Keeping these words of wisdom in mind

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marine component of this larger project for which they developed baseline information that can be used in the future to understand changes in the marine environment.

we ensured that any of the research we were conducting could contribute to the questions that arose from the community which included but are not limited to: how healthy is Kahalu´u Bay and how can the marine resources at the bay be monitored and sustained?

As the project matured we met quarterly with the community and shared our findings and continued to seek their comments and questions. We tried to incorporate their new comments and suggestions as we progressed. Moreover, we wanted to keep the community as involved in this project as possible. This was the community's project and we were just the vessel to make it happen. Again we let questions from the community drive our research. Eventually an online portal (http://portals.intelesense.net/tkc/) which included our research findings, biotic and abiotic mapping, and community question forum was created. This allowed the larger community to access information about the project so that it could be at their disposal. Furthermore, we continued annual visits to the local schools in the area. Coupled with information found on the portal and with our help, we worked with students to develop research projects. Beyond just inquires and concerns, the community wanted to understand how they could monitor the resources themselves. Based on recommendations from the TKC and Kahalu´u Community a community based monitoring program was developed. This program included monitoring coral health, temperature, fish and turtle abundance and distributions as well as monitoring human impacts. Recently the TKC has receiving funding for some aspects of the monitoring program.

Aside from our interactions with the larger community, we worked intimately with the kūpuna of the area. Their contributions were priceless. At the beginning of this project, we were introduced to a couple of the kūpuna in the area who are revered for their *´ike* about the marine resources at Kahalu´u Bay. TKC introduced us to kūpuna Mitchell Fujisaka and Dr. Ku´ulei Rodgers introduced kūpuna Chikao Kunitake. From the moment we were introduced to them, they were very welcoming and were delighted to have researchers study the bay where they were born and raised. After our initial introductions, we were asked by Aunty Cindi Punihaole of TKC to mālama these kūpuna as they are very valuable to the community. She understood the immense knowledge these kūpuna hold and how important it is for the community to understand and be cognizant of their knowledge. Knowing the value of these kūpuna we made sure that they were not peripheral to the research occurring at the bay. Before conducting research at the bay we sought permission and comments from them. In fact kūpuna Fujisaka said to me, "even if you know the answer is yes, you still need to ask for permission". Once permission was granted we started to conduct surveys at the bay.

In order to ensure the kūpuna's intimacy with the project I met with them frequently. Each time we visited, usually about every two months, we made sure to see the kūpuna to seek permission for our visitation to the bay to conduct our monitoring, share the knowledge we learned from our previous trip as well as make sure that we brought a *hoʻokupu* (ex. fish and *poi*) for them each time as they shared their knowledge with me. As with most local residents, I was always

taught by my kūpuna that when you visit someone's house you must bring something for them.

After a couple of visits the kūpuna expressed a desire to share their *´ike* about the bay with me. Thereafter in addition to our meetings about our research, I engaged in informal "talk story sessions" or *kama´ilio* with them. In the Hawaiian culture it is formal protocol for an intimate relationship to be developed before any "personal or privately held information" is shared. In these informal sessions, about every two months, information about one's life (i.e. where you are from, where you grew up) was shared. In addition, these meetings were pivotal in fulfilling an aspect of the Hawaiian culture: "*kulikuli kou waha, a ho'olohe kou pepeiao*" or "close your mouth, and listen with your ears". It was necessary to listen first as questions I had were often answered without me even posing them. It also indicated my ability to be patient and demonstrated my humility. Only after ample dialogue, approximately three months, did I feel that I could begin to ask questions of them. All stages up until this point were not recorded since personal and confidential information was shared.

Once the introductory period passed, approximately three years from our initial introduction, I asked these two kūpuna if they would consent to being interviewed and having their knowledge documented (both film and written). I chose to interview these two kūpuna as the community was interested in what the bay was like in the past and these kūpuna expressed the willingness to share this information. Only two kūpuna were interviewed because this entire project was time limited. To ensure that other kūpuna in the area were not offended at these

meetings we expressed our apologies if anyone felt left out it was not our intension. I did note that we hope that others will follow our interviews and build upon this documented knowledge.

Upon their agreement to participate in this oral history project, I submitted a Human Subjects Research Exempt Application to the University of Hawai´i's Committee on Human Studies (CHS). All documents required for this application were generated under the guidance, mentorship, and review of Dr. Warren Nishimoto who is the director of oral history at the University of Hawai´i. His help was invaluable. After a three month period, the CHS granted me the permission to conduct this project. I approached and sought permission from a cultural perspective and then gained approval according to Western protocol.

After approval from the CHS, I approached the kūpuna and scheduled a time and place for the interview. I wanted them to be comfortable so I asked which time and would best suit them. Kūpuna Kunitake selected to be interviewed at his home in Hōlualoa. Kūpuna Fujisaka wanted to be interviewed near Kahalu´u Bay, so we selected to interview him in a room in the Outrigger Keauhou Beach Resort. At the time that the interviews were scheduled both of them were given the questions they would be asked to prepare themselves. On the day of the interviews, they were consulted one last time about participating in this project. Both kūpuna were excited to share and have their *´ike* documented. Furthermore, to provide them with options they were informed they could discontinue the interview at any time. Once they understood how the process would take place, they were asked to sign a letter of consent which included a

description of the project and that stated any risks and benefits. Interviews were conducted on 13 April 2012 (Kupuna Fujisaka) and 14 April 2012 (Kupuna Kunitake).

All interviews were recorded using a Canon 2Ti SLR digital camera. Foundation questions, which built the credentials of the interviewees, were asked first. These included their occupation, families, and interactions with the bay. Subsequently, these individuals were asked a series of questions about the bay and coral reef resources eg. Description of Kahalu´u Bay (past to present), description of coral and fish populations through time, how marine resources were managed, description of freshwater sources, and the description of climate change impacts. At the conclusion they were asked if they had any questions for us. In addition, they were asked if the content documented can be used and distributed. At the end of the interviews both kūpuna were very appreciative for the opportunity to share their *´ike*. I reciprocated our appreciation and told them that we will maintain our intimate relationship.

Subsequently the footage was reviewed and the interviews were transcribed. Post-editing, the interviewees were asked to review the footage and transcripts if they desired and sign a Transcript/ Video Release form, which indicates their approval of content. Responses from the interview allowed for hypotheses concerning coral reef resources to be generated and were statistically tested according to western science protocols.

Currently I am in the process of providing copies of the interviews to the interviewees (for personal use and for family record), submitting these recorded

oral histories to the UH library for archival purposes, posting them on the UH/TKC portal website (http://portals.intelesense.net/tkc/), and including excerpts in my doctoral dissertation. In terms of my relationship with the kūpuna, I continue to call them periodically and keep them informed about the interviews as well as projects that are occurring at the bay. I anticipate we will share a lifelong relationship with each other. This also applies to the Kahalu´u community as they are as much a part of my life as I am a part of theirs.

5.4 Interviewees

While information about the marine resources at Kahalu´u Bay was pursued, only Mitchell M. Fujisaka and Ray "Chikao" Kunitake were interviewed as they possess intimate knowledge about this area. Other knowledgeable individuals exist but due to time constraints I was unable to interview all possible informants. Fujisaka acquired his extensive knowledge through his own fishing experiences, his family's strong ocean ties, his elder was a *po´olawai´a* (head fisher) of the area, and he assisted Kekahuna, a renowned archeologist, in mapping cultural sites within this *ahupua´a* in the early 1950's; and Kunitake through his own fishing experiences. These interviewees provided recollections of Kahalu´u Bay (past to present), it's associated marine resources, and observed environmental changes.

Brief descriptions of each interviewee is provided below. Full transcripts of each interview in raw form is located in the appendices (XX and XXI).

5.4.1 Biographical Summary: Mitchell M. Fujisaka

" Nobody fishes on Sundays. You go swimming on Sundays. Nobody fish. If you don't have fish your house, you just tell someone… you know, one of your ohana, you know, they'll be happy. Because you know at that time, you know they say trade, you know. I catch fish here and then I trade with you there. The word trade wasn't in their vocabulary. You know, it's I catch fish I give, I give you the fish. If you have anything you give it back to me. But I don't ask you to…its… But fish, multitude, lots of fish. You know they didn't over fish, so there's a multitude of fish. The other thing is the ahupua´a system is from the mountain to the sea. My grandmother told me this that you know I pass on to people that the ahupua´a was only for the kānaka, the humans. She told me the pulelehua, the fish, they don't know what is an ahupua´a so they go from ahupua´a to ahupua´a. See in that is the same way as the fish. They say the fish goes out so much. They don't go beyond that depth. They go this way (motions with hands across). So if you have a good table, like the papa of Kahalu´u. If you have a good table, the fish will come."

Mitchell Mikiala Fujisaka was born in the *ahupua´*a of Kahalu´u on October 8, 1936. He was raised by his kūpuna. His mother's side of the family are the Kahinus and were originally from Kekaha, Hawai´i. His father's side are the Koholomus which were from Kahalu´u.

Uncle Mitchell learned a great deal about fishing from both sides of his family. They were very knowledgeable about the bay and its associated resources. This was evident in the fact that one of his tūtū was considered to be the *po´olawai´a*

(head fisher) at one time. When fish was being caught his tūtū would determine how the fish was distributed.

As a young boy he was selected by tūtū Naluahine to assist Henry E.P. Kekahuna, a retired accountant turn cultural archeologist. His contributions allowed Kekahuna to map cultural sites within the Kahalu´u *ahupua´a*. These historical maps are still used today and were pivotal in rebuilding cultural sites along the coastline.

Until this day Uncle Mitchell frequents Kahalu´u Bay, noting the marine resources and the changes that have occurred over the years.

5.4.1.1 Summary of Interview: Mitchell M. Fujisaka

Uncle Mitchell was very knowledgeable about the Kahalu´u *ahupua´a*. He shared his *mana´o* (knowledge) about how the environment changed throughout his lifetime. He also spoke about the marine resources at the bay, how plentiful they were and how their abundances and distributions changes as the environment and community changed. Moreover, he talked about the different types of fishing techniques that were employed and what species of fish were caught and eaten. Furthermore Uncle Mitchell shared stories about being an assistant for Kekahuna, a renowned archeologist, for whom he helped mapping cultural sites within the *ahupua´a*. His stories and knowledge truly reflected the strong connectivity the Kahalu´u people shared with the land and sea.

5.4.2 Biographical Summary: Ray "Chikao" Kunitake

"…Kahalu'u and Keauhou Kahalu'u for us kids and adults there was lotta fishes, lots of fishes, lots of coral, lotta birds and lotta freshwater around that area where the hotel is you know. That's where it all, I remember it use to be so cold and I use to catch lotta 'aholehole… I use to bring it home but they were fingerlings you know and I use to raise um I had no food I use to throw it to the pond and they eat up the mosquito fishes you know… I don't know today but before the hotel came up there was lots of freshwater and whole, whole bay you could actually feel that water coming out and it was pretty good to drink too… it would come out, you could see it, seeping out, low tide not high tide because you take the salt you know, you could see it. When you took you took a little bit you know. The whole coast use to be that way. Kailua had a lots of water coming out of it, right in the bay till today you can see the spring coming out till today but Honokohau, lots of water there. Kona Village, Ka'upulehu lots a water. So I guess even Makalawena and Kukio those places had water…"

Ray "Chikao" Kunitake also known as "Chick" was born on his family's coffee farm in Holualoa on February 4, 1937. He has six brothers and six sisters. He is the eldest son. His father was born in Honoapu and his mother in Honaunau. As a child, Chick would walk from the Holualoa farm down to Kahalu´u Bay to fish and swim. He reminisced of the times he would be the bag boy for his father, who would catch a substantial amount of fish. Chick said he would let the bag down to let whatever fish could swim out so that he didn't have to carry it all

the way home. As a result of his long travels home, he notes that only certain fish could be taken as they would not spoil.

Chick was a jeweler as a young man and then returned to Holualoa to care for his aging parents. Once he returned he took over the family's coffee farm with some of his siblings.

Although Chick does not drive he still frequents Kahalu´u Bay and has noted changes that have occurred there. As a result of living 900' up in Holualoa, Chick has noted larger scale changes along West Hawai´i including the Kahalu´u Bay area. Uncle Chick provides a *makai* (ocean) and *mauka* (upland) perspective of Kahalu´u.

5.4.2.1 Summary of Interview: Ray "Chikao" Kunitake

Uncle Chick provided a *mauka* (upland) perspective of Kahalu´u Bay. Similar to Uncle Mitchell he shared stories of the *ahupua´a* and how it changed throughout his life time. Moreover, he shared his knowledge about the fish and how abundant they were. Furthermore, he also indicated what fish could be caught and brought up the mountain. He noted that certain types of fish would not survive the trek as their soft flesh would rot. The amount of freshwater sources, where they were located, and climate change impacts were among the most significant and interesting information shared. Uncle Chick's marine and terrestrial connection made him an ideal informant for knowledge pertaining to the Kahalu´u *ahupua´a*.

5.5 Summary/Conclusion

There have been instances in the past for which others were met with opposition upon their entry into the community. In these cases, community-science integration was not achieved. We on the other hand were welcomed with open arms from our first step. We attributed our success to the partnerships that were developed prior to our first interactions with the larger community. Moreover the community was very receptive to our method of approach. Our methodology included: seeking permission and ensuring community involvement. It was through this process that we were so successful. Although the project has concluded we still are integral in the community's effort to seek sustainability. We will be a part of this community for life.

Oral histories collection is a challenging but significantly important facet of understanding the natural environment. Interviews of the two *kūpuna*, Mitchell and Kunitake, provided a glimpse into the past as well as provided a historical baseline. They shared profound knowledge that was handed down to them, some of which is not published in any written text. Both drove home the notion that traditional knowledge is invaluable and the documentation of their knowledge is important for future generations. Their knowledge can provide many insights in marine ecology as it can help to explain phenomena that are observed. It was a pleasure to learn from such knowledgeable individuals. Our relationship is undying and continues to till today.

CHAPTER 6 SUMMARY

6.1 Introduction

The marine seascape and biota at Kahalu´u Bay are driven by a variety of abiotic and biotic factors, as indicated by the statistical findings. This chapter will focus on: reviewing the findings of this case study, synthesizing them together, and understanding how the bay compares to other locations within the Hawaiian archipelago.

6.2 Review of Findings

6.2.1 Abiotic-Biotic Interactions

6.2.1.1 Corals

Salinity and depth drive coral communities at the bay. These corals prefer areas where the salinity is close to ambient conditions. Conversely, areas near freshwater sources (i.e. springs, river mouths) are not favorable for corals as less saline areas impairs growth, development, and reproduction.

Depth plays a major role in the distribution and abundance of corals. Deeper sites, within the photic zone, reduced the impacts of irradiance, temperature, and coral trampling. High coral coverage was also observed inside and adjacent to the breakwall in extremely shallow water. In the absence of depth, strong ocean currents there mitigate temperature and irradiance effects as open ocean water is flushed constantly through this section. Trampling is also prevented in this area as it is difficult for most to swim there.

6.2.1.2 All Fish

Depth, salinity, temperature, and pH influenced the numerical abundance and biomass of all surveyed fish at the bay. Fish are influenced by depth (Pittman et al. 2009) as shelter and food availability is increased while human interaction is reduced. Fish are also regulated by salinity (Sponaugle and Pinkard 2004). Research by Boeuf and Payan (2001) showed that lowered salinity impair fish development and growth. Temperature also controls fish abundances (Green and Fisher 2004). Fish prefer ambient water temperatures as colder one disrupt or impair spawning intensity (Danilowicz 1995). Fish are also controlled by pH levels. Ambient pH levels are preferred because of its relationship to salinity, which as mentioned above can impair fish development and growth.

6.2.1.3 Trophic Level

<u>Herbivores</u>

Herbivore number and biomass are regulated by temperature, salinity, and pH. Colder temperatures can impair spawning intensities. Changes in pH are related to less saline conditions which disrupt growth and development. Statistically, depth influences herbivore biomass as shelter and food availability is increased while anthropogenic impacts are reduced.

<u>Invertebrate Feeders</u>

Depth, temperature, and salinity influence the biomass of invertebrates. Increased depth increases food and shelter availability while also reducing human interactions. Colder temperatures and lowered salinity levels impair

development, growth, and reproductive output. None of the measured abiotic factors significantly explained their numerical abundance.

Piscivores

Similar to invertebrate feeders, none of the measured abiotic factors statistically influenced the numerical abundance of piscivores. However, piscivore biomass is regulated by salinity and pH level which have been shown to impair or disrupt spawning intensities in some reef fish.

Zooplanktivores

Zooplanktivores abundances were only influenced by the pH. Acidic conditions often related to freshwater sources can impair reproductive output.

6.2.2 Benthic Composition Relationship with Fish Assemblages

6.2.2.1 All Fish

Location, sand, and coral significantly influenced the numerical abundance and biomass of all fish.

Outside locations yielded higher abundances and biomasses than those inside the breakwall. Outside stations were deeper and possessed greater coral cover. Consequently, they have greater spatial reliefs, and thus provide larger areas for securing shelters and food.

Rugosity is a strong factor that influences the formation of fish assemblages (Friedlander and Parrish 1998a). Fish biomass and numbers are reduced in the presence of sand as it lacks spatial complexity. Thus, shelter and

food availability are limited in these areas. Corals are highly rugose and thus enhance fish communities as it provides greater number of shelter and food for reef fish. Additionally predation is reduced as shelters are greater (Beukers and Jones 1997, Hixon 1991).

6.2.2.2 Trophic Level

Herbivores

Station location and coral presence significantly impacted the abundance and distribution of herbivores. Recall that outside locations are deeper and have greater coral cover. These sites have greater spatial complexities which can support larger numbers and biomasses of fish as shelter and food availability is increased. Furthermore, the presence of turf algae enhanced herbivore populations as it is serves as the primary food resources for them (Friedlander and Parrish 1998a).

Invertebrate Feeders

The presence of shelf, rubble and coral influenced the abundance and biomass of invertebrate feeders. In the presence of a shelf and rubble, which have low spatial complexities, the abundance of invertebrate feeders is greatly reduced as shelters and food are less prevent in these areas. However in presence of coral, which have high spatial complexities, invertebrate feeders were enhanced, meaning greater biomasses and numerical abundances.

Piscivores

The abundance, by number and weight, of piscivores is influenced by location and the primary substrate. Piscivores were more abundant outside and preferred carbonate substrates. Friedlander and Parrish (1998a) noted a positive relationship between depth and the abundance of Piscivores. Recall that depths on the outside of the bay are much deeper than those on the interior. Friedlander and Parrish (1998a) also noted that foraging occurred near the reef edge. Outside stations are shallow near the breakwall and sharply drop off represent the reef edge, which is primarily composed on corals which are carbonate in origin.

Zooplanktivores

Location was only variable that influenced their abundance and distribution. Zooplanktivore abundance is positively related to depth (Friedlander and Parrish 1998a). They are found in deeper locations as their food, transient zooplankton aggregate in the water column near areas of water motion (Hobson 1991).

6.2.3 TEK Bridged with Science

6.2.3.1 Rugosity Relationship with Fish Abundance and Biomass

Results of this investigation demonstrate how apparent contradictions between the Western science method and TEK can be resolved. The error in understanding what *mana´o* (wisdom) this kupuna shared was a consequence of misinterpretation. The TEK was that rock piles have higher rugosity and are a

better food source for the desirable fish species (herbivores) than corals. The TEK was lost in translation. He was explaining that the coral reef system at Kahalu´u Bay did not have great spatial complexity and as such was not suitable for housing and feeding fish. The Western science data and the statistical result from this study are congruent with the TEK shared by *kūpuna* Fujisaka, as rugosity increases the number and weigh of fish increases.

