Honolua Bay Review:
A review and analysis of available marine, terrestrial and land-use information in the Honolua Ahupua‘a Maui 1970- 2007

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Prepared for Hawaii's Land-based Pollution Threats to Coral Reefs Local Action Strategy

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Executive Summary

Introduction

Honolua Bay is a popular recreational area for locals and tourists alike and offers some of the best snorkeling and surfing conditions on Maui. It is considered to have one of the most diverse, unique and abundant reef formations on Maui and provides habitat for atleast one species of rare coral, and is a resting ground for the green sea turtle. Honolua bay and adjoining Mokuleia Bay are designated a Marine Life Conservation District and protected from fishing and harvesting.

The watershed has a long history of diverse land uses that have influenced the condition of the Bay. These include grazing, agriculture, development activities, and the introduction of feral ungulates in the upper watershed. Until recently pineapple cultivation was the major land-use in the lower watershed. Public concern over perceived increases in sediment and chemical pollution associated with agricultural and development activities grew in the 1990's and continues today. Now that agriculture has ended, the community is concerned about the future of watershed and associated impacts on Honolua's reefs. In addition up to 600 snorkelers visit the Bay daily and there are no formal management measures or visitor facilities.

The diversity of Honolua's reefs and concerns about its health has lead to a plethora of research and monitoring projects in the Bay and the adjacent watershed. Studies have assessed the economic, cultural, and biological