6.2.3.2 Fish and Freshwater Associations

The statistical findings from the ANOVA and chi-square test supports the TEK report that these species, *āholehole* and *´ama´ama*, have an affinity for fresh and brackish water. The kūpuna's knowledge is congruent to findings which used Western science methodologies.

6.2.3.3 Fish and Sand Associations

A majority of the findings fail to reject the null hypothesis that relationships observed between the benthic characteristic, sand, and goatfish are independent of each other. *Mulloidichthys vanicolensis* (yellowfin goatfish and *weke´ula*)($p=0.048$, $\alpha=0.05$) was the only species to agree with the TEK indicating that sand and this goatfish species are not independent of each other, and the observed degree of association is stronger than we would expect by chance or random sampling.

This example does note that the TEK of this area may not be accurate today. This is not saying that the kūpuna was wrong or untruthful but merely

indicating that this knowledge was accurate at one time but as the environment changed the *mana´o* (knowledge) may have indeed changed as well. This is supported by the fact that the kūpuna noted that tremendous amounts of sand disappeared from Kahalu´u Bay over the years. In summary, TEK is not always in concert with western science or modern knowledge but we may be able to learn from the TEK and use it to understand how the environmental baseline has shifted historically.

6.3 Synthesizing Case Study Findings

6.3.1 Biological

The findings from this study indicated that biological organisms at Kahalu´u Bay are bounded and regulated by their minimal physiological requirements and the availability of food and shelter.

6.3.1.1 Corals

Corals are sensitive organisms that thrive only under specific conditions. They cannot survive in low saline areas as it retards growth and may alter reproductive output. There is a preference for coral growth to occur in deeper locations, within the photic zone, as they are not exposed to high irradiance levels and temperatures, which can cause cellular damage and impair growth and reproduction. Anthropogenic impacts are another important influencing factor.

Deeper depths mitigate these impacts as incidences of coral-human contact (i.e. trampling) are reduced.

Coral communities are concentrated in two areas: along the breakwall in shallow water and outside of the breakwall. Corals adjacent to the break wall can survive in shallow conditions as strong currents mitigate irradiance and temperature impacts while also flushing these areas regularly with open ocean sea water.

6.3.1.2 Fish Communities

Minimal physiological requirement and the availability of food and shelter are significant drivers which controls fish assemblages. A majority of fish were observed on the outside of the breakwall. Outside stations are located in the open ocean and are: greater in depth, exhibit ambient water quality (salinity, temperature, dissolved oxygen, and pH), possess high coral cover, and have great spatial complexity. These characteristics generate greater areas for shelter, predator evasion, and increases food availability (ex. turf algae for herbivores, and zooplankton for Zooplanktivores).

6.3.2 Bridging TEK and Science

Indigenous cultures and science often operate autonomously of each other as fundamental differences exist between the two. From an indigent's perspective, scientist and their associated works is not trusted or respected. This stems from long histories of being colonized, stripped of their culture, and the theft of their intellectual rights without being fairly compensated. From a scientific

perspective, Traditional Environmental Knowledge (TEK) of indigenous people is often disregarded as they people who hold this knowledge have not been Western trained and is downplayed as being stories, myths, and legends. This dissertation research has allowed for fundamental differences between the two disciplines to be bridged. A majority of TEK is based on long-term observations and their explanations are often misconstrued or misinterpreted. Through my understanding of the Hawaiian culture and marine background, I was able to test and confirm shared TEK. A majority of the TEK was confirmed using Western methodologies and proved its importance on many levels for both the Hawaiian and scientific community. Culturally this project brought pride to the Hawaiian community as it was demonstrated how knowledgeable the elders were about their natural resources, environmental conditions, and employed management schemes. Scientifically this project provided baseline data about the area, insights into future management and demonstrated the importance for TEK to be incorporated into scientific practices.

6.4 Comparison of Marine Resources at Kahalu´u Bay to Other Locations

6.4.1 Comparing Sites Along West Hawai´i

Compared to other Coral Reef Assessment and Monitoring Program (CRAMP) sites with similar depths along West Hawai´i, Kahalu´u Bay possessed the highest cover of coral with 35 % (Table. 5.1). The next highest site was Kawaihae (3m) which yielded a 30% total coral cover. All other sites had coral

coverages less than 10%. High coral cover at the bay can be explained by strong ocean currents that allows for short water residence time as well as the prevention of coral-human interaction.

Figure 6.1. Summary of surveyed sites along West Hawaiʻi and Hanauma Bay.

Island	Site	Depth (m)	Total Coral Cover (%)
Hawaiʻi	Kaʻapuna	4	4
Hawaiʻi	Kawaihae	3	30
Hawaiʻi	Laʻaloa	3	10
Hawaiʻi	Nenue	5	5
Hawaiʻi	Kahaluʻu Bay	4.05 (Outside Stations)	38
Oʻahu	Hanauma Bay	3	25

6.4.2 Comparing Kahalu´u Bay with Hanauma Bay

Kahalu´u Bay is the second most visited bay within the Hawaiian Archipelago. It is only behind Hanauma Bay. Investigating the two sites is important as it can indicate how coral and fish resource at Kahalu´u Bay rank in comparison. Like sites along West Hawai´i, coral coverage at Kahalu´u Bay was greater (35 %) than comparable sites at Hanauma Bay (25 %). The difference between the two sites was more than 10%.

6.5 Conclusion

Kahalu´u Bay is a unique area in the Hawaiian archipelago. It has the highest coral coverage along West Hawai´i and does have a substantial abundance of fish.

This dissertation research has contributed new and has revived traditional knowledge. It is hoped that the findings of this case study will serve as a baseline for future monitoring and research, while allowing the community to use this information in their efforts to sustain marine resources in a change world. Additionally, it is hope that this research has shed new light on the importance of Traditional Ecological Knowledge (TEK). It is envisioned that TEK will be factored into scientific approaches not only the surface but also embedded into future management and sound decision making.

Appendix I. All Fish Spp. by Number				
Species	**Common Name**	**Hawaiian Name**	**Total Number**	**% of Total Number**
Acanthurus triostegus	Convict Tang	Manini	1577	16.16
Acanthurus nigrofuscus	Brown Surgeonfish	Mā´i´i´i	1252	12.83
Zebrasoma flavescens	Yellow Tang	Lau´īpala	1159	11.88
Thalassoma duperrey	Saddle Wrasse	Hīnālea	931	9.54
Abudefduf abdominalis	Sargent Major	Mamo	638	6.54
Chromis vanderbilti	Blackfin Chromis	N/A	443	4.54
Melichthys niger	Black Durgon	Humhumu ´ele´ele	328	3.36
Acanthurus leucopareius	Whitebar Surgeonfish	Maīkoko	265	2.72
Gomphosus varius	Bird Wrasse	Hīnālea ´i´iwi, ´Akilolo	254	2.60
Stethojulis balteata	Belted Wrasse	‘Omaka	209	2.14
Chaetodon lunula	Racoon Butterflyfish	Kīkākapu	206	2.11
Naso lituratus	Orangespine Unicornfish	Umauma Lei	197	2.02
Scarus	Scarus sp.	Uhu	197	2.02
Mulloidichthys vanicolensis	Yellowfin Goatfish	Weke ´ula	185	1.90
Mulloidichthys flavolineatus	Yellowstripe Goatfish	Weke	169	1.73
Plectroglyphidodon imparipennis	Brighteye Damselfish	N/A	150	1.54
Acanthurus olivaceus	Orangeband Surgeonfish	Na´ena´e	146	1.50
Stegastes fasciolatus	Pacific Gregory	N/A	90	0.92
Kuhlia sandvicensis	Hawaiian Flagtail	Āholehole	84	0.86
Rhinecanthus rectangulus	Reef Triggerfish	Humuhumunukunukuāpua´a	69	0.71
Zanclus cornutus	Moorish idol	Kihikihi	68	0.70
Mugil cephalus	Striped Mullet	´Ama´ama,´Anae	60	0.61
Abudefduf vaigiensis	Indo-Pacific Sargent	Mamo	58	0.59
Acanthurus blochii	Ringtail Surgeonfish	Pualu	54	0.55
Chlorurus sordidus	Bullethead Parrotfish	Uhu	53	0.54
Chaetodon ornatissimus	Ornate Butterflyfish	Kīkākapu	53	0.54
Coris gaimard	Yellowtail Coris	Hīnālea ´akilolo	45	0.46
Thalassoma purpureum	Surge Wrasse	Hou	43	0.44

Appendix I. All Fish Spp. by Number (Cont.)				
Species	**Common Name**	**Hawaiian Name**	**Total Number**	**% of Total Number**
Scarus rubroviolaceus	Redlip Parrotfish	Pālukaluka	41	0.42
Canthigaster jactator	HI Whitespotted	N/A	40	0.41
Scarus dubius	Regal Parrotfish	Lauia	39	0.40
Abudefduf sordidus	Blackspot Sargent	Kūpīpī	38	0.39
Scarus psittacus	Palenose Parrotfish	Uhu	35	0.36
Zebrasoma veliferum	Sailfin tang	Māne´one´o	33	0.34
Monotaxis grandoculis	Bigeye Emperor	Mū	29	0.30
Ostracion meleagris	Spotted Boxfish	Moa	29	0.30
Parupeneus multifasciatus	Manybar Goatfish	Moano	29	0.30
Ctenochaetus strigosus	Goldring Surgeonfish	Kole	27	0.28
Chlorurus perspicillatus	Spectacled Parrotfish	Uhu uliuli	26	0.27
Chaetodon auriga	Threadfin Butterflyfish	Kīkākapu	24	0.25
Kyphosus vaigiensis	Lowfin Chub	Nenue	22	0.23
Cephalopholis argus	Blue-spotted Grouper	Roi (Tahitian)	21	0.22
Naso unicornis	Bluespine Unicornfish	Kala	20	0.20
Gobiidae species	Goby	´O´opu	20	0.20
Forcipiger longirostris	Longnose Butterflyfish	Lauwiliwilinukunuku´oi´oi	17	0.17
Paracirrhites arcatus	Arc-eye Hawkfish	Piliko´a	17	0.17
Ctenochaetus hawaiiensis	Black Surgeonfish	N/A	16	0.16
Chaetodon quadrimaculatus	Fourspot Butterflyfish	Lauhau	13	0.13
Plectroglyphidodon johnstonianus	Blue-eye Damselfish	N/A	13	0.13
Lutjanus fulvus	Blacktail Snapper	To´au (Tahitian)	13	0.13
Lutjanus kasmira	Bluestripe Snapper	Ta´ape (Tahitian)	13	0.13
Canthigaster amboinensis	Ambon Toby	N/A	12	0.12
Microcanthus strigatus	Stripey	N/A	11	0.11
Thalassoma trilobatum	Christmas Wrasse	´Awela	10	0.10
Hemiramphus depauperatus	Polynesian halfbeak	Iheihe	9	0.09
Melichthys vidua	Pinktail Durgon	Humuhumu hi´u kole	9	0.09

Appendix I. All Fish Spp. by Number (Cont.)				
Species	**Common Name**	**Hawaiian Name**	**Total Number**	**% of Total Number**
Forcipiger flavissimus	Forcepsfish	Lauwiliwilinukunuku´oi´oi	9	0.09
Parupeneus cyclostomus	Blue Goatfish	Moano kea	9	0.09
Calotomus carolinus	Stareye Parrotfish	Pōnuhunuhu	8	0.08
Fistularia commersonii	Cornetfish	Nūnū	8	0.08
Dascyllus albisella	Hawaiian Dascyllus	´Ālo´ilo´i	8	0.08
Acanthurus achilles	Achilles Tang	Pāku´iku´i	7	0.07
Sufflamen bursa	Lei Triggerfish	Humuhumu lei	7	0.07
Caranx ignobilis	Giant White Trevally	Ulua aukea	7	0.07
Acanthurus guttatus	Whitespotted Surgeonfish	´Api	6	0.06
Novaculichthys taeniourus	Rockmover	N/A	6	0.06
Aulostomus chinensis	Trumpet	Nūnū	6	0.06
Chaetodon multicinctus	Multiband Butterflyfish	Kīkākapu	5	0.05
Arothron meleagris	Spotted Puffer	´O´opu hue, Kēkē	5	0.05
Chaetodon ephippium	Saddleback Butterflyfish	Kīkākapu	5	0.05
Parupeneus bifasciatus	Doublebar Goatfish	Munu	5	0.05
Acanthurus dussumieri	Eye-stripe Surgeonfish	Palani	4	0.04
Blenniidae	Blenny sp.	N/A	4	0.04
Paracirrhites forsteri	Blackside Hawkfish	Hilu piliko´a	4	0.04
Cantherhines sandwichiensis	Squaretail Filefish	´Ō´ili lepa	3	0.03
Thalassoma ballieui	Blacktail Wrasse	Hīnālea luahine	3	0.03
Cantherhines dumerilii	Barred Filefish	´Ō´ili	3	0.03
Diodon hystrix	Porcupine	Kōkala	3	0.03
Labroides phthirophagus	HawaiianI Cleaner Wrasse	N/A	3	0.03
Cirripectes vanderbilti	Scarface Blenny	Pāo´o	2	0.02
Kyphosus bigibbus	Brown Chub	Nenue	2	0.02
Oxycheilinus unifasciatus	Ringtail Wrasse	Po´ou	2	0.02
Synodus variegatus	Variegated Lizardfish	´Ulae	2	0.02
Chromis hanui	Chocolate-dip Chromis	N/A	2	0.02

Appendix I. All Fish Spp. by Number (Cont.)				
Species	**Common Name**	**Hawaiian Name**	**Total Number**	**% of Total Number**
Gunnellichthys curiosus	Curious Wormfish	N/A	2	0.02
Entomacrodus marmoratus	Marbled Blenny	Pāo´o	1	0.01
Anampses cuvier	Pearl Wrasse	´Opule	1	0.01
Cirrhitus pinnulatus	Stocky Hawkfish	Po´opa´a	1	0.01
Diodon holocanthus	Spiny Puffer	Kōkala, ´O´opū ōkala	1	0.01
Echidna nebulosa	Snowflake Moray	Puhi kāpā	1	0.01
Gymnothorax eurostus	Stout Moray	Puhi	1	0.01
Parupeneus pleurostigma	Sidespot Goatfish	Moano	1	0.01
Plagiotremus goslinei	Scale-eating Blenny	N/A	1	0.01

Appendix II. All Fish Spp. by Biomass

Species	Common Name	Hawaiian Name	Total Biomass	% of Total Biomass
Acanthurus triostegus	Convict Tang	Manini	83333.79	17.19
Acanthurus nigrofuscus	Brown Surgeonfish	Mā´i´i´i	48536.95	10.01
Zebrasoma flavescens	Yellow Tang	Lau´īpala	44746.29	9.23
Melichthys niger	Black Durgon	Humhumu ´ele´ele	43312.94	8.93
Abudefduf abdominalis	Sargent Major	Mamo	30733.65	6.34
Acanthurus leucopareius	Whitebar Surgeonfish	Maīkoko	28827.25	5.95
Naso lituratus	Orangespine Unicornfish	Umauma Lei	27786.19	5.73
Scarus	Scarus sp.	Uhu	15964.12	3.29
Acanthurus olivaceus	Orangeband Surgeonfish	Na´ena´e	10407.54	2.15
Thalassoma duperrey	Saddle Wrasse	Hīnālea	9940.75	2.05
Gomphosus varius	Bird Wrasse	Hīnālea ´i´iwi, ´Akilolo	9365.42	1.93
Stegastes fasciolatus	Pacific Gregory	N/A	8707.2	1.8
Stethojulis balteata	Belted Wrasse	‘Omaka	8671.08	1.79
Chaetodon lunula	Racoon Butterflyfish	Kīkākapu	8303.57	1.71
Mulloidichthys vanicolensis	Yellowfin Goatfish	Weke ´ula	8160.53	1.68
Mugil cephalus	Striped Mullet	´Ama´ama,´Anae	8101.27	1.67
Mulloidichthys flavolineatus	Yellowstripe Goatfish	Weke	6852.97	1.41
Acanthurus blochii	Ringtail Surgeonfish	Pualu	6544.17	1.35
Plectroglyphidodon imparipennis	Brighteye Damselfish	N/A	6425.08	1.33
Chlorurus sordidus	Bullethead Parrotfish	Uhu	4802.6	0.99
Rhinecanthus rectangulus	Reef Triggerfish	Humuhumunukunukuāpua´a	4210.05	0.87
Chromis vanderbilti	Blackfin Chromis	N/A	4201.67	0.87

Appendix II. All Fish Spp. by Biomass (Cont.)				
Species	**Common Name**	**Hawaiian Name**	**Total Biomass**	**% of Total Biomass**
Scarus rubroviolaceus	Redlip Parrotfish	Pālukaluka	4070.18	0.84
Cephalopholis argus	Blue-spotted Grouper	Roi (Tahitian)	3693.76	0.76
Canthigaster jactator	HI Whitespotted	N/A	3097.76	0.64
Scarus dubius	Regal Parrotfish	Lauia	2567.42	0.53
Abudefduf sordidus	Blackspot Sargent	Kūpīpī	2481.67	0.51
Zanclus cornutus	Moorish idol	Kihikihi	2474.93	0.51
Chaetodon ornatissimus	Ornate Butterflyfish	Kīkākapu	2330.05	0.48
Scarus psittacus	Palenose Parrotfish	Uhu	1984.91	0.41
Parupeneus cyclostomus	Blue Goatfish	Moano kea	1867.66	0.39
Coris gaimard	Yellowtail Coris	Hīnālea ´akilolo	1728.25	0.36
Thalassoma purpureum	Surge Wrasse	Hou	1643.54	0.34
Monotaxis grandoculis	Bigeye Emperor	Mū	1631.25	0.34
Ostracion meleagris	Spotted Boxfish	Moa	1447.63	0.3
Zebrasoma veliferum	Sailfin tang	Māne´one´o	1429.11	0.29
Ctenochaetus strigosus	Goldring Surgeonfish	Kole	1410.43	0.29
Chlorurus perspicillatus	Spectacled Parrotfish	Uhu uliuli	1355.86	0.28
Parupeneus multifasciatus	Manybar Goatfish	Moano	1269.67	0.26
Kyphosus vaigiensis	Lowfin Chub	Nenue	1046.63	0.22
Naso unicornis	Bluespine Unicornfish	Kala	1036.87	0.21
Chaetodon auriga	Threadfin Butterflyfish	Kīkākapu	1033.97	0.21
Fistularia commersonii	Cornetfish	Nūnū	1024.97	0.21
Gobiidae species	Goby	´O´opu	1021.17	0.21

Appendix II. All Fish Spp. by Biomass (Cont.)				
Species	**Common Name**	**Hawaiian Name**	**Total Biomass**	**% of Total Biomass**
Ctenochaetus hawaiiensis	Black Surgeonfish	N/A	1010.38	0.21
Canthigaster amboinensis	Ambon Toby	N/A	921.03	0.19
Forcipiger longirostris	Longnose Butterflyfish	Lauwiliwilinukunuku´oi´oi	830.41	0.17
Caranx ignobilis	Giant White Trevally	Ulua aukea	788.03	0.16
Paracirrhites arcatus	Arc-eye Hawkfish	Piliko´a	768.62	0.16
Hemiramphus depauperatus	Polynesian halfbeak	Iheihe	744.56	0.15
Chaetodon quadrimaculatus	Fourspot Butterflyfish	Lauhau	716.18	0.15
Melichthys vidua	Pinktail Durgon	Humuhumu hi´u kole	660.33	0.14
Calotomus carolinus	Stareye Parrotfish	Pōnuhunuhu	614.78	0.13
Lutjanus fulvus	Blacktail Snapper	To´au (Tahitian)	548.3	0.11
Lutjanus kasmira	Bluestripe Snapper	Ta´ape (Tahitian)	536.69	0.11
Plectroglyphidodon johnstonianus	Blue-eye Damselfish	N/A	525.32	0.11
Aulostomus chinensis	Trumpet	Nūnū	520.89	0.11
Microcanthus strigatus	Stripey	N/A	520.28	0.11
Thalassoma trilobatum	Christmas Wrasse	´Awela	499.81	0.1
Forcipiger flavissimus	Forcepsfish	Lauwiliwilinukunuku´oi´oi	477.18	0.1
Sufflamen bursa	Lei Triggerfish	Humuhumu lei	422.92	0.09
Novaculichthys taeniourus	Rockmover	N/A	419.56	0.09
Acanthurus achilles	Achilles Tang	Pāku´iku´i	376.16	0.08
Arothron meleagris	Spotted Puffer	´O´opu hue, Kēkē	365.75	0.08
Kuhlia sandvicensis	Hawaiian Flagtail	Āholehole	287.65	0.06
Acanthurus guttatus	Whitespotted Surgeonfish	´Api	268.79	0.06

Appendix II. All Fish Spp. by Biomass (Cont.)				
Species	**Common Name**	**Hawaiian Name**	**Total Biomass**	**% of Total Biomass**
Chaetodon ephippium	Saddleback Butterflyfish	Kīkākapu	253.47	0.05
Acanthurus dussumieri	Eye-stripe Surgeonfish	Palani	241.17	0.05
Blenniidae	Blenny sp.	N/A	225.05	0.05
Cantherhines sandwichiensis	Squaretail Filefish	´Ō´ili lepa	220.1	0.05
Chaetodon multicinctus	Multiband Butterflyfish	Kīkākapu	167.86	0.03
Parupeneus bifasciatus	Doublebar Goatfish	Munu	143.36	0.03
Cantherhines dumerilii	Barred Filefish	´Ō´ili	131.69	0.03
Paracirrhites forsteri	Blackside Hawkfish	Hilu piliko´a	120.96	0.02
Diodon hystrix	Porcupine	Kōkala	113.39	0.02
Labroides phthirophagus	HawaiianI Cleaner Wrasse	N/A	109.96	0.02
Abudefduf vaigiensis	Indo-Pacific Sargent	Mamo	108.37	0.02
Thalassoma ballieui	Blacktail Wrasse	Hīnālea luahine	104.13	0.02
Anampses cuvier	Pearl Wrasse	´Opule	94.93	0.02
Dascyllus albisella	Hawaiian Dascyllus	´Ālo´ilo´i	91.89	0.02
Cirrhitus pinnulatus	Stocky Hawkfish	Po´opa´a	89.98	0.02
Diodon holocanthus	Spiny Puffer	Kōkala, ´O´opū ōkala	72.42	0.01
Echidna nebulosa	Snowflake Moray	Puhi kāpā	50.83	0.01
Chromis hanui	Chocolate-dip Chromis	N/A	36.76	0.01
Cirripectes vanderbilti	Scarface Blenny	Pāo´o	16.64	0
Oxycheilinus unifasciatus	Ringtail Wrasse	Po´ou	15.6	0
Kyphosus bigibbus	Brown Chub	Nenue	10.34	0
Synodus variegatus	Variegated Lizardfish	´Ulae	4.63	0

Appendix II. All Fish Spp. by Biomass (Cont.)				
Species	**Common Name**	**Hawaiian Name**	**Total Biomass**	**% of Total Biomass**
Gymnothorax eurostus	Stout Moray	Puhi	2.43	0
Parupeneus pleurostigma	Sidespot Goatfish	Moano	2.35	0
Entomacrodus marmoratus	Marbled Blenny	Pāo´o	1.62	0
Gunnellichthys curiosus	Curious Wormfish	N/A	0.61	0
Plagiotremus goslinei	Scale-eating Blenny	N/A	0.42	0

Appendix III. Herbivore Spp. by Number				
Species	**Common Name**	**Hawaiian Name**	**Total Number**	**% of Total H Number**
Acanthurus triostegus	Convict Tang	Manini	1577	27.27
Acanthurus nigrofuscus	Brown Surgeonfish	Mā´i´i´i	1252	21.65
Zebrasoma flavescens	Yellow Tang	Lau´īpala	1159	20.04
Melichthys niger	Black Durgon	Humhumu ´ele´ele	328	5.67
Acanthurus leucopareius	Whitebar Surgeonfish	Maīkoko	265	4.58
Naso lituratus	Orangespine Unicornfish	Umauma Lei	197	3.41
Scarus	Scarus sp.	Uhu	197	3.41
Acanthurus olivaceus	Orangeband Surgeonfish	Na´ena´e	146	2.53
Stegastes fasciolatus	Pacific Gregory	N/A	90	1.56
Mugil cephalus	Striped Mullet	´Ama´ama,´Anae	60	1.04
Acanthurus blochii	Ringtail Surgeonfish	Pualu	54	0.93
Chlorurus sordidus	Bullethead Parrotfish	Uhu	53	0.92
Scarus rubroviolaceus	Redlip Parrotfish	Pālukaluka	41	0.71
Canthigaster jactator	HI Whitespotted	N/A	40	0.69
Scarus dubius	Regal Parrotfish	Lauia	39	0.67
Abudefduf sordidus	Blackspot Sargent	Kūpīpī	38	0.66
Scarus psittacus	Palenose Parrotfish	Uhu	35	0.61
Zebrasoma veliferum	Sailfin tang	Māne´one´o	33	0.57
Ctenochaetus strigosus	Goldring Surgeonfish	Kole	27	0.47
Chlorurus perspicillatus	Spectacled Parrotfish	Uhu uliuli	26	0.45
Kyphosus vaigiensis	Lowfin Chub	Nenue	22	0.38
Naso unicornis	Bluespine Unicornfish	Kala	20	0.35
Ctenochaetus hawaiiensis	Black Surgeonfish	N/A	16	0.28
Canthigaster amboinensis	Ambon Toby	N/A	12	0.21
Hemiramphus depauperatus	Polynesian halfbeak	Iheihe	9	0.16
Melichthys vidua	Pinktail Durgon	Humuhumu hi´u kole	9	0.16
Calotomus carolinus	Stareye Parrotfish	Pōnuhunuhu	8	0.14
Acanthurus achilles	Achilles Tang	Pāku´iku´i	7	0.12
Acanthurus guttatus	Whitespotted Surgeonfish	´Api	6	0.10

Appendix III. Herbivore Spp. by Number (Cont.)				
Species	**Common Name**	**Hawaiian Name**	**Total Number**	**% of Total H Number**
Acanthurus dussumieri	Eye-stripe Surgeonfish	Palani	4	0.07
Blenniidae	Blenny sp.	N/A	4	0.07
Cantherhines sandwichiensis	Squaretail Filefish	´Ō´ili lepa	3	0.05
Cirripectes vanderbilti	Scarface Blenny	Pāo´o	2	0.03
Kyphosus bigibbus	Brown Chub	Nenue	2	0.03
Entomacrodus marmoratus	Marbled Blenny	Pāo´o	1	0.02

Appendix IV. Herbivore Spp. by Biomass				
Species	**Common Name**	**Hawaiian Name**	**Total Biomass**	**% of Total H Biomass**
Acanthurus triostegus	Convict Tang	Manini	83333.79	23.35
Acanthurus nigrofuscus	Brown Surgeonfish	Mā´i´i´i	48536.95	13.60
Zebrasoma flavescens	Yellow Tang	Lau´īpala	44746.29	12.54
Melichthys niger	Black Durgon	Humhumu ´ele´ele	43312.94	12.14
Acanthurus leucopareius	Whitebar Surgeonfish	Maīkoko	28827.25	8.08
Naso lituratus	Orangespine Unicornfish	Umauma Lei	27786.19	7.79
Scarus	Scarus sp.	Uhu	15964.12	4.47
Acanthurus olivaceus	Orangeband Surgeonfish	Na´ena´e	10407.54	2.92
Stegastes fasciolatus	Pacific Gregory	N/A	8707.20	2.44
Mugil cephalus	Striped Mullet	´Ama´ama,´Anae	8101.27	2.27
Acanthurus blochii	Ringtail Surgeonfish	Pualu	6544.17	1.83
Chlorurus sordidus	Bullethead Parrotfish	Uhu	4802.60	1.35
Scarus rubroviolaceus	Redlip Parrotfish	Pālukaluka	4070.18	1.14
Canthigaster jactator	HI Whitespotted	N/A	3097.76	0.87
Scarus dubius	Regal Parrotfish	Lauia	2567.42	0.72
Abudefduf sordidus	Blackspot Sargent	Kūpīpī	2481.67	0.70
Scarus psittacus	Palenose Parrotfish	Uhu	1984.91	0.56
Zebrasoma veliferum	Sailfin tang	Māne´one´o	1429.11	0.40
Ctenochaetus strigosus	Goldring Surgeonfish	Kole	1410.43	0.40
Chlorurus perspicillatus	Spectacled Parrotfish	Uhu uliuli	1355.86	0.38
Kyphosus vaigiensis	Lowfin Chub	Nenue	1046.63	0.29
Naso unicornis	Bluespine Unicornfish	Kala	1036.87	0.29
Ctenochaetus hawaiiensis	Black Surgeonfish	N/A	1010.38	0.28
Canthigaster amboinensis	Ambon Toby	N/A	921.03	0.26
Hemiramphus depauperatus	Polynesian halfbeak	Iheihe	744.56	0.21
Melichthys vidua	Pinktail Durgon	Humuhumu hi´u kole	660.33	0.19
Calotomus carolinus	Stareye Parrotfish	Pōnuhunuhu	614.78	0.17
Acanthurus achilles	Achilles Tang	Pāku´iku´i	376.16	0.11
Acanthurus guttatus	Whitespotted Surgeonfish	´Api	268.79	0.08

Appendix IV. Herbivore Spp. by Biomass (Cont.)				
Species	**Common Name**	**Hawaiian Name**	**Total Biomass**	**% of Total H Biomass**
Acanthurus dussumieri	Eye-stripe Surgeonfish	Palani	241.17	0.07
Blenniidae	Blenny sp.	N/A	225.05	0.06
Cantherhines sandwichiensis	Squaretail Filefish	´Ō´ili lepa	220.10	0.06
Cirripectes vanderbilti	Scarface Blenny	Pāo´o	16.64	0.00
Kyphosus bigibbus	Brown Chub	Nenue	10.34	0.00
Entomacrodus marmoratus	Marbled Blenny	Pāo´o	1.62	0.00

Appendix V. Invertebrate Feeder Spp. by Number				
Species	**Common Name**	**Hawaiian Name**	**Total Number**	**%of Total INV Number**
Thalassoma duperrey	Saddle Wrasse	Hīnālea	931	34.78
Gomphosus varius	Bird Wrasse	Hīnālea ´i´iwi, ´Akilolo	254	9.49
Stethojulis balteata	Belted Wrasse	‘Omaka	209	7.81
Chaetodon lunula	Racoon Butterflyfish	Kīkākapu	206	7.70
Mulloidichthys vanicolensis	Yellowfin Goatfish	Weke ´ula	185	6.91
Mulloidichthys flavolineatus	Yellowstripe Goatfish	Weke	169	6.31
Plectroglyphidodon imparipennis	Brighteye Damselfish	N/A	150	5.60
Rhinecanthus rectangulus	Reef Triggerfish	Humuhumunukunukuāpua´a	69	2.58
Zanclus cornutus	Moorish idol	Kihikihi	68	2.54
Chaetodon ornatissimus	Ornate Butterflyfish	Kīkākapu	53	1.98
Coris gaimard	Yellowtail Coris	Hīnālea ´akilolo	45	1.68
Thalassoma purpureum	Surge Wrasse	Hou	43	1.61
Monotaxis grandoculis	Bigeye Emperor	Mū	29	1.08
Ostracion meleagris	Spotted Boxfish	Moa	29	1.08
Parupeneus multifasciatus	Manybar Goatfish	Moano	29	1.08
Chaetodon auriga	Threadfin Butterflyfish	Kīkākapu	24	0.90
Gobiidae species	Goby	´O´opu	20	0.75
Forcipiger longirostris	Longnose Butterflyfish	Lauwiliwilinukunuku´oi´oi	17	0.64
Paracirrhites arcatus	Arc-eye Hawkfish	Piliko´a	17	0.64
Chaetodon quadrimaculatus	Fourspot Butterflyfish	Lauhau	13	0.49
Plectroglyphidodon johnstonianus	Blue-eye Damselfish	N/A	13	0.49
Lutjanus fulvus	Blacktail Snapper	To´au (Tahitian)	13	0.49
Lutjanus kasmira	Bluestripe Snapper	Ta´ape (Tahitian)	13	0.49
Microcanthus strigatus	Stripey	N/A	11	0.41
Thalassoma trilobatum	Christmas Wrasse	´Awela	10	0.37
Forcipiger flavissimus	Forcepsfish	Lauwiliwilinukunuku´oi´oi	9	0.34

Appendix V. Invertebrate Feeder Spp. by Number (Cont.)				
Species	**Common Name**	**Hawaiian Name**	**Total Number**	**%of Total INV Number**
Sufflamen bursa	Lei Triggerfish	Humuhumu lei	7	0.26
Novaculichthys taeniourus	Rockmover	N/A	6	0.22
Chaetodon multicinctus	Multiband Butterflyfish	Kīkākapu	5	0.19
Arothron meleagris	Spotted Puffer	´O´opu hue, Kēkē	5	0.19
Chaetodon ephippium	Saddleback Butterflyfish	Kīkākapu	5	0.19
Parupeneus bifasciatus	Doublebar Goatfish	Munu	5	0.19
Thalassoma ballieui	Blacktail Wrasse	Hīnālea luahine	3	0.11
Cantherhines dumerilii	Barred Filefish	´Ō´ili	3	0.11
Diodon hystrix	Porcupine	Kōkala	3	0.11
Anampses cuvier	Pearl Wrasse	´Opule	1	0.04
Cirrhitus pinnulatus	Stocky Hawkfish	Po´opa´a	1	0.04
Diodon holocanthus	Spiny Puffer	Kōkala, ´O´opū ōkala	1	0.04
Echidna nebulosa	Snowflake Moray	Puhi kāpā	1	0.04
Gymnothorax eurostus	Stout Moray	Puhi	1	0.04
Parupeneus pleurostigma	Sidespot Goatfish	Moano	1	0.04

Appendix VI. Invertebrate Feeder Spp. by Biomass				
Species	**Common Name**	**Hawaiian Name**	**Total Biomass**	**% of Total INV biomass**
Thalassoma duperrey	Saddle Wrasse	Hīnālea	9940.75	11.78
Gomphosus varius	Bird Wrasse	Hīnālea ´i´iwi, ´Akilolo	9365.42	11.10
Stethojulis balteata	Belted Wrasse	‘Omaka	8671.08	10.28
Chaetodon lunula	Racoon Butterflyfish	Kīkākapu	8303.57	9.84
Mulloidichthys vanicolensis	Yellowfin Goatfish	Weke ´ula	8160.53	9.67
Mulloidichthys flavolineatus	Yellowstripe Goatfish	Weke	6852.97	8.12
Plectroglyphidodon imparipennis	Brighteye Damselfish	N/A	6425.08	7.62
Rhinecanthus rectangulus	Reef Triggerfish	Humuhumunukunuku āpua´a	4210.05	4.99
Zanclus cornutus	Moorish idol	Kihikihi	2474.93	2.93
Chaetodon ornatissimus	Ornate Butterflyfish	Kīkākapu	2330.05	2.76
Coris gaimard	Yellowtail Coris	Hīnālea ´akilolo	1728.25	2.05
Thalassoma purpureum	Surge Wrasse	Hou	1643.54	1.95
Monotaxis grandoculis	Bigeye Emperor	Mū	1631.25	1.93
Ostracion meleagris	Spotted Boxfish	Moa	1447.63	1.72
Parupeneus multifasciatus	Manybar Goatfish	Moano	1269.67	1.50
Chaetodon auriga	Threadfin Butterflyfish	Kīkākapu	1033.97	1.23
Gobiidae species	Goby	´O´opu	1021.17	1.21
Forcipiger longirostris	Longnose Butterflyfish	Lauwiliwilinukunuku´oi´oi	830.41	0.98
Paracirrhites arcatus	Arc-eye Hawkfish	Piliko´a	768.62	0.91
Chaetodon quadrimaculatus	Fourspot Butterflyfish	Lauhau	716.18	0.85
Lutjanus fulvus	Blacktail Snapper	To´au (Tahitian)	548.30	0.65
Lutjanus kasmira	Bluestripe Snapper	Ta´ape (Tahitian)	536.69	0.64
Plectroglyphidodon johnstonianus	Blue-eye Damselfish	N/A	525.32	0.62
Microcanthus strigatus	Stripey	N/A	520.28	0.62
Thalassoma trilobatum	Christmas Wrasse	´Awela	499.81	0.59
Forcipiger flavissimus	Forcepsfish	Lauwiliwilinukunuku´oi´oi	477.18	0.57
Sufflamen bursa	Lei Triggerfish	Humuhumu lei	422.92	0.50
Novaculichthys taeniourus	Rockmover	N/A	419.56	0.50

Appendix VI. Invertebrate Feeder Spp. by Biomass (Cont.)				
Species	**Common Name**	**Hawaiian Name**	**Total Biomass**	**% of Total INV biomass**
Arothron meleagris	Spotted Puffer	´O´opu hue, Kēkē	365.75	0.43
Chaetodon ephippium	Saddleback Butterflyfish	Kīkākapu	253.47	0.30
Chaetodon multicinctus	Multiband Butterflyfish	Kīkākapu	167.86	0.20
Parupeneus bifasciatus	Doublebar Goatfish	Munu	143.36	0.17
Cantherhines dumerilii	Barred Filefish	´Ō´ili	131.69	0.16
Diodon hystrix	Porcupine	Kōkala	113.39	0.13
Thalassoma ballieui	Blacktail Wrasse	Hīnālea luahine	104.13	0.12
Anampses cuvier	Pearl Wrasse	´Opule	94.93	0.11
Cirrhitus pinnulatus	Stocky Hawkfish	Po´opa´a	89.98	0.11
Diodon holocanthus	Spiny Puffer	Kōkala, ´O´opū ōkala	72.42	0.09
Echidna nebulosa	Snowflake Moray	Puhi kāpā	50.83	0.06
Gymnothorax eurostus	Stout Moray	Puhi	2.43	0.00
Parupeneus pleurostigma	Sidespot Goatfish	Moano	2.35	0.00

Appendix VII. Piscivore Spp. by Number				
Species	**Common Name**	**Hawaiian Name**	**Total Number**	**% of Total P Number**
Cephalopholis argus	Blue-spotted Grouper	Roi (Tahitian)	21	33.33
Parupeneus cyclostomus	Blue Goatfish	Moano kea	9	14.29
Fistularia commersonii	Cornetfish	Nūnū	8	12.70
Caranx ignobilis	Giant White Trevally	Ulua aukea	7	11.11
Aulostomus chinensis	Trumpet	Nūnū	6	9.52
Paracirrhites forsteri	Blackside Hawkfish	Hilu piliko´a	4	6.35
Labroides phthirophagus	HawaiianI Cleaner Wrasse	N/A	3	4.76
Oxycheilinus unifasciatus	Ringtail Wrasse	Po´ou	2	3.17
Synodus variegatus	Variegated Lizardfish	´Ulae	2	3.17
Plagiotremus goslinei	Scale-eating Blenny	N/A	1	1.59

Appendix VIII. Piscivore Spp. by Biomass				
Species	**Common Name**	**Hawaiian Name**	**Total Biomass**	**% of Total P Biomass**
Cephalopholis argus	Blue-spotted Grouper	Roi (Tahitian)	3693.76	45.34
Parupeneus cyclostomus	Blue Goatfish	Moano kea	1867.66	22.92
Fistularia commersonii	Cornetfish	Nūnū	1024.97	12.58
Caranx ignobilis	Giant White Trevally	Ulua aukea	788.03	9.67
Aulostomus chinensis	Trumpet	Nūnū	520.89	6.39
Paracirrhites forsteri	Blackside Hawkfish	Hilu piliko´a	120.96	1.48
Labroides phthirophagus	HawaiianI Cleaner Wrasse	N/A	109.96	1.35
Oxycheilinus unifasciatus	Ringtail Wrasse	Po´ou	15.60	0.19
Synodus variegatus	Variegated Lizardfish	´Ulae	4.63	0.06
Plagiotremus goslinei	Scale-eating Blenny	N/A	0.42	0.01

Appendix IX. Zooplanktivore Spp. by Number				
Species	**Common Name**	**Hawaiian Name**	**Total Number**	**% of Total Z Number**
Abudefduf abdominalis	Sargent Major	Mamo	638	51.66
Chromis vanderbilti	Blackfin Chromis	N/A	443	35.87
Kuhlia sandvicensis	Hawaiian Flagtail	Āholehole	84	6.8
Abudefduf vaigiensis	Indo-Pacific Sargent	Mamo	58	4.7
Dascyllus albisella	Hawaiian Dascyllus	´Ālo´ilo´i	8	0.65
Chromis hanui	Chocolate-dip Chromis	N/A	2	0.16
Gunnellichthys curiosus	Curious Wormfish	N/A	2	0.16

Appendix X. Zooplanktivore Spp. by Biomass				
Species	**Common Name**	**Hawaiian Name**	**Total Biomass**	**% Total Z Biomass**
Abudefduf abdominalis	Sargent Major	Mamo	30733.65	86.67
Chromis vanderbilti	Blackfin Chromis	N/A	4201.67	11.85
Kuhlia sandvicensis	Hawaiian Flagtail	Āholehole	287.65	0.81
Abudefduf vaigiensis	Indo-Pacific Sargent	Mamo	108.37	0.31
Dascyllus albisella	Hawaiian Dascyllus	´Ālo´ilo´i	91.89	0.26
Chromis hanui	Chocolate-dip Chromis	N/A	36.76	0.10
Gunnellichthys curiosus	Curious Wormfish	N/A	0.61	0.00

Appendix XI. Species List of Endemic Fish Found at Kahalu'u Bay, Hawai'i.		
Endemic		
Species	**Common Name**	**Hawaiian Name**
Abudefduf abdominalis	Sargent Major	Mamo
Acanthurus triostegus	Convict Tang	Manini
Anampses cuvier	Pearl Wrasse	´Opule
Cantherhines sandwichiensis	Squaretail Filefish	´Ō´ili lepa
Canthigaster jactator	Hawaiian Whitespotted Toby	N/A
Chaetodon multicinctus	Multiband Butterflyfish	Kīkākapu
Chlorurus perspicillatus	Spectacled Parrotfish	Uhu uliuli
Chromis hanui	Chocolate-dip Chromis	N/A
Cirripectes vanderbilti	Scarface Blenny	Pāo´o
Dascyllus albisella	Hawaiian Dascyllus	´Ālo´ilo´i
Entomacrodus marmoratus	Marbled Blenny	Pāo´o
Kuhlia sandvicensis	Hawaiian Flagtail	Āholehole
Labroides phthirophagus	Hawaiian Cleaner Wrasse	N/A
Plagiotremus goslinei	Gosline's Fang Blenny	N/A
Scarus dubius	Regal Parrotfish	Lauia
Stethojulis balteata	Belted Wrasse	‘Omaka
Thalassoma ballieui	Blacktail Wrasse	Hīnālea luahine
Thalassoma duperrey	Saddle Wrasse	Hīnālea

Appendix XII. Species List of Indigenous Fish Found at Kahalu'u Bay, Hawai'i.		
Indigenous		
Species	**Common Name**	**Hawaiian Name**
Abudefduf sordidus	Blackspot Sargent	Kūpīpī
Abudefduf vaigiensis	Indo-Pacific Sargent	Mamo
Acanthurus achilles	Achilles Tang	Pāku´iku´i
Acanthurus blochii	Ringtail Surgeonfish	Pualu
Acanthurus dussumieri	Eye-stripe Surgeonfish	Palani
Acanthurus guttatus	Whitespotted Surgeonfish	´Api
Acanthurus leucopareius	Whitebar Surgeonfish	Maīkoko
Acanthurus nigrofuscus	Brown Surgeonfish	Mā´i´i´i
Acanthurus olivaceus	Orangeband Surgeonfish	Na´ena´e
Arothron meleagris	Spotted Puffer	´O´opu hue, Kēkē
Aulostomus chinensis	Trumpet	Nūnū
Blenniidae	Blenny sp.	N/A
Calotomus carolinus	Stareye Parrotfish	Pōnuhunuhu
Cantherhines dumerilii	Barred Filefish	´Ō´ili
Canthigaster amboinensis	Ambon Toby	N/A
Caranx ignobilis	Giant White Trevally	Ulua aukea
Chaetodon auriga	Threadfin Butterflyfish	Kīkākapu
Chaetodon ephippium	Saddleback Butterflyfish	Kīkākapu
Chaetodon lunula	Racoon Butterflyfish	Kīkākapu
Chaetodon ornatissimus	Ornate Butterflyfish	Kīkākapu
Chaetodon quadrimaculatus	Fourspot Butterflyfish	Lauhau
Chlorurus sordidus	Bullethead Parrotfish	Uhu
Chromis vanderbilti	Blackfin Chromis	N/A
Cirrhitus pinnulatus	Stocky Hawkfish	Po´opa´a
Coris gaimard	Yellowtail Coris	Hīnālea ´akilolo
Ctenochaetus hawaiiensis	Black Surgeonfish	N/A
Ctenochaetus strigosus	Goldring Surgeonfish	Kole
Diodon holocanthus	Spiny Puffer	Kōkala, ´O´opū ōkala
Diodon hystrix	Porcupine	Kōkala
Echidna nebulosa	Snowflake Moray	Puhi kāpā
Fistularia commersonii	Cornetfish	Nūnū
Forcipiger flavissimus	Forcepsfish	Lauwiliwilinukunuku´oi´oi
Forcipiger longirostris	Longnose Butterflyfish	Lauwiliwilinukunuku´oi´oi
Gobiidae species	Goby	´O´opu
Gomphosus varius	Bird Wrasse	Hīnālea ´i´iwi, ´Akilolo

Appendix XII. Species List of Indigenous Fish Found at Kahalu'u Bay, Hawai'i (Cont.).		
Species	**Common Name**	**Hawaiian Name**
Gunnellichthys curiosus	Curious Wormfish	N/A
Gymnothorax eurostus	Stout Moray	Puhi
Hemiramphus depauperatus	Polynesian halfbeak	Iheihe
Kyphosus bigibbus	Brown Chub	Nenue
Kyphosus vaigiensis	Lowfin Chub	Nenue
Melichthys niger	Black Durgon	Humhumu ´ele´ele
Melichthys vidua	Pinktail Durgon	Humuhumu hi´u kole
Microcanthus strigatus	Stripey	N/A
Monotaxis grandoculis	Bigeye Emperor	Mū
Mugil cephalus	Striped Mullet	´Ama´ama,´Anae
Mulloidichthys flavolineatus	Yellowstripe Goatfish	Weke
Mulloidichthys vanicolensis	Yellowfin Goatfish	Weke ´ula
Naso lituratus	Orangespine Unicornfish	Umauma Lei
Naso unicornis	Bluespine Unicornfish	Kala
Novaculichthys taeniourus	Rockmover Wrasse	N/A
Ostracion meleagris	Spotted Boxfish	Moa
Oxycheilinus unifasciatus	Ringtail Wrasse	Po´ou
Paracirrhites arcatus	Arc-eye Hawkfish	Piliko´a
Paracirrhites forsteri	Blackside Hawkfish	Hilu piliko´a
Parupeneus bifasciatus	Doublebar Goatfish	Munu
Parupeneus cyclostomus	Blue Goatfish	Moano kea
Parupeneus multifasciatus	Manybar Goatfish	Moano
Parupeneus pleurostigma	Sidespot Goatfish	Moano
Plectroglyphidodon imparipennis	Brighteye Damselfish	N/A
Plectroglyphidodon johnstonianus	Blue-eye Damselfish	N/A
Rhinecanthus rectangulus	Reef Triggerfish	Humuhumunukunukuāpua´a
Scarus	Scarus sp.	Uhu
Scarus psittacus	Palenose Parrotfish	Uhu
Scarus rubroviolaceus	Redlip Parrotfish	Pālukaluka
Stegastes fasciolatus	Pacific Gregory	N/A
Sufflamen bursa	Lei Triggerfish	Humuhumu lei
Synodus variegatus	Variegated Lizardfish	´Ulae
Thalassoma purpureum	Surge Wrasse	Hou
Thalassoma trilobatum	Christmas Wrasse	´Awela
Zanclus cornutus	Moorish idol	Kihikihi
Zebrasoma flavescens	Yellow Tang	Lau´īpala

Appendix XII. Species List of Indigenous Fish Found at Kahalu'u Bay, Hawai'i (Cont.).		
Species	**Common Name**	**Hawaiian Name**
Zebrasoma veliferum	Sailfin tang	Māne´one´o

Appendix XIII. Species list of Non-native fish found at Kahalu'u Bay, Hawai'i.		
Non-native		
Species	**Common Name**	**Tahitian Name**
Cephalopholis argus	Blue-spotted Grouper	Roi
Lutjanus fulvus	Blacktail Snapper	To´au
Lutjanus kasmira	Bluestripe Snapper	Ta´ape

Appendix XIV. Letter of Project Approval From the Committee on Human Studies (CHS).

UNIVERSITY OF HAWAI'I

Committee on Human Studies

October 26, 2011

TO: Kaipo Perez III
Principal Investigator
Zoology

FROM: Nancy R. King
Director

Re: CHS #19498- "The Connectivity Between Ecological Knowledge (TEK) and Science"

This letter is your record of CHS approval of this study as exempt.

On October 26, 2011, the University of Hawai'i (UH) Committee on Human Studies (CHS) approved this study as exempt from federal regulations pertaining to the protection of human research participants. The authority for the exemption applicable to your study is documented in the Code of Federal Regulations at 45 CRF 46 (2).

Exempt studies are subject to the ethical principles articulated in The Belmont Report, found at http://www.hawaii.edu/irb/html/manual/appendices/A/belmont.html

Exempt studies do not require regular continuing review by the Committee on Human Studies. However, if you propose to modify your study, you must receive approval from CHS prior to implementing any changes. You can submit your proposed changes via email at uhirb@hawaii.edu. (The subject line should read: Exempt Study Modification.) CHS may review the exempt status at that time and request an application for approval as non-exempt research.

In order to protect the confidentiality of research participants, we encourage you to destroy private information which can be linked to the identities of individuals as soon as it is reasonable to do so. Signed consent forms, as applicable to your study, should be maintained for at least the duration of your project.

This approval does not expire. However, please notify CHS when your study is complete. Upon notification, we will close our files pertaining to your study.

If you have any questions relating to the protection of human research participants, please contact CHS at 956-5007 or uhirb@hawaii.edu. We wish you success in carrying out your research project.

1960 East-West Road, Biomedical Building, Room B-104, Honolulu, HI 96822-2303
Telephone: (808) 956-5007, Facsimile: (808) 956-8683, Website: www.hawaii.edu/irb, E-mail: uhirb@hawaii.edu

Appendix XV. Questions Asked During Interviews.

What is your name, year of birth and tell me about yourself?

What is your relationship to the Kahalu´u Ahupua´a (in particular Kahalu´u Bay)?

What did Kahalu´u Bay look like in the old days?

How has the bay changed since you were young?

What were the major contributors to these changes?

In your opinion what are the most significant changes?

How much coral were in the bay? Fish? (Compared to now)

Types of fish eaten?

Describe fish activities? Who got to fish and when?

Was fishing sustainable?

Describe sustainable practices by your *tutu mā* (elder folks)?

How much fresh water entered the bay then and now? Location?

Seen any impacts of global climate change? (Rise in sea level, ocean temperature, organism distribution)

If you could manage this bay what would you do to ensure its sustainability?

If no closure, how would you restore the bay?

Words of advice?

Anything else you'd like to add?

Appendix XVI. Agreement to Participate Form.

Agreement to Participate in the Ecological Monitoring, Assessment, and Mapping of Marine Ecosystem Health in Kahalu´u Bay, Hawai´i
Kaipo Perez III, Ethnographer, The University of Hawai´i[I,II]

You are invited to participate in a study that will document and investigate the traditional ecological knowledge (or TEK) of coral reef resources (past and present) at Kahalu´u Bay, Hawai´i (herein referred to as the "Project"). This project is being conducted by the University of Hawai´i, a public education/research institution. The ethnographer, Kaipo Perez III, will explain the purpose of this Project, the procedures that will be followed, and the potential benefits and risks of participating. A brief description of the Project is written below. Feel free to ask any questions at any time if the Project or procedures need further clarification. If you decide to participate in the Project, please sign the attached Consent Form. A copy of this form will be provided to you for your personal record.

Description of the Project
Traditional ecological knowledge (or TEK) is seldom integrated with science. This knowledge has often been disregarded, as these people do not hold educational degrees in the topics or disciplines they speak of, nor have their observations been tested according to scientific protocols. Recently, there has been an expansion and integration of TEK and culture into science and management programs providing acceptance and recognition of Hawaiian values. This forward movement will likely continue to influence my field of study (marine biology). The purposes of this research are to amass information about coral reef resources (past and present) at Kahalu´u Bay, Hawai´i in the *ahupua´a* (or land division) of Kahalu´u through interviews with individuals who are knowledgeable about this region, and/or about information including cultural practices, legend, chants, or songs anddemonstrate the important connectivity between TEK (concerning coral reef resources) and science. The objectives for this research are listed below:

- Interview key individual(s), with particular attention to the *kūpuna* or elders, who hold information concerning coral reef resources (past and present) at Kahalu´u Bay, Hawai´i.
- Document this TEK for archival purposes
- Use the acquired TEK to formulate and test hypotheses concerning coral reef resources.
- Bridge the gap between both disciplines.

Procedures
After agreeing to participate in the Project and signing the Consent Form, the ethnographer will record your interview and have it transcribed. The transcript will be sent to you for editing and final approval. Data from the interview will be used as part of the entho-history report for this project and transcripts may be included in part or in full as the appendix to the report. The ethnographer may take notes and photographs and ask you to spell out names of unfamiliar words.

Discomfort and Risks

Possible discomforts and/ or risks resulting from participation in this Project may include but are not limited to the following: being interviewed and recorded; having to speak loudly for the recorder; providing personal information which may be used in the future as a public reference;

Appendix XVI. Agreement to Participate Form. (Cont.)

your uncompensated dedication of time; possible misunderstanding in the transcribing of information; loss of privacy; and worry that your comments may not be understood in the manner you understand them. It is not possible to identify all the potential risks, although reasonable safeguards have been taken to mitigate them.

Benefits

This Project will give you the opportunity to express your thoughts, opinions, and your *mana´o* (or knowledge), which will be considered, shared, and documented for future generations. Your shared knowledge may be instrumental in the preservation of cultural resources, practices, and information

Confidentiality

Your rights of privacy, confidentiality and/or anonymity will be protected upon request. You may request, that your name and/or sex not be mentioned in the Project material, such as written notes, on camera interview, and in reports; or you may request that some of the information you provide remain off-the-record and not be recorded in any way. To ensure protection of your privacy, confidentiality and/or anonymity, you should immediately inform the ethnographer of your request. The ethnographer will ask you to specify the method of protection, and note it on the Consent Form.

Refusal/ Withdraw

At any time you may choose to not participate any further and ask the ethnographer for the video and/or notes. Please note that you will be given an opportunity to review your transcript, and to revise or delete any part of the interview.

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[i] Credit to Keala Pono Archaeological Consulting, LLC for aid in the creation of this document

[ii] Thanks to Dr. Warren Nishimoto (Director of the Center for Oral History at the University of Hawai´i at Mānoa) for reviewing document.

Appendix XVII. Letter of Consent.

Consent Form

I, _____, am a participant in the Ecological Monitoring, Assessment, and Mapping of Marine Ecosystem Health in Kahalu´u Bay, Hawai´i (herein referred to as the "Project"). I understand that the purpose of this Project is to conduct oral history interviews with knowledgeable individuals concerning coral reef resources (past and present) at Kahalu´u Bay, which is located in the Kona region on Hawai´i Island. I understand that the University of Hawai´i and all others associated with this Project will retain this product of my participation (video recording, interview transcripts, etc.) as part of their permanent collection and that the materials may be used for scholarly, educational, and other purposes.

_____ I hereby grant to the University of Hawai´i and their associates ownership of the physical property and the right to use the property that is the product of my participation (e.g., interview, photographs, written materials, etc.) as stated above. By giving permission, I understand that I do not give up any copyright or performance rights that I may hold.

_____ I hereby also grant to the University of Hawai´i and their associates my consent for any photographs provided by me or taken of me in the course of my participation in the Project to be used, published, and copied by the University of Hawai´i and their associates in any medium for purposes of the Project.

_____ I hereby agree that the University of Hawai´i and its associates may use my name, photographic image, biographical information, statements, and voice reproduction for this Project without further approval on my part.

_____ I understand that I will have the opportunity to review my footage and transcripts to ensure that they are accurately depicting what I meant to convey. I also understand that if I do not return the revised transcript after two weeks from the date or receipt, my signature below will indicate my release of information for reporting,

By signing this permission form, I am acknowledging that I have been informed about the purpose of this Project, the procedure, how the data will be gathered, and how the data will be analyzed. I understand my participation is strictly voluntary, and that I may withdraw from participation at any time without consequence.

_____

Consultant Signature **Date**

_____

Print Name **Date**

_____

Address

Mahalo for participating in this study.[i]

[i] Thanks to Dr. Warren Nishimoto (Director of the Center for Oral History at the University of Hawai´i at Mānoa) for reviewing document.

Appendix XVIII. Transcript Release Form.

Transcript/ Video Release[i,ii]

I, _____, am a participant in the Ecological Monitoring, Assessment, and Mapping of Marine Ecosystem Health in Kahalu´u Bay, Hawai´i (herein referred to as the "Project") and have been interviewed for the Project. I have reviewed the transcripts and video of the interview and agree that both are complete and accurate except for those matters delineated below under the heading "CLARIFICATION, CORRECTIONS, ADDITIONS, and DELETIONS."

I agree that the University of Hawai´i and their associates may use and release my identity, biographical information, and other interview information, for the purpose of including such information in a report to be made public, subject to my specific objections, to release as set forth below in the heading "OBJECTIONS TO RELEASE OF INTERVIEW MATERIALS."

CLARIFICATION, CORRECTIONS, ADDITIONS, and DELETIONS:

OBJECTIONS TO RELEASE OF INTERVIEW MATERIALS:

_____

Consultant Signature **Date**

_____

Print Name **Date**

_____

Address

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[i] Credit to Keala Pono Archaeological Consulting, LLC for aid in the creation of this document

[ii] Thanks to Dr. Warren Nishimoto (Director of the Center for Oral History at the University of Hawai´i at Mānoa) for reviewing document.

Appendix XIX. Kahalu´u Bay: Connecting the Community and Science Document.

Kahalu´u Bay, Hawai´i: Connecting the Community and Scientist

Acknowledgment:

Welina Mai! Before we (the scientists) begin to work at Kahalu´u Bay it is vital that we work with the community to make them aware of our plans and how it may benefit them. It is understood that we are "outsiders" or "visitors" to Kahalu´u and therefore it is significantly important that we make sure that everything we plan to do is "*pono*" or done in the right way. It is dually important that we make sure that our presence and plans at the bay are transparent. Here we have prepared a document (which is addressed to the *Kūpuna*, the community and other key parties) detailing who I am, and what is planned to be done in two different contexts (cultural and scientific perspectives). The cultural portion will inform the community how our research/findings may benefit them. Whereas the scientific perspective portion of this document will specify exactly what we plan to do at Kahalu´u Bay following *Kūpuna* approval and input.

About Me:

Aloha mai Kākou! My name is Kaipo Perez III and I am from Kaimukī, O´ahu. Although being born and raised on O´ahu, Hawai´i Island holds a dear part of my heart as my *´ohana* are from Kohala, Hawai´i. My love for the ocean and all its inhabitants emerged from the very first time that I can remember exploring the tide pools at Makapu´u or diving at Māhukona Beach. I also remember visiting other beaches on Hawai'i Island, including Kahalu´u bay, when I was younger. I grew up in an 'ohana lawai'a, or fishing family, who are great stewards of the terrestrial and marine environment. Their passion to conserve and protect the land and sea is their gift to me. It wasn't until high school when I enrolled in marine biology that I discovered my true interests, Marine Ecology (living organisms and their environment). This is also the time of my awakening as I departed from the naïve, "perfect world" and became very cognizant of the detrimental problems caused by some humans. Throughout my life I have noticed alterations in the terrestrial and marine environments that have led to their deterioration. Since then I am devoted to make a change and have received a marine biology degree (BS) at the University of Hawai'i at Mānoa (UHM). Currently I am pursing a PhD in zoology (with a focus in coral ecology) at UHM.

As a student, I have been able to build and hone my skills in coral reef ecology. In the summer of 2007, I was selected to participate in a National Science Foundation (NSF) funded internship program - UMEB (Undergraduate Mentoring in Environmental Biology). In this 10 week program, I was paired with research mentors, Drs. Paul Jokiel and Ku'ulei Rodgers, at the Hawai'i Institute of Marine Biology (HIMB). Ku'ulei was also born and raised on O'ahu with paternal roots to the Island of Hawai'i and shares the same love and respect for the *'aina* that I do. With their input, I developed my own research project, in which I investigated the effects of terrigenous sediment on the viability of settlement by larvae from *the* lace coral, a common hermatypic, reef building coral in Hawai'i. At the conclusion of this study I was asked to continue as a year-round intern and since then have continued exploring my research interests.

During the summer of 2008 I investigated coral recruitment at various depths. At each depth coral growth (linear extension and buoyant weight methods) and the physical factors (temperature, water motion, accumulated sediment) that might influence the manner of recruitment were measured. Collectively both research projects have strengthened my understanding of the dynamics of coral reefs and how biotic and abiotic factors can influence change in this coastal ecosystem. The methodologies mastered during these experiments also served as essential tools that can be applicable to future research that I hope to continue and expand on. Segue to what that future research would be, in a nutshell I would like to understand the relationship/connectivity between land and sea and apply this knowledge to identify key problems in the marine environment that need to be corrected.

Since childhood a proverb or 'ōlelo no'eau has been instilled within me. "He ali'i ka 'aina he kauā ke kanaka", "take care of the land and it will take care of you". As a part of my graduate studies I have the desire to continue and expand on the knowledge that I have gained. In the future, I would like to examine the impacts of anthropological factors, such as sedimentation and eutrophication, as stressors on coral reefs. In collaboration I would also like to monitor coral recruitment in various areas around the Main Hawaiian islands and identify the possible factors that might influence their recruitment. It is my intension that these findings will collectively be used to ameliorate the impacts on coral reefs in Hawai'i. In addition this work will hopefully give insight into the dynamics of reefs and serve as my contribution to the stewardship of these islands.

There are many long-terms goals I would like to achieve in the span of my professional career. The first goal would be to sustain field and laboratory research with the intent of identifying sources of detriment to the coral reef ecosystems of Hawai'i. Taking this a step further I would also want to address the local communities and/or the legislature on the measures that can be taken to remedy/reverse these detrimental effects. I believe scientists need to work intimately with the community, managers, and policy makers to preserve our "precious reefs". Finally I would like

to encourage Hawaiian students to major in marine biology and play an active role in protecting their "home" ecosystem. It is time for Hawaiians to restore their role as being great stewards of the island on which they live.

The Game Plan:

The title of this project is "Kahalu'u, Hawai'i Investigation – Ecological Component (Mapping, Assessment, Monitoring) Implementation Plan". It is part of a larger grant with the National Science Foundation's EPSCoR, Experimental Program to Stimulate Competitive Research Program concerning climate change impacts on water resources across Alaska and the Hawaiian Islands. The motivation and desire of this study is to ensure the sustainability of Kahalu'u Bay, Hawai'i. To accomplish this goal, we (the scientists) must first build a baseline of the natural resources present and identify the possible sources of impacts (both terrestrial and marine) acting on the bay. In addition it is vitally important that the community, managers, policy makers, key players, and scientists develop an intimate relationship to accomplish this goal. The following subsections are different context in which our research plans integrate. In the cultural perspective, we are trying to target the community and those who are interested in our intensions (which is to ensure the longevity of Kahalu'u Bay). In the scientific perspective our approach is to inform those who are interested as to what we plan to do in order to achieve the underlying goal of this project.

Cultural Perspective:

Before selecting this project as being part of my graduate studies I was offered other places to work at, but none appealed or had greater value to me than Kahalu'u Bay. This is due to the fact that Hawai´i Island holds a dear part of my heart as my *´ohana* are from Kohala, Hawai´i. I feel as though my research now is going to influence "things closer to home". I also wanted to change the face of science and be able to integrate the Hawaiian culture with western science. It is something that is lacking presently and may be the future of my field.

We understand how important Kahalu´u Bay is to the community or the *´ohana nui* of this area. For generations and even till this day many of the *´ohana* who reside in this area have used the bay for many activities which include: fishing, swimming, and family gatherings. As previously mentions, I myself grew up in a *´ohana lawai´a* (or fishing family) and understand the community's concerns on how "outsiders" can come into an area and cause much *pilikia.* This is why we asscientists are stressing that all the work that will be done will serve a purpose for the community. We want to leave a lasting legacy for generations to come.

Science and culture can blend together to benefit the community. We will be assessing the health of the bay as well as working with the community, and developing maps for the community to access. We will be assessing health by looking at the coral, limu, and fish found within the bay. Understanding the bay's "health" may provide insights for management action and its sustainability for future generations. I believe this is important to the community to pass down the treasured resources of this bay to their *mo´opuna*. Working with the community through education and outreach we would like to share our limited *mana'o* and gain from your extensive traditional knowledge so together we can improve and sustain the marine life in Kahalu'u Bay. Ultimately it is our goal is to work together with the Kohala Center, schools (including a kula kaiapuni), and the community to model this project into one that will be driven by them. Through this process we believe that we can learn from the community as the community can learn from us since we all have the same ultimate goal of protecting Kahalu'u Bay's resources. All parties involved can grow together in our path towards the protection and sustainability of the bay. The mapping part of the project may be important to the community as it might indicate areas of great significant (both scientifically and culturally) as well as point out places where environmental problems exist. The mapping process may also provide historical data that can be used by the community to track how the bay has changed over the years and be used to monitor its "health". We feel this project can succeed once we all work harmoniously to ensure the sustainability and health of beloved Kahalu´u Bay.

Scientific Perspective:

The primary reason for conducting this study is to evaluate the ecological status of the coral reef resources of Kahalu´u, Hawai'i and integrate this research into community and educational efforts. Our marine component will also be integrated with the terrestrial component of the much larger research project. The following are the four parts to the marine component: Ecosystem Health, Monitoring, Community Participation, and Mapping.

Ecosystem Health - Understanding the health of Kahalu´u Bay is important to understand if the bay is "stable" and "sustainable". Benthic and fish communities will be quantified within each habitat along with the major physical factors controlling distribution (depth, spatial complexity, sediment, patterns of human activity etc.). New data will be acquired using the standard Hawai'i Coral Reef Assessment and Monitoring Program (CRAMP) rapid assessment technique. These data will be interpreted in relation to an existing data set to

assess the present status of the Kahalu´u reef as compared to over 200 stations throughout the Hawaiian Archipelago. This allows a comparison of over 40 biological and environmental factors (ie: fish biomass and trophic levels, coral cover and diversity, human population, wave regimes, sediment composition etc.) in the Kahalu´u region with comparable sites. This marine ecosystem health data will further integrate with the freshwater and terrestrial components to allow an ecosystem approach in understanding and managing the entire Kahalu´u ahupua´a.

Monitoring - Monitoring "sites" are essential to understanding the health of the bay and determining impacts on the bay. A long range monitoring plan will be developed and implemented. We will review and resurvey data including transects taken by Dr. Ku´ulei Rodgers at this site in 1999, ongoing fish monitoring by Sea Grant's Reef Watchers, and the status of the 14 CRAMP monitoring sites that have been in place for 10 years along the West Hawai'i coast. Global impacts (e.g. bleaching, storm conditions) will be monitored along with the local impacts (e.g. activity use and sedimentation). Small recording thermometers will be deployed at our monitoring sites to collect temperature along with a highly sensitive temperature recording device that will link to other meteorological data accessible to the commuinity.

Community Participation (Educational and Outreach Component) – The overall design of this project is based on a traditional approach that is supported by scientific knowledge and research with a focus on bridging gaps between science, community, and traditional knowledge. Local organizations, individuals and schools will play an active role in identifying the information and educational needs of the community. They will participate in the surveys of the benthos and reef fish and gather data on temperature, salinity and water circulation. Community workshops and seminars will be held and given the opportunity to contribute to the interpretation and application of the marine data. In addition to broad community participation, local schools within the area will serve as a focus for information dissemination and sources of data collection. A major goal of this component is to build a community base for continued involvement in the monitoring, assessment and oversight of the marine and terrestrial resources of ahupua'a in the future.

Resource Mapping – Creating a map of the bay is vital to visualizing all the resources present at Kahalu´u. Through this map insights about how the bay can be managed may result. Map layers for the Kahalu´u area (and watershed) will be produced in a Geographic Information System (GIS) format and developed using our extensive existing database as compiled from various sources. These will include: aerial photographs, habitat maps, boundaries, bathymetry and a wide range of metrological and other relevant information on the watershed.

Map Layers to be developed:

Currents: Current patterns will be tracked with the use of GPS. Wave, tide, and offshore buoy data will be collected.

Temperature: Temperature within the Bay will be determined including nearshore negative anomalies in relation to freshwater seepage.

Benthic community distribution and abundance: Coral, algae, sand, and other substrate will be determined using rapid assessment transects.

Summary:

This is document has been prepared for the community and all interested parties, detailing what our (the scientists) plans are, how it may benefit you, and requesting your input and approval. We will be surveying the bay and creating a "baseline', a starting point for future monitoring This data will then be accessible through GIS layers, reports, and presentations. The results from this data will display the unique natural resources and indicate impacts to the bay. The ultimate goal of this project is to sustain Kahalu'u bay and strengthen the bond and understanding between science, the community, and key stakeholders. If there are any questions, comments, or request feel free to email me (Kaipo Perez III) at kaipop@hawaii.edu.

Thank you very much for your time and concern. We look forward to working together with all of you to achieve the ultimate goal of this project, ensuring the sustainability of Kahalu´u Bay.

Aloha ke akua,
Kaipo Perez III

Appendix XX. Raw Transcript: Mitchell Mikiala Fujisaka.

Kaipo Perez (KP):

Today is Friday April 13, 2012 and we are interviewing one of the kūpuna of the Kahalu´u ahupua´a, Uncle Mitchell Fujisaka.

Uncle Mitchell can you state your name and the year you were born and a little about yourself.

Mitchell M. Fujisaka (MF):

Okay. My name is Mitchell Mikiala Fujisaka. I was born October 8th nineteen hundred and thirty six, right in the ahupua´a of Kahalu´u. I say not to far from where we are sitting right now. When we talk Kahalu´u, its where I was born, I was raised, I was brought up with all my kūpuna's. We knew every family that lived in the ahupua´a from the beach to the farmlands mauka. So in growing up in Kahalu´u as a child you know it was to me it was to me a previlige because every kūpuna in the area knew us as family. We were all family. You could go from one house to the next house, to the next house, you'll never get hungry. They would always offer you something to eat. Whether you hungry or not you have to take a bite to satisfy them. So you know growing up along the beach because that's our main thing. Chores we didn't have much chore to do because we didn't have yard to mow. All we had is you know little vegetable gardens. So we weed it every once in a while. But beach activity was our main thing. That was our playground. That was our fun thing. We would have breakfast, forget lunch. Nobody worried about lunch. We would eat lunch from the land. Coconuts, whatever fruits we could find. That's what or we'd catch fish you know with our hands. We'd eat it raw or we'd start a fire. We pūlehu it. That's how we grew up, carefree, easy going. But, you know if you did something wrong your parent, your guardian, your grandmother would know about it. Like I was brought up with my grandparents, so I was fortunate. So if you did anything wrong while you were out they would find out about it. And the consequences you know not it how it is now, you know the consequences was, you'd have it on your butt (laughs). So you know that is how I grew up. And it was fun. I enjoyed it. Whereas I can't say much about the children today.

KP:

So tell me about your ohana, your family?

MF:

Okay, my family on my mother's side are the Kahinu's. They were raised well…whoever Kahalu´u. They were Kahalu´u family, both of them. My mother's side was Kahinu. My mother's side…ah…my father's side was the Koholomu's. They have the Koholomu estate till today. It's a….theres a family grave site up there. So the last one that got buried I think there was just about a year ago. So that grave site is over hundred years old. And then, my mother's side, the Kahinu side of the family, they started from Kekaha. That's where Kona village area was. That's where they started from. And…

KP:

Kala mai… What side was the fishing side, the fishing family side?

MF:

The fishing family side was both sides.

KP:

Oh was both sides.

MF:

They were fishermen and farmers. You see at that time they had up mauka, we had homes up mauka and homes on the beach.

KP:

Oh

MF:

Its not just living down the beach you go up mauka and you farm. During the winter months when it was rough, they would go up mauka and farm.

KP:

Oh

MF:

And then taro season in between they would still go mauka.

KP:

You know you were telling us something interesting before that would be nice to know is. You know you said the families we really intertwined here and they were really interconnected and they were.... Although shared different… although they had different last names they shared each other as being part of a bigger ohana. Mmm… What would happen if you guys couldn't make it home late at night?

MF:

Okay…at, at that time. You know when we were growing up, after the sun goes down so much, you know they say because its dark you don't know what comes out at night, so you have to be home before that. And if you cannot make it you go to the closest house and they would whistle. If you know if you way down this corner here and the house is up there, they would whistle and they would pass on until your tūtū hears, until my tūtū hear, hear the whistle and then they would answer back, saying its ok. But there's another whistle that they use to use. If they use one hand, its you know its ok. If they use two hands you better move fast (laughing). Because its just like their voice. You know the louder the voice, the madder they are, it's the same as the whistle.

KP:

Wow that's…

MF:

You know that in this ahupua´a. Other ahupua´as I don't know if they use this same method.

KP:

Mm… You know another thing you were telling me about was that the ahu, the ahupua´a of Kahalu´u has something special in it has a Po´o Hawai´i and uh can you tell us alittle about Po´o Hawai´i?

MF:

Okay. Po´o Hawai´i is a fish pond that is right out here. Right in the, Right out here in the grounds. That's the name they gave to the fish pond to hold the name Po´o Hawai´I, because Po´o Hawai´i was an ahupua´a for royalty, within the ahupua´a of Kahalu´u. So those are royalty grounds. So not to lose the name they gave it to the pond, to hold Po´o Hawai´i.

KP:

And it was kind of right where were sitting around the hotel?

MF:

Right, Right here. Right where were sitting.

KP:

Oh…

MF:

This is it.

KP:

Mm… You were mentioning before that one of your first jobs was working with Kekahuna. Where you mapped the area…

MF:

Right…

KP:

Tell us a little bit about that?

MF:

Well you know…I first met Kekahuna was in uh was in the early 50's. Actually I heard about him in 49. Because he, he, when he comes overs he use to stay with my tūtū. Because everybody here was tūtū. But we knew the name tūtū. He was Tūtū Naluahine. And then there Tūtū Upchurch, but everyone was tūtū because they were same age as my grandparents. Okay, so I that I first met him you know he wasn't a big man. But you know when I look at him, and say gosh he must be hundred years old. Because I was young. But you know when he speaks, he speaks with authority. If he say you go get something, you don't look at him, you just move and go pick it up. So in the 19… I say 1950, 51, 52 you know I worked with them in the summer. Worked with him not meaning getting paid to work. Just to go out and help, help him because. When they first asked me is, it was my cousin and I that went down to Naluahine's house and he was there. So they were looking for somebody to go out with them on the field. So, he asked Tūtū Naluahine you know which one of this two shall I take. He, He needed only one of us. So Tūtū Naluahine told him that you take this one because hes ´eleu. ´Eleu means you can (motions with hands) you know. I didn't know what I was going to do. So I agreed. That protocol is ok I agreed but its not my decision to make. Its my grandmothers decisions to make so its up to them to ask her if she say ok, its ok. So she gave me you know the ok. Now… I didn't know what I got myself into (laughing). I thought it was all fun (shaking head). No, but it was an experience you know that I never forgot. He was a very stern, stern person you know. He kind of makes you tremble when he talks. If he say you go in this straight line, he say you go there, you go there. If the, If a coconut tree was blocking the way, you don't ask him, how do I get on the otherside you know. Its up to you to find out how to get on the other side. So I helped him measure the five heiaus within this district ah within this ahupua´a. The five major oh 6 with a Ku´e Manu and then these small ones across the stre… road I helped him. So it was, it was a good experience. I would you know, I would recommend it now if anybody you know came up to do that… I would recommend the kids you know like how a Pai guys is doing.

[END OF CLIP 1: MVI_0183]

[START OF CLIP 2: MVI_0184]

MF:

Oh and another thing, Kekahuna had only one leg (laughs). You know they use to call him peg leg but he had, didn't have a wooden leg. All he had is his leg to the ankle.

KP:

Mm…

MF:

You know, he, we went up, you know, go look for the heiaus to measure. So we tell him 'Tūtū come on this side its easier'. No, he just going to go that way. That's the ways hes going. Theres a barbwire fence, he would jump over it (laughs). You know, he would put his cane. He would hop over it. Put his leg on it and then hop over. We would go climbing up the heiau, you know when you had definitely need two hands and two feet…

KP:

…And he would do it with...

MF:

Yeah. All his way… You'd you'd put your hand out here …you would put our your hand for, to help him he'd get his stick and he'd hit your hand (laugh). That didn't stop him.

KP:

So…mmm… What did Kahalu´u look like in the old days when you were younger, the bays itself and the resources?

MF:

Okay, when I was growing up. When I was young the bay…uhhh…

KP:

This is like elementary school days?

MF:

Yeah. You know it was sand. It was a lot of sand. You know its hard to describe how it was. But the sand was if you look at it now, like our, you know you can see it. Now… It it wasn't what it is. The sand wa, it… You had sand dunes before you hit the shore.

KP:

Mm hmm…

MF:

That was my time. Now there was a Ke'eaumoku at a house site…

KP:

Mm hmmm…

MF:

…You know right next of Kalani Kai. He had a house site. During my dad's days, when he was growing up, he said there were nine coconut trees there.

KP:

Mm hmmm…

MF:

Okay… During my days growing up there were two and a half coconut trees.

KP:

Oh…

MF:

You see hard far it…

KP:

Yeah…

MF:

…it it eroded. It started erode from his time.

KP:

Oh…

MF:

You know… and then it came out to my time, it was still eroding.

KP:

Mmm… What about the coral and the fish and the limu?

MF:

Coral, fish… there were lots of fish. Because they didn't overfish.

KP:

Mmm…

MF:

They controlled the fishing. Theres time you can fish. Theres time you don't fish. Sundays you don't fish.

KP:

Sundays…

MF:

Nobody fishes on Sundays. You go swimming on Sundays. Nobody fish. If you don't have fish your house, you just tell someone…you know... one of your ohanas…you know… they'll be happy… Because you know at that time, you know they say trade, you know… I I catch fish here and then I trade with you there… The trade wasn't in their vocabulary. You know, its I catch fish I give, I give you the fish. If you have anything you give it back to me. But I don't ask you to… its… But fish, multitude….lots of fish. You know they didn't over fish…so there's a multitude of fish. The other thing is the ahupua´a system is from the mountain to the sea. My grandmother told me this that you know I pass on to people that the ahupua´a was only for the *kanaka*, the humans. She told me the pulelehua, the fish, they don't know what is ahupua´a so they go from ahupua´a to ahupua´a. See in that is the same way as the fish. They say the fish goes out so much. They don't go beyond that depth. They go this way (motions with hands across). So if you have a good table, like the papa of Kahalu´u. If you have a good table, the fish will come. They would come feed on that table because theres lots of limu.

KP:

Mm hmmm…

MF:

Coral you know… theres certain coral that we would keep because that's a coral that has algae on top then the fish, mostly manini, would eat… manini and uhu.

KP:

Mm hmmm…

MF:

Theres uhu to crunch the coral.

KP:

Mm hmmm…

MF:

Okay that coral we would keep.

KP:

Mm hmmm…

MF:

Now theres this other coral that I don't know what they call it… we call it the flower coral.

KP:

Mm hmmm…

MF:

Finger coral or what?

KP:

Looks like a cauliflower?

MF:

Yeah.

KP:

Oh yeah, yeah, yeah.

MF:

Okay, if that was in the way that comes out…

KP:

Oh…

MF:

… we'd take it out. And when we take it out we don't leave it there. You take it completely out of the ocean. Because you know that coral was no use… Because it would snag their net. The fish cannot hide under it.

KP:

Mm hmmm…

MF:

You know if theres food on it than its limited… small amount.

KP:

Mm hmmm…

MF:

You know like I say, if we did… If we do now what we did then… We would be in jail… for destroying the coral.

KP:

Right.

MF:

Yeah… but you know we taking out one thing to replenish another. For that, you know so that the fish can…

KP:

So its more of a balance?

MF:

Right, right…

KP:

So you were telling me…oh kala mai…

MF:

Go ahead.

KP:

You were telling me before the people would not only take it out (coral) completely but they would flip them over and pile them up.

MF:

Uhhh… not not the coral.

KP:

Not the coral?

MF:

No… coral, if you take the coral the coral will come out. I think when we talked that…that's I think that was in the 57s or 58…

KP:

Mm hmmm…

MF:

…when people use to come down and find for shells…

KP:

Mm mmmm…

MF:

….so they would flip up all this big coral. You know, well we put a stop to it. We told them they couldn't do that.

KP:

Yeah, yeah, yeah, yeah.

MF:

Yeah, because you flip the coral over and then the thing bleaches in the sun you know…

KP:

Yeah, yeah, yeah

MF:

…it dies. So you know we told them that they couldn't do it so you know they stopped. Other than that no. Oh and fish, we go back to fish. You know there are certain types of fish certain variety of fish that you didn't find in Kahalu´u Bay like how you do now...

KP:

Mm hmmm…

MF:

…the humuhumu, the black humuhumu, the la´i pala, that fish wasn't in the bay...

KP:

Mm hmmm…

MF:

…like It is now. That fish was outside the break water.

KP:

Mmmm… And a, so before you guys would take out coral or mov…shift them around in order to a provide habitat for them to give…

MF:

Oh, okay, okay, okay… That part is, it wasn't coral…

KP:

Oh…

MF:

…it was regular basalt rock…

KP:

Oh, oh.

MF:

…that was in the ocean…

KP:

Right, right, right…

MF:

…you know because that's the rock they use because had limu on top.

KP:

Mm hmmm…

MF:

You know so they would stack it up like how you do if you kalua pig…

KP:

Right, right, right…

MF:

…you stack up the imu…

KP:

Right…

MF:

That's how you would do…

KP:

Oh...

MF:

…okay you, they'd you would say you put a, the main rock underneath. That's called the 'piko' rock…

KP:

Mm hmmm…

MF:

…okay, so it was a flat… flat rock. You raise it up on one side so that the fish can go under. Then, you find all the other rocks around. Then you wait till the tide come up. Certain tide, it comes up. Then you would get rocks and you would throw it. You can see the fish around because they would come around there. So you would throw rock on the outside and the fish would all…go in the rock. You'd throw your net over it.…

KP:

Mm hmmm…

MF:

…you take the rock out one at a time. So this why you don't want too much rocks. Take out your rocks one at a time. They would go till they hit the 'piko' rock. Then they would go underneath. But the time your net is right there. You just lift the rock up.

KP:

Mm hmmm…

MF:

That's the easy way of catching fish.

KP:

And a… I think one of the things you told me when we were first met is that. I asked you know what was one of the things that changed the most over the past fifty years or since you were younger and I think you mentioned they were too much coral or or a lot of coral than there was before.

MF:

Yes, yes, yes…

KP:

…and I think you said because of that there wasn't as much plentiful fish as they were before?

MF:

… Yeah mm hmmm… Now now there you know a lot of coral like I say, so now you got all kinds of different fish coming in…

KP:
Right.

MF:
…you know like you get the humuhumus…

KP:
Mm hmmm…

MF:
…the la´i palas, all of that, all of that fish. You know we didn't have inside…

KP:
And…

MF:
…within the bay.

KP:
So what fish were here before instead of those fish?

MF:
You have your, the good fish.

KP:
Mm hmmm…

MF:
Okay, you had your weke…

KP:
Mmm…

MF:
…Moano…

KP:
Yeah…

MF:
…uhus, all the varieties of uhu: panunu, lauwea, halahala. Those are all the big scale fish.

KP:
Mm hmmm…

MF:
Okay they were plentiful in here.

KP:
Ahh haa…

MF:
You know manini. There is a lot of manini. Certain places you would catch Kala…

KP:

Oh…

MF:

… umaumalei. You know they…they weren't scattered all over the bay. There were certain…places.

KP:

Oh so they were a certain place for each…

MF:

Right…

KP:

…particular fish…

MF:

… for each particular fish…

KP:

Oh…

MF:

You know you can s… theres theres trails lets say where this certain fish would run…

KP:

Uh huh…

MF:

… okay that where they would set their net. And then they know they going to catch this certain amount of fish…

KP:

Mm hmm…

MF:

…in, within that area. And then theres two places where they would set their net and catch only manini….

KP:

Mm hmmm…

MF:

…nothing else. Only manini. Not the big maninis but the medium size.

KP:

Mm hmmm… Who would decide when and what types of fish would you be able to catch and not catch during a certain time?

MF:

Well… you know if, but doing that you would say who would be the head fisherman…

KP:

Mm hmmm…

MF:

…nobody…

KP:

Mm hmmm…

MF:

…you know when I was growing up before that yes I heard that. You know one of my grand uncle was a head fisherman. Any time you want to go fish, you would go to him. But when I… My time everybody had their own net…

KP:

Mm hmmm…

MF:

… so you want to go, you go to fish. You go today. Next guy go tomorrow. Or you go this morning. The next guy go in the afternoon. You know that's how it was. There was nobody that was a leader...

KP:

Mm hmmm…

MF:

… not unless you go down to Keauhou…

KP:

Mm hmmm…

MF:

…you know when there big fish, akule fish comes in. Akule school comes in. Then they would come and grab my grand uncle.

KP:

Mm hmmm…

MF:

…and have him go oversee the… [END of CLIP 2: Cutoff by Camera]

[END OF CLIP 2: MVI_0184]

[START OF CLIP 3: MVI_0185]

KP:

What were some of the major changes that you seen happen at the bay, mmm, over the past, since you were young until now?

MF:

The major thing is the erosion of the sand. Theres lot of different theories people say rock wall this and that but it's been going on for generations. You know we don't know how far out the sand was or but you know that's a major thing the generation and population. You see most of the people that come to Kahalu´u, they come to Kahalu´u to relax. They don't come you know to take all the fish. Or they don't come with their big trucks loaded of nets and try to take the fish. They come to relax. So they are not taking home the sand. The ocean is taking the sand. The ocean brought the sand. The ocean is takes it away.

KP:

Any other changes you seen over your time?

MF:

Well..

KP:

Construction maybe or other things?

MF:

Yeah you see other things buildings. Whereas when I grow up we would only drink whatever water we could find. There was lots of… but there's certain places we have freshwater you know on the shoreline that we would, we could drink. We didn't take bottle water or you know water in a can. No, that was our source of water. We knew where they were. I can't find them today. That and theres brackish water. Now that I think of it the main thing that, that you know when I was growing up is how healthy the water was, the ocean water was. Because my grand folks when we went to fish, you know when they came down to go mess around and that they would always go in the shore… the first thing they would do is they would take a scoop of water put it in their mouth and then you know they wouldn't spit it out they would swallow it. They knew…this is going to be a good day. Nowadays you know or another thing when we went use to go *mauka* we use to play in the grass then we use to get all sores (using hands to indicate sores on legs)… you know we use to call them *kakio*. We didn't go to the doctor. When we came down we went straight to the ocean. We went to the ocean and swam in it you know it cleaned everything out. You know you would see the thing just like puss in it yellow, when you got out of the ocean that was pink. It was all dried up. You would lay in the sun for a little while. That thing would be all dried up, within a few days nothing. Now you go in there, what happen… staph (laughs)… they talk staph… you know so just like the water you know if were so thirsty we would drink brackish water. You know that didn't faze us. But I wouldn't drink today (laugh). I don't think you would.

KP:

So the water quality itself was It way…

MF:

The water quality itself was pristine, because if the tide is low you can see the, the water, the brackish water. We call it brackish water right on the surface and then if you walk in you can feel it because it is cold. So that's the water that they scooped.

KP:

And uh… sorry going back to the question about you know the because there is more coral now and your saying that there not enough fish… Was it all, all different kinds of fish or just the more edible fish you guys considered back in those days?

MF:

Well… They were. You know all fish were edible during you know when I was growing up… all fish.

KP:

Right…

MF:

The only thing that we didn't, I could say that we didn't care for was the puffer fish...

KP:

Mm hmmm…

MF:

…the ballon fish… with the you know…

KP:

Mm hmmm…

MF:

…the spines on it. And lots of those you know. And then there's the *Humuhumu nukunuku apua´a*. That fish nobody ate.

KP:

Mm hmmm…

MF:

Because that's considered royalty so… So other than that you know all fish was edible. But it's the type, the variety of fish that frequented the bay. Because you know you got *palani*, you got *pualu*, they would, they would come they would come to certain part of the bay. They wouldn't just, because if you see a big school of *pualu* boy theres about 50 or 60. But when they would come in here you know you would see two three. Because those are you know they eat algae and sand.

KP:

Right, right, right… So ummm… What it really was it was all fish were edible in Kahalu´u except for the puffer fish…

MF:

Right…

KP:

And… ummm… The only thing that changed was as there was, as coral increased the fish the different types of fish species changed.

MF:

Right…

KP:

So there was a shift in…

MF:

Right…

KP:

… different, fish coming in and other fish leaving.

MF:

Right, right right, right, right… Just like I told you about the *Humuhumu* and *la´i pala*.

KP:

Right, right, right…

MF:

You see now they are way in. When I grew up the fish that uh that we I, I, I said that we didn't eat much of was the *kihikihi*…

KP:

Mmmhmm…

MF:

Because they were the ones that brought the fish in…

KP:

Mmmhmm…

MF:

Because if you sit on the sand you see the *kihikihi* come in you know other fish are following. It's a, it's a guarantee.

KP:

Mmmhmm…

MF:

You know once they come in they make their turn you watch other fishes are coming in.

KP:

Mmmhmm…

MF:

So those are things we would watch.

KP:

Yeah… that's…

MF:

Yeah and talking about coral, you know, theres coral that's really close to the shore that we didn't have….

KP:

Mmmhmmm…

MF:

… We took it out… We see anything that looks like coral or color, any color that we didn't agree or like how they told, you know, my *Kūpuna* told me…

KP:

Mmmhmm…

MF:

… You know if you see green color, red color, purple color, they said that's no good.

KP:

Mmmhmm…

MF:

So…

KP:

So its not like you guys were killing, it's more like pruning…

MF:

Right…

KP:

And kind of taking care of that… So in Kahalu´u you would find more fish in areas that were not dominated by corals.

MF:

That is correct… You see co… most of the coral you'll find it closer to the breakwater.

KP:

Right…

MF:

If you go along the breakwater you'd find all that smooth green colored coral.

KP:

Right…

MF:

You'd find it all along there.

KP:

… And that didn't have that much fish?

MF:

That… you know… out… It had fish…

KP:

Yeah

MF:

But its certain time of the day, you know…

KP:

Oh…

MF:

The breakwater there certain places, there is a break in the breakwater that's where the fish comes in

KP:

Right, right

MF:

They come they by-pass the coral and then they go, come inside and eat.

KP:

And so they would pass the coral but they wouldn't stick around. The fish you guys wanted to eat didn't stick around by the coral….

MF:

No, they were inside the coral

KP:

Yeah they went around the rocks that had all the algae… that were

MF:

Yeah, yeah, but you see their, their road of going back out was through the coral.

KP:

Mmmhmm…

MF:

…. So that's where they would you clean out the coral…

KP:

Mmmhmm…

MF:

…. So that they could put their net…

KP:

Mmmm…. And uhh I think you were telling me before that you know that there are rocks out here that kind of uhhh… kind of like your guys *ko´a*…

MF:

Ah ha….

KP:

… that's where you guys… but you guys wouldn't collect it… you wouldn't collect where there were the most amount of fish.

MF:

No, no, no

KP:

Ummm… Could you tell me that story again… it, uhhh, when you guys would go out there and there would be the area where you have… I think you said theres little bit amount of fish but you guys knew where the fish was but you guys didn't go there…

MF:

Yah… yah… because if you want to catch a big amount of fish okay you have to have more people…

KP:

Mmmm…

MF:

… So most of the family would go with about four or five… you know… so if you want to catch a bigger amount of fish where the… we call it, we call it uh the *ku´una*… you know where you set your net you have to have more because they are gonna have to swim from shore close to the break water out there… to the Menehune wall… so that's where the net was set you know. And then if you want to catch more fish, if there is a big party then you take your net on the outside of the breakwater… then you would catch more fish. Same thing they would swim from the sand all the way out. That's just like you could put all the *ku´una*s together just by setting this one spot.

KP:

Mmmhmm… And so I know you consider yourself a fisherman so what was, how was it growing up to be a fisherman? Because when I was growing up you were the bag boy first… so the step and how you got to be up to a level where you could fish. What was that?

MF:

Well… my experience was growing up to fish… we didn't carry bag.

KP:

Mmm…

MF:

The kupuna's carried the bag, the older people, because the bag was always heavy.

KP:

Mmm…

MF:

So my first experience of fish was using my hands…

KP:

Oh…

MF:

Just going around the rocks and trying to feel. Then if you feel small manini or something you just grab it and pull it out…

KP:

Mmmhmmm….

MF:

…that's you know that's where, how we first learned how to fish. Because at that time we didn't have what, what they now, this modern you know goggles or fins or you know we didn't have that. It was all with our naked eyes. So I guess you know we were born…uhh… I say more in tune of seeing the fish.

KP:

Mmmhmmm.. . And then so after you guys learned how to fish with your hands and you got more better at that…

MF:

Yeah

KP:

…then you learned newer techniques for the kūpuna?

MF:

Yeah. You know you see the reefs out here there's lots of cracks.

[END OF CLIP 3: MVI_0185]

Question repeated as Tape Segment Ended

[START OF CLIP 4: MVI_0186]

KP:

Okay I have to ask you the question again sorry. Okay so uncle, how was it you know growing up from apprentice to actually getting out there fishing either with nets or poles? Tell alitle bit about that.

MF:

Okay… you say talking about poles you know as kids we were growing up we think pole was for girls (laughs)… because our thing is getting into the water you know…

KP:

Mmm…mmm…

MF:

Girls they sit on the rocks (laughs) so it was their thing. So like you know I fished with my hands and then there's cracks out there that they had altered… the cracks were there but they had put rocks within the crack you know so that when the tide comes up, certain tides the fish would go, come inside so you would scare the fish by throwing rocks and they would go in the crack… so you would go with a stick or with a net, scoop net, put it on one side and the fish would go in the net… so that was another thing. Until you know some, some uhhh… Filipinos moved, they were helping farmers up mauka, coffee farmers, so when coffee season was over they would come down to the beach. They were the ones that started making goggles. They hand made everything, every goggles. So they would make goggles for all of us, we in turn would catch fish…

KP:

Oh…

MF:

… and give it to them.

KP:

So that must have been pretty cool the first time you put on the goggles…

MF:

Oh yeah… You look at it wow it's a different world under there (laughs)… not like the technology you get today you know you get big mask, snorkel… you know we didn't have fins till the late 50s you know but to us you know we were as fast as the fish, because we caught ummm… We caught the fish.

KP:

What were the different, I know we already went over some, what were the different types of fishing that happened here?

MF:

Okay… The major the… the major one is upena ku… see you catch more in less amount of time.

KP:

And what was upena ku?

MF:

Okay… Upena ku´u…Ku´u is to stand… the net you know, you put your net around. The net stands straight up and down and then when the fish runs it gets the net so that's

upena ku´u… you know the standing net. So there's trails where the fish run that's where you'd put your net… you know the fish would hit that then you would catch your fish… that's upena ku´u. And then there's throw net you now but not everybody was fortunate enough to have a throw net you know so that was another one. Then… scoop net, that's to catch the small fish or in the crack. Or there's another method that my tūtū guys use to use it was ka´ai…

KP:

Ka´ai…

MF:

Yeah… it was a basket, fish basket. They would put it in the crack chase the fish and the fish would go in. And then there's, there's you fish for different type of fish bamboo or you fish for aha or whatever other fish different type of bait. And then there's also fish for eel, for puhi. They, you know, we didn't you know, care for it, but the people from mauka they loved it, so… My dad told me that they would catch the white eel, uha, okay they would dry it. That's the only fish they would trade…

KP:

Oh…

MF:

They would trade it for beer (laughs)…

KP:

Oh…

MF:

Japanese up mauka use to make rice beer. So… they know, you know they loved that so that's the only thing that they traded. Fish, no they didn't trade it. They gave it.

KP:

You told me they use to feed the eel by hand yeah?

MF:

What, what they ate. Uha. It's the uha, because they uha didn't have teeth. So they would feel, you know, they would put the bait on their hand and they would go in feel. They would pull pull pull till the eel came out. So they say oh this is the one. You know there three or four in this one hole so we'd say this is the one. You know, it wasn't long, but it was (motions with hands to indicate its large girth), because we fed it. We fed it every day. Every chance we get we would feed it. You know we would feed it shrimp, crab, pumpkin…

KP:

Pumpkin (Laughs)

MF:

You know sweet potato…yeah… we would feed it you know anything we had we would feed it. So it didn't grow long, it grow (motions with hand large girth)…

KP:

Fat…

MF:

Mmmhmm…Fat…

KP:

Momona… Oh…

MF:

So that's, you know, that's what they would trade. Because they would catch it, cut it up, dry it, you know, and they would take it up mauka and trade.

KP:

And uh… You're telling me about aha yeah?

MF:

Aha (Nods)

KP:

And how there were only a certain amount of people who could fish at a time…

MF:

You know, theres, theres an aha spot out here, okay, where you can have only three people that fish. Okay before that uh the night, I would say the night before that they would go fishing, they didn't know the aha was in. They would list, they could hear the wave pounding on this certain rock. It would make a certain sound, that they heard. And then the following morning they would prepare and they would come down and go fish. Because it has to be rough. And the three people that fished aha, if you go out there and look where, the three people they couldn't swim (smiles).

KP:

(Laughs)

MF:

My dad was one of them. They couldn't swim (Laughs). But you know to get to the spot, you figured how they did it, you know, but they knew how to do it. And then, you figure, the wall, the wall, the menehune wall is on the outside, you figure they would stand on the menehune wall and fish. You cannot. You stand on the menehune wall its dry, your standing way up in the air. You cannot fish. The fish won't bite, they see, they see you standing up on the wall, you know, so they would move away. The only way is there's three places where they can stand, and they can fish.

KP:

Yeah, that's really really interesting, you know, I am sure most people if they came to an area and they saw… Ho they would go like this, "ho the aha is over there, oh we can all bring the poles over there". But only the people who did it every day or did it, you know, knew when they could fish could they mmmm… understand exactly where you could be.

MF:

Because, the people that caught the fish, would distribute it, you know, because they would, they had their bags long under their (motion under arm) and you know they would just fill it up and then take it out and empty it and go back again. So they would give it away.

[END OF CLIP 4: MVI_0186]

[START OF CLIP 5: MVI_0187]

KP:

Okay Uncle Mitchell, so mmmm, you know we were just talking about, you know, knowing specifics about where to fish like the aha, you know there were only a certain

amount of people who could fish. So, were they there special nights when you could fish or couldn't fish or certain days or times or when did you know it was a good night or good day to fish?

MF:

Well, when growing up they always fished by the moon. Okay, you know full moon is good to go huka, u'u. And then dark nights they go lamalama, torching, you know. So…

KP:

Lamalama?

MF:

Yeah.

KP:

What is that torching?

MF:

Torching…

KP:

Mmm…

MF:

Yeah… So, you know, people say well you know you go lamalama you catch crab, you know, its hard to catch crab because they light spreads, not like now you use a flash light. It hits one spot. At the time it was hard, we would catch a few crabs but the main purpose was to catch kūpe´e, shellfish or any shellfish...

KP:

Mmmhmm…

MF:

… you know that was the main purpose for lamalama. Or you go in the ponds and catch small manini…

KP:

Mmmhmm…

MF:

… that's you know, one method of catching fish. Then upena kū, throw net, you know, and then after it came modern then spearfishing, you know. But we didn't go buy our spear. We made our own...

KP:

Oh, oh…

MF:

… It was made with galvanized tank wire (laughs). You know, we'd get a piece maybe about 5 feet, galvanized you know, mmhmmm. Heat up the end, you bend it, make a small barb, and then you get your inner tube. You know you cut two strips. Put a bamboo, you know tie it on. Then put a string in the back. And that, that was your sling. That's, that's, that's the original Hawaiian sling…

KP:

Oh…

MF:

Yeah…

KP:

And so they mostly fished by the moon? That was the signal…

MF:

… Yeah, fish by the moon. Because of the, the moon determines the tide, you know. So they would fish by the moon.

KP:

And uh… So moving on to question, uh, like, how did the climate change in the Kahalu´u ahpua´a or at even with the, at the bay itself? Did like sea level or temperature or rain or all this kind of stuff, did anything change?

MF:

All this drastic change, you know, like uh, the sea level, is it rising or is the land eroding. I say the sea is rising. Temperature change theres lot of, because the water temperature changed, because of the, you know, development. There's, you know, not that much fresh water flowing in. I, I, you know, I don't know to what if freshwater effects the coral or…

KP:

And uh, do you think there is less rain than there was before?

MF:

There, there is less rain. Definitely there is less rain.

KP:

So the change seem to be mmmm, that you think that the, the, the sea level rised a little bit or to some extent…

MF:

It did, it did.

KP:

… and then mmmm, the water isn't as cold as it was before. And there isn't as much rain as there was before.

MF:

Yea… Because you know, I can remember way back that we use to walk right out here, you know, we use to walk go crossing the, from one rock you jump to the next one, to get across. Now that rock is underwater…

KP:

Oh…

MF:

So it's not the tide. Because we doing, the same, the same time. But we know that the waters rising.

KP:

Mmmhmm… And uh, so then this is between your lifetime, that it's changed, from when you were a young boy till now…

MF:

Till now…

KP:

… And so that I mean, that isn't a very long time you know to have that kind of changes…

MF:

No, no, no… It's not.

KP:

And uh, so other questions were mmmm… you know they all talk about mmmm, how they should manage the bay, you know, and maybe not change the types of things that were here but uh, as a kūpuna and living here for a long time, what would you suggest would, would help the bay continue to survive and provide for the community.

MF:

Mmmm, that's an odd question, you know, to me I think the bay is the fine the way it is now, you know, there's fish out there, you know, but there's less beach, but the fish are still there. Now how can we change that? I, that, that's something that you know, I cannot answer.

KP:

Do you think it's more… that in order for us to pro… in order for anyone to protect the resources here the community needs to be involved and make sure that they mmmm… don't I guess over take resources maybe.

MF:

I guess you can, you can say, you know you can look at the education. Educate the public. Because you can educate the local people and they will understand, but you know, it's the outside people that… but like I say at one time, the outside people is not the people that come in and takes the resources… it's the local people. So you know that the management by the local people is, you know, because there is still fish here.

KP:

Mmmhmmm…. mmmhmmm… mmmhmmm… I guess do you have any final, you have, you have, oh sorry, some words of advice?

MF:

Okay (claps hands) my words of advice is to do more studies like how you (Kaipo) are doing. Studies will bring results. You do your studies you bring back reports, ten years from now other people do studies, they'll bring their report. Did anybody do it ten years ago? Not that I know of. So you know, yours would be first. Who, how we compare yours, we cannot compare yours to some other, you know, other island, or another…

KP:

So just to this site? Compare this site to this site…

MF:

You just compare this site to this site.

KP:

And that is kind of like uh, a little bit of newer age of the kūpuna style of knowledge…

MF:

That's right…

KP:

Instead of me just knowing it for myself I'm writing it down so everybody can see.

MF:

That's right… yea. So you know if I, if I were to go right out I would say I would call my kūpuna and ask them, "did I do the right thing?" It's from me down, it's not from me up. You see, you're doing studies for you up. You are doing studies for the future and not for the past. Like, I, I can talk about the past and dream of the future (laughs).

KP:

But I think your mana´o, your understanding of the, you know, how you know when it is three quarters tide or half tide…

MF:

That's right…

KP:

… you know and all the information you share with me isn't in the text books and so for me to learn from you it's a, it's a great honor, you know that you are willing to share that type of information the you know would mostly be either lost because kūpuna don't feel like have trusted individuals to share this information with.

MF:

That's, that's correct.

KP:

… and so…

MF:

… that is true…

KP:

Would you like to add anything else before we end?

MF:

No, I think we had a good conversation.

KP:

Okay…

[END OF CLIP 5: MVI_0187]

[START OF CLIP 6: MVI_0188] (Question asked again)

KP:

So Uncle Mitchell, you were uh, you were saying uh, you know again just as a clarification with the coral and the fish. So back in the old days when you had areas that were mostly coral those areas didn't have as much fish as areas that were equal in coral, equal in rock?

MF:

Well, there was, but now there's more coral, okay, so we say there's invasive…

KP:

Right, right right…

MF:

…fish coming in that weren't there so you know they would eat with the local fish was eating so it's mostly invasive fish that's it. So the coral on the outside of the wall, inside of the wall the fish wouldn't feed on that. They would fish (feed) inside of the coral. Because inside of the coral to the shore that's where the limu was. That's what the fish came in to eat. And, let me tell you another thing that I just remembered. You know the Hawaiians, when I was growing up, or the people in this ahupua´a, there's uh, let me say there's three fish that they prized highly, the manini, the kala, and the nenue. Why… because they would eat everything. They would the, they would eat from the lips to the tail. Even the, the na´au. Because those three fish eat only limu. Whereas the other fish they would eat limu and sand. You know, so those are the three fish, that they would eat everything. Because manini, they would take the insides and they would make palu, you know.

KP:

So as those other fish, in the old days you had a certain amount like here is it like manini you said and some other of those other fish. So , mmmm… what were the fish you were growing up with? What were there? And what moved out and what came in again?

MF:

Well, no, the fish that I grew up with they'll still, they'll still here. But not in the abundance.

KP:

And those were what fish again, just like before?

MF:

Okay, you can take the, lauwea, there's a big scale uhu family, lawea, the uhu, you know those type of fish they moved further out or they moved (motions outwards with hands) not as much as it was in the bay. Manini there is, there is still manini in here. And kala, and kala the same thing they moved out.

KP:

And in came the la´ī pala.

MF:

In came the la´ī pala and the humuhumu, you know that black humhumu.

KP:

You know it's really interesting that you know it changed like that…

MF:

Yeah…

KP:

Do you, you know why it changed maybe?

MF:

Well… you know, like we started off the coral… So if the coral could grow it could attract. But not like the fish we wanted to try. Because if you go where the catholic church is, you know right at the side, there was no coral over there. Now there's a lot of coral. Then the black humhumu would just use it, that as their home. You scare mmmm, they go.

[END OF CLIP 6: MVI_0188]

Appendix XXI. Raw Transcript: Ray "Chikao" Kunitake.

Kaipo Perez (KP):

Today is April 14th, 2012 and we are on a coffee farm in Holualoa and we're joined by one of the kupuna that is very knowledgeable about not only the mauka end but also the makai end including Kahalu'u Bay. Could you state your name and your date of birth and tell me a little bit about yourself and your family.

Ray "Chick" Kunitake (CK):

Ok. My name is Ray Kunitake but the kine, my friends call me Chick, nickname and I was born on this property February 4th, 1937 that's 75 years ago and I have six brothers and six sisters and I'm the oldest boy numba one son. And my parents, my dad was born in Honoapu and my mother in Honaunau. And then, this property we're on now is in the family about 92, 93 years, and this property used to be plantation, sugar in Kona, and then we name our coffee Waiaha because I use to play in the stream up here, right up here and whenever it rained hard we would have the overflow of the stream would come down to our property so and we used to, I used to go up to Waiaha stream to swim, that's where all of us kids would swim in the waterhole. When it rains we would listen and we could hear the stream flowing we all run up there and wait for the pool to get water so we can, and that's where we all learned to swim, Waiaha. They said it means Waiaha means where the water gathers. And that's why I named the coffee Waiaha River Coffee. And lotta people don't even know about now farm the water but it's one of the most important things you know even down to the beach area and Kahalu'u Bay ok it was a beautiful, beautiful place for everybody to go, even today. But in those days was really nice cuz got lotta freshwater but now I look back you know it deteriorated somewhat because of the years of the wall you know. We use to walk on the wall, way out, there were big boulders. I don't know where it came from but they call it the Menehune Wall. And Kahalu'u and Keauhou Kahalu'u for us kids and adults there was lotta fishes, lots of fishes, lots of coral, lotta birds and lotta freshwater around that area where the hotel is you know. That's where it all, I remember it use to be so cold and I use to catch lotta 'aholehole.

KP:

'Aholehole?

CK:

And I use to bring it home but they were fingerlings you know and I use to raise um I had no food I use to throw it to the pond and they eat up the mosquito fishes you know but that's why it was a bunch of freshwater down Kahalu'u. I don't know today but before the hotel came up there was lots of freshwater and whole, whole bay you could actually feel that water coming out and it was pretty good to drink too because we go down there was no bathroom, no water but today, so we take little bit I like you cut the tree and take the coconut.

KP:

So you guys were actually just drinking water from…

CK:

Yah, it would come out, you could see it, seeping out, low tide not high tide because you take the salt you know, you could see it. When you took you took a little bit you know. The whole coast use to be that way. Kailua had a lots of water coming out of it, right in the bay till today you can see the spring coming out till today but Honokohau, lots of water there. Kona Village, Ka'upulehu lots a water. So I guess even Makalawena and Kukio those places had water and so and the big thing I miss is the birds.

KP:

The birds.

CK:

Yah the birds was abundant, lotta plovers and you sit down next to the shoreline they be coming and land beautifully landing right in front of you and they be looking for food you know and then they fly to the next place and then they come back and then all day the birds would feed. That's what when I go down the beach I miss. As a kid I use to really look at that and say so nice all in a whole flock you know and I enjoyed it and along the all along the coast you could see fishes. Get fish, all kinds of fish all colors and whenever it you watch a wave where there's waves you could see like a like a aquarium you know when the waves just about breaking you could all even in front of Hulihe'e you could see all colors of them even to Old Airport you see all the beautiful. And you look in the tidepools you could see 'opae lotsa 'opae where there's brackish water especially lotta 'opae.

KP:

The red ones or the grey ones or?

CK:

Mostly the white ones.

KP:

Oh the white one yah, yah ,yah, yah

CK:

And you could, in the anchialline pond you would find the red one, you could find a lot I use to see a lot of it you know. But the white one you could use it for bait and you could even eat it also you know so it was pretty good you know. We get a towel or something and we could catch it all you know. That's nice. And then, I don't I don't I look at the ocean today and it's like it's polluted like. The water is grey, it's not as brilliant and nice and clear like then you know. And you could see the fishes swimming before. That's why I'm happy when people like you folks show up. You try to help through university all these volunteers they try to help to keep the place in order again you know.

KP:

Thank-you.

CK:

It goes but till then we should all be able to help a little bit put some kind of effort into it so that next generation people can help but we need leaders to do that somebody that will go ahead, hopefully I don't want to do it you know but if people like you folks come here and do it I don't mind. We need all the help we can especially in Kona.

KP:

So what was your personal connection to Kahalu'u?

CK:

Well that was where we all of us kids even in the '50's that was my connection there was we were gonna have lotta fun, that connection that I had. I knew some people but not too many but when you go there you know you gonna enjoy that place you had water you had coconut, you had tamarind you know all the mangoes and all that they grew there but most of all it was the freshwater you know. It was kinda chilly but you get into it but it was nice to see that the low tide you could see the thing coming out. That was something you know you don't know why or where but it came out of the ground and you said wow freshwater and you could drink it taste it and we drank a lot of it, I drank a lot of the stuff

but like I was telling you before if you drink it today you die (laughs). It's polluted. But at the time you know you go down to the beach and it was there. So the Hawaiian people knew exactly what they had there. It came out a lot. It was nice and clear, it was drinkable. I, I don't know today, like I said my connection with Kahalu'u was you could go to the wall and you could walk across low tide you could jump on the big boulders. I don't know where it came from but that's what it was. But today as I look at it today the wave action and everything is kinda disappearing you know but before it was high and you wonder how did it get there because you never did see, you don't know where it came from. Where did they bring it from? I don't know. But you see boulders on boulders on boulders all right through, huge, huge. Even the bulldozer can't move it today. I don't think so. It's too big. But it was out there. So it was, it's a mystery, I don't think anybody know where it came from either. It was too long ago. But when you think about it, Kahalu'u, it bothers your mind to see that if you saw it but I think back when I go down there I see the wall there but it's hardly anything anymore. The connection there to me is unbelievable when you think about it and how did they move it? I don't know. Nobody knows but if you can walk on it and think about it and then wow. It was, it's a beautiful, beautiful place. It still is but over there again too when you, when you walking on the beach rocks in between the boulders you can see lotsa fish underneath.

KP:
Lotsa fish.

CK:
Lotsa fish, all kine. maiko, manini, you know aholehole, kole

KP:
What's the first one you when say before the manini?

CK:
huh?

KP:
Before the manini you said?

CK:
Manini?

KP:
The one before that one?

CK:
Maiko, kole, all the edible fish.

[END OF CLIP 1: MVI_0245]

[START OF CLIP 2: MVI_0246]

KP:
OK so we already talked about a little bit about Kahalu'u and we wanted to know what it looked like in the old days, how did it change over the years, and about what time that happened and what do you think caused those changes.

CK:
Well, In the old days, in the old days there were no houses.

KP:

No houses.

CK:

K, so not many people to begin with and you can go any, every day and some days and some days you can not one person, nobodys there unless the people who live on the backside and when, when I look at it like I said nobody. Today you go everyday, every hour there's people there either in the water or walking over or driving their car right to the there was no hotel those days and even across the street there was no impact, There was no impact whatsoever when we use to go there. No people, no houses, no cars, no pollution.

KP:

So this was when about the like grade school for you, so elementary?

CK:

Yah, elementary, in the 40's and into the 50's it still was. And I don't know, I was gone in the in the late 50's I wasn't here but in those days you know there were lotta sand but I guess the buildings and hotels you gonna have impact there you know when you do. There's a big hotel there. There was nothing our days. They had, I remember there were some hau trees in the water you know they would grow and way out. And then there were lotta water flowing where the hotel is, there were, that was one of the main waterways I think but they built the hotel so now there isn't any you know. And right now when i see the place it for the bay area its sad because you know it cannot be fixed anymore. There's no way they can fix it. And then because the way the water hit on that side and you know that thing would it would come circle you know the water could circulate. And now even the shoreline it can take so much there's no way the water is going to circulate.

KP:

Is gonna circulate yah, yah. So what about the fish and the coral back in those days?

CK:

There were lot. There were lot a coral. They even though they say that the freshwater but as you go little bit out there were lot a coral. But like I say the impact, Corals don't have a chance to grow in Kahalu'u, I don't, it's pretty hard because of the impact of people. They going step on it you know even though because they gotta see it and adults them want to see the turtles so it's bound to break its down the coral but you know the round, big coral?

KP:

Yah.

CK:

That's a lot a them. And whatever was growing we use to swim there a lot but we didn't know what coral really was. It's a natural, it's a seed it is but today they can. Protect it. But, so that's and the fishes live next to the coral. There must a been a lot a shrimp, a lot a animal in the coral you know when you break it you see you see all this animal in the coral. That's why you had lot a fish, all kinds of fish.

KP:

But was it with a with a lot of coral or when it's a coral little bit of coral little bit of something else so it's more balanced, was there more fish? Were there more fish where there was just no just all coral or were there more when there was more balance with coral and something else?

CK:

Well, I, I think lot a coral and that's what, that's why I said the fishes were there at the time but today there is lot a fishes there too you know and there is lot a turtles. I see more turtles now then I see before.

KP:

So more turtles?

CK:

Yah. Now. But there were turtles all over the coast, the whole Kona coast. Kahalu'u you use to see them among the rocks, the big rocks just resting you know. And like I said there were, they didn't see too much tang in those days but there were lot a manini in balls. They use to travel in balls, in schools and the weke use to travel all in schools. We didn't see them, aholehole, uoauoa. All those fishes are all school fishes and they travel the whole in schools.

KP:

So what type of fish was there in the old days?

CK:

Manini, what is there today but once in a while I see something that I never see before.

KP:

Yah.

CK:

But I see the same fish but not abundant. I see the same type of fish in Kahalu'u today but not abundant like it use to be.

KP:

What do you think caused that?

CK:

I think because the coral I think. The corals gone. I think they fed on those things. And the limu I think because of the pollution they cannot come and eat.

KP:

Yah, Yah, Yah.

CK:

Because I use to see where the tide is coming up you could see aholehole, manini things feeding on the coral on the seaweed I guess the plants let go and like weke but they use to take the sand and things but they were lots you know. And at night you catch upapalu and things like the fish you still taking fish and there were a lot of that. So you use to just go there and then pole and you reach. In those days you would set wall net so right in the bay we use to catch papio and the other kind of fish just get stuck in the net. We were just young kids.

KP:

So wall net you said?

CK:

Yeah. Wall net.

KP:

What other kinds of fishing did you guys do besides wall net?

CK:

Mmm… Torch…

KP:

Torch.

CK:

… with a spear and then use to get this kerosene with a bamboo, bamboo and you roll a burlap bag and you soak it and then you light it. Because there wasn't a flashlight that today you can go diving with (laughs) in those days you know. There wasn't anything like that or you go with a lantern with the harpoon, spear and you go and catch whatever like uhu be sleeping and then you (signals spearing fish). We pick up a lot of in Kahalu´u, we picked up a lot of cucumbers. You know a lot of people like that. So when the tide would be coming in they would be rolling in with the tide. So they all in the deep over there but we would wait till you could see the later the better and we would go and pick it up. That was my time. And then one in a while you had the small little manini, in Kahalu´u, there use to be thousands of them, I don't know, maybe small little ones and we would go with the towel and catch and bring it home and fry it good. I guess lots of Hawaiian ate that with their poi or something. That's what was plentiful at Kahalu´u, Kahalu´u was grand for us. At certain times, the little, small manini by the millions, thousands and thousands and we would scoop it up and bring it home.

KP:

So Kahalu´u always had fish?

CK:

Always had fish. People, if you didn't have food you go over there, I guarantee you catch fish.

KP:

And now what, what you think now?

CK:

Now I don't know, I haven't gone there but I don't think you can catch anything. And besides you cannot catch there because they get angry with you because people looking with the snorkel (laughs) and you catching all the fish. You can't do that. I never went there, when people started to go there I never went there to fish because its not nice to, people are trying to look at the fish and you trying to eat. You taking away from there (Laugh). Kahalu´u you gonna catch something. I'm pretty sure when they didn't have food on the table they'd run down there throw the pole (laughs), no I not kidding you. I'm sure a lot of people did that in Kona. The people who lived down the ocean, they hungry, they just go down to the shoreline put the pole in.

KP:

So you knew you could always be fed by the ocean?

CK:

Yes.

KP:

As long and you take care of mmm?

CK:

At the time we never thought about taking care of the ocean because it was so abundant. But when you look back it was so simple but there was so much fish. You could just go down there (signal dropping fishing line). You know, well me and my dad use to go, we use to go down to Kahalu´u and throw his net. A lot of times I had to carry the bag, bag boy, and then throw the net and untie the fishes from the net and then when you're young you don't want to carry, be a bag boy, you want to play to so I would put the fish in the water and whatever swam away was fine with me. I would pick up the dead ones (laughs). I didn't want to carry the fish.

KP:

That's how plentiful it was. You had to let go of fish instead of take home.

CK:

I did because I didn't want to carry the darn thing. You know pretty soon it was fifty pounds and I only weighed fifty pounds (laughs). That was my job. I had to follow him. And then sometimes he'd throw his net and catch uouoa, twenty-five thirty in one throw.

KP:

One throw?

CK:

Yea. Moi about this size (signals six inches to a foot with hands). You try catch, you cannot even carry the net out. And when you look at the fishes coming up feeding at the tide run and then he would get ready to. I would pray please don't catch fish already.

KP:

You prayed for him not to catch any fish?

CK:

Yea, because I had to carry the darn thing (laughs). So whenever he would catch the fish if manini or whatever kind of fish you know I would just uh I would let whatever swam away. I just let it go. Pick from the dead ones.

KP:

So you were conscious enough only to let, let mmm go so you could walk.

CK:

Yea. So I don't have to carry it.

[END OF CLIP 2: MVI_0246]

[START OF CLIP 3: MVI_0247]

KP:

So…mmm… how did you guys fish sustainability when you … I mean you guys obviously caught a lot of fish but you guys didn't take more than you need and what did your parents teach you guys how to fish? When to stop and stuff like that?

CK:

Well… lot of times when my dad would go down with us we, he go for certain type of fish. He'd look at the ocean and say well today we'll catch some uouoa.

KP:

Uouoa…

CK:

K. Check the tide. He would look at the tide. And he would figure out certain type of fish would be at certain places at certain times. He would be able to throw his net. So we go down to catch some moi. And we go to the old airport. (His brother Earl walks in front the camera while filming) So he would say we go catch some moi today. How he would know we don't know. But he could see the ocean and find out how and what kind of fish is going to be caught. The Hawaiians that's what they did I'm sure. And so we'd go down… Earl…Any ways that's what he use to do. So I'd follow him and I'd watch all the time... [Interupted by his brother Earl]. So when he'd talked about catching moi… he catch so much and we'd have to come home right away because moi is very very… Earl… Earl she is taking pictures (laughs). That's ok (laughs). That's ok. He ate too much fish when he was young. But anyway he would say okay today we catch moi or uouoa. He would know exactly the conditions of the ocean. So we would go and sure enough we would catch moi. He would throw and sometimes he would throw his net he'd catch about thirty in one throw because they come in schools. So he'll sneak up on them and fill his net with manini or uouoa. We always got variety.

KP:

A variety of fish.

CK:

Varieties of fish.

KP:

So what kinds of fish did you guys eat?

CK:

Maiko, aholeahole, moi, and others like uouoa. Those are the better fish to eat, you know.

KP:

What is the maiko?

CK:

Maiko.

KP:

What is that?

CK:

It's a brown looking fish. And that pet, they have a lot of pet names. And then once in a while you catch uhu. Mostly he went for, just uh, many or anything that was abundant. He could catch one throw, he could catch more because there all were in schools. They feed in…

KP:

So he caught based on the conditions yeah you said?

CK:

Conditions.

KP:

The ocean conditions and what everything looked like. And he knew when to go.

CK:

He knew when to go.

KP:

It wasn't just guessing?

CK:

No… He could… From here he could go see the ocean and say he'd tell us today no more fish no go.

KP:

Oh from up here?

CK:

From here, yeah. From Holualoa he'd look the ocean and that's what he would say… No… We want to go down to the beach he'd say "no, today is not right". So that's what happened. How he was raised. He would find a way down and they would just drop him off and he'd find another way to come back. Along the way he'd catch too much he'd give it to all the neighbors. He would stop by here and give them. So they all can have fish too. Nothing was wasted. Even though he could a lot it was all evenly distributed nicely…

KP:

So that they did have to go and fish, he just brought it for them...

CK:

Yeah… they could eat one or two meals.

KP:

Yeah, yeah, yeah.

CK:

That's what he did. And when he came home. We had not too much fish but everybody had something to eat.

KP:

So what… I remember you telling me that only… you would have to go down there and camp to eat some fish because they wouldn't survive coming up.

CK:

Well its certain fish you catch down there you cannot bring it home because it was too long the day. You had no ice...

KP:

Oh, yeah…

CK:

There was no plastic. There was no ice chest before you know (laughs). So you couldn't keep it too long.

KP:

So what fish couldn't you bring up?

CK:

Well if you catch the fish early, let's say the moi or nenue. They would, somehow the meat is very soft. So you cannot keep it all day because we didn't have ice in those days when we were growing up. Whether you live, you're in Kahalu´u, blow hole, or Holualoa beach or anywhere you had to know what's the best fish to catch. You think, if you go

too early you going catch nenue. You cannot sit there all day. You gotta come home fast because like I said they would spoil. When my mother use to go she would be cleaning the fish, so they had to come home much quicker, you know.

KP:

So how long would it take you guys to come down to Kahalu´u, where and how did you guys get there?

CK:

We had car. Once in a while peopled take. And sometimes they are dropping off there. They'd say be here at a certain time, that's how we'd. We didn't have a car you know.

KP:

Did you guys walk there sometimes?

CK:

Well us kids, we walk every Sunday, when there's not coffee. We'd all ran down the beach from here, from Holualoa. We'd always. Because there was no cars for us. But we loved the beach, so we use to run down.

KP:

And how long did it take you guys to go down and up?

CK:

Well down was fast, downhill, you have plenty energy… in the morning. In the afternoon slow but we went a lot of times. And then like I said if you go to Kailua or Kahalu´u you know… you want to stay as long as you can because you can't go there every day you know. So that's what we did, my parents did that, they didn't catch, certain type of fish they would catch it because they knew they would be there a long long because if they brought it home and it spoils. Unless you salt fast. Clean then salt and then you take it up. Whenever we went down there he would catch the fish and he'd get it and put it in the shade. That's how we… we survived on, a lot of fish.

KP:

So you guys not only… you guys caught a lot of fish only to distribute…

CK:

We shared with everyone. That's how it was before. You catch all the fish, you ask if you want fish or your come home and you give it to whoever, your neighbors. So it's not only us that ate the fish, everybody ate.

KP:

So everybody didn't have to fish all the time cause people would bring fish back for each other?

CK:

Yeah, yeah.

KP:

It wasn't everybody fishing at the same time?

CK:

That's right. That's right.

KP:

Cause you said it was empty right yeah, there wasn't a lot of people along the shoreline?

CK:

No (In agreement). He would take me to, let's say… We would go to Honokohau. We'd walk across from Kailua all the way to Honokohau beach. And then there was not trees. No trees, no shade, you'd catch a big fish there you cannot bring it home because it's too far… you need about three hours to walk from Kailua to Honokohau. There were no trees nothing, it was barren. But todays there's a lot trees growing in the shade. And you got plastic you can put your water in, before it was glass. So when you lay down, on your way walking over, you gotta leave your cap or you cannot throw the glass down because it might crack, you don't have any water. And when you get to the other end well you have to stay there over night. You cannot walk back right away. But Kahalu´u to all of us my age, seventies and above, that was a beautiful place for us to go to. I mean look at the people who go there today… you know, thousands. And before when you go there, you may need a day, you stay there all day most of the time. Most of us from up go down there we stay down there. Kahalu´u is very very important to everybody.

[END OF CLIP 3: MVI_0247]

[START OF CLIP 4: MVI_0248]

KP:

Okay so… now we are looking at the fish, the biological stuff. What about the climate, how has the climate change cause now we are going to go into things like global climate change? So how has the climate changed either in Holualoa or at Kahalu´u over… since you were young till now?

CK:

Well, up here where we live, Holualoa, well uh when we were younger, okay years back you know if you talk about rain well… I remember many many a days that when it rained here it rained at certain times of the day. And it was very consistent. Okay let's say okay every day 4:00 pm, 4:30 pm and you'd be picking coffee let's say, and coffee season winter time and even then when there were lots of August, August, September, October, November, December, every day I remembered it comes about 4:00 pm, 4:30 pm. The clouds would come over and we would have rain. Guarantee.

KP:

Guarantee…

CK:

Guarantee rain before. Every day nicely it would just come, not hard, but softly, but you would have rain. You could predict it was going to rain. And that's how it was…

KP:

And you could predict when it was going to rain and at what time is was based on the…

CK:

Yeah… so you can. you know, when you are working the fields you know oh it's going to rain a certain time and certain you know. So what you would do, you would have to close the platform (hoshidana: drying platform for coffee) because the coffee is drying and things like that. So you knew more or less when it was going to rain. And today you don't see it anymore. It's amazing you know when you think back and then now, today, it's not the same. You don't know when it's gonna rain. You don't know how long it is going to rain.

KP:

When did it stop?

CK:

I don't know. I don't know when it stopped…

KP:

Ten years ago?

CK:

When I went up… could be. Could be ten years.

KP:

Maybe longer?

CK:

Yeah… yeah little longer I think. It use to… growing up also my high school time it rained at certain times of the day. Somehow it came, you just take that for granted already. "Oh it's going to rain today about 4:00 pm". You know, so you can't do anything you know like outdoors kind of stuff. And then mmmm… So that's how we got use to that. You take everything for granted after a while and after a sudden you don't have it and you say to yourself, "not like before". You don't know why. We don't know why. We not scientist you know but you could feel it, because you know that does happen. Although we had our drought too before. You know we had drought time too. But consistently, it use to be that way where we live, Kona side.

KP:

What about the temperature? Did it get warmer? No? You don't see that much changes? You don't know?

CK:

No, I don't know.

KP:

What about the ocean anything different too?

CK:

Well…

KP:

In terms of the climate? Rain less at the ocean? The water was warmer? You're not sure?

CK:

I'm not sure about that.

KP:

But I'm sure the rain, since it wasn't raining up here (in Holualoa) that means the water wasn't going down there either.

CK:

Yeah, that's right. But even trickle slowly but when it rains hard that thing be really coming out. Even in… okay Kahalu´u was the same because people don't have any idea how much freshwater use to come out of that area. And then in Kailua when it rains hard, rain all the time hard, you could see the water boiling out, right in the bay. Till today, there is a spring there that use… when you go there in the morning, when it's very calm you can still see the water coming out today. By that Banyan, Bayan tree there is a Bayan tree right in town after Hulihe´e Palace. If you look straight at Hulihe´e Palace,

you could see the spring there. A big one. Use to be about two or three, but now all I see only one. But if you wanna have an idea of how it was you can see it.

KP:

So right off of Hulihe´e Palace?

CK:

Yeah, right across. As you looking at towards T. Chan from Hulihe´e Palace. You look you just see the thing still coming out. In the mornings especially when the tide is low. The thing really bubble out. And I guess all the coast use to be that way. But the climate change I don't really…

KP:

Besides the rain at least?

CK:

Yes. But I know the rain is not as consistent though. It's a way way big difference.

KP:

Yeah… I'm sure especially since these are all farmers yeah.

CK:

Yeah.

KP:

And I'm sure what they could plant changed.

CK:

Yes.

KP:

Since it does not rain as much anymore, did you see different types of birds or animals leave here because it doesn't rain as much?

CK:

Well… they they yeah the birds. It's all important anyway the birds. And then right now. Since the tsunami came I see different types of birds. You know in Japan they had a big… and I guess they lost their habitat. But I see them but I never see them before yeah you know but they getting more and more birds where we live. Because they brought in people from the wildlife people I guess they let go. They're beautiful though but there not, there from somewhere else. But I see the hawk. The Hawaiian hawk still lives here. Sometimes it's like National Geographic. You see them hunting you know. And you can hear the owls.

KP:

How does it hunt, the hawk?

CK:

Well they're on the trees or they can see a rat from a mile or a half a mile. You can see them really coming in to attack. The catch a lot of birds and then they take it up to feed. Then you go next to it here and you can see it eating it, like National Geographic you can really see it picking up the rat, baby chicks or whatever you know. And that a bird a beautiful bird.

KP:

And you told me stuff about like when it's done eating. What happens? It cannot fly away?

CK:

Yeah. They catch a big rat or something a big one and they eat it. They don't waste anything they eat everything. And then when they pick up a big bird or something they can't fly off, far away. If you look among the tree you will find them because they can't fly you know. They too full yet. They eat everything except the feathers. They catch the bird and they eat the feather. They don't eat the feathers they eat the whole thing. But they say it was endangered at one time and now it's okay they are coming back. I see them you know.

KP:

What about the bats, the bats too yeah?

CK:

Yeah there were lots of bats here. All of a sudden they disappeared. I don't know. I haven't seen one in six months already.

KP:

Six months?

CK:

Yeah. I don't know what happ… I use to see them in the evening they would come out and you could see them squawking all over. And at night when the light is on next to the building they come in and catch the bugs. It's beautiful and I use to get a sling shot and I use to shoot bread and they use to go and pick it up. Not to shoot mmm down but to see if they chase it you know. Soon as I put something in and I shoot it they chase after that because they have radar I think. I used to play with that.

KP:

That's when you were younger? You use to shoot them with a sling shot?

CK:

Yeah. But not shoot them down. Just so they chase the food. You didn't have much toys so this is the things you do you know. That's an amazing, amazing animal. At night that's when they come out. At night time. You can see them. They were a lot, lots. They losing their habitat too I guess. But uh, they still around though. But and then at night sometimes you can see them coming around and flying catching the moths and things like that.

KP:

But you just haven't seen them in a long time.

CK:

Six months now. Maybe they lost their habitat and had to go someplace or something. Those are beautiful animals when you think about it. When you look at what they do. You never know how much bugs at night here in Kona. Dark night you shine mmm flashlight you can see the moths flying so. That's a food source I guess.

[END OF CLIP 4: MVI_0248]

[START OF CLIP 5: MVI_0251]

KP:

So, What are your words of advice in terms of the Kona community, in terms of Kahalu‘u Bay and as well as words of advice for maybe your family, or either the ocean or about the coffee?

CK:

Well, Kahalu‘u Bay my advice is for people like you to keep coming back so then we, people can get motivated so it’s so important to get outside help now. We ourselves who live here all our lives we don’t know how healthy the reefs is, we don’t know to motivate people to take care of the ocean. We gotta learn this you know. ‘Cuz we’re so far removed already. You folks have access to lotta things that we’re not. So if you go and University of Hawai‘i come like all those Drs. degrees and they can more or less get an idea of what we should do. Then we can do something but just standard like us people like us we don’t know what to do. We’re culturally lost already, we’re losing it so we need outside help. Especially university who have access to many things and all those people who volunteer, they go all around the world to volunteer, people who live here. Because I’m sure that if you do have people like you folks come over and do some research and we would like to keep our backyard nice or front yard whatever you call it beautiful so people can enjoy it you know. But if people like you stop then it will stop too. It takes a long time before you can get people to volunteer nicely and to understand the ocean. Most of us, we don’t understand but we know what is out there but we don’t know how to go about it. We need outside help right now, big time you know and then this way the kids, then the young kids, they can do something. But if just now, like my age kinda guys, we don’t know. We don’t have enough knowledge. So I don’t know. You gotta drag the kids into the ocean, you gotta drag them down. So who has the power you know can do that? So that’s what I see, you need the young kids, six years old, five years old, elementary school kine, these are the ones that take a long time to learn. Today we don’t even know what kinda things are even in the ocean. People don’t go to the beach to eat fish anymore but we need it for like tourism, economy wise, we need the ocean for that because in Kona we had nothing, all we had is the ocean, for tourism, for survival, jobs, and we have to depend on you know, the ocean. And my advice is come help us. I’m begging, I’m begging, people like you guys to do that.

KP:

Well, we’ll try to do the best we can.

CK:

Yah, that’s why I always had Dr. Ku’ulei Rodgers I’m very happy they take care of us. We’re very grateful for people from UH, people like you or anybody come along about it even those people who paint, take photos of the ocean, it’s a big decision, they can see how beautiful it is. Whales, turtles, there are people who can study the sand or the ocean, the salt, you know, and these are the things that I’d like to see happen in Kona. We need more marine biologists so they can target and protect the area because we losing it, every day goes by mention the ocean, unless we have people that know something about it come down and tell us, it helps then we can’t do it. And then we need it because our economy in Kona is tourism and we need them, bad, big time we need them to come. That’s why I always tell Dr. Ku’ulei thank-you for coming, you know. But unless you love, you think about the ocean a lot, you don’t really know, you just go down the beach and that’s it, you know, you come home and you don’t really think about it. Nobody knows, the pollution but it’s there, it’s out there, everyday it’s polluted, every day the ocean. The Kailua area, if I drive the car, that’s oil, come rain time, it goes into the ocean, right there, right in front of us. And then lotta times I see where even the Old Airport people cleaning the place up but they drive their diesel truck right on the sand, right on the ocean. Right there already. They park their cars next to the ocean yah, it run off and goes in there, but you can’t help that. That’s the way they are you know, we want access but we don’t want to take care. Yah, Waikiki same, right there.

KP:

So, you have any last words? Any additional things you want to say before we conclude this interview?

CK:

Yah, Come to Kona, beautiful ocean. Please come to Kona. Stay at our hotels. Eat at our restaurants. But Kona is, I find it's a very unique place. I don't think there is, this is one of the very few places where you can enjoy. It's expensive to live in Kona today but just the same, it's nice. So we live here, we don't know it but we should be very grateful that we live in Kona. That's why King Kamehameha stayed here. He knew it was a great place.

KP:

Ok, Thank-you very much for allowing us to interview you so we could document your knowledge because it's really important because people don't have that knowledge from that far back you know and you really speak of things that come into the same context as other kupuna that we interview. Thank-you very much.

CK:

You're welcome. Anytime, especially you people from UH, all you marine biologists. Come to Kona. Help. We need help. Thank-you.

KP:

Thank-you.

[END OF CLIP 5: MVI_0251]

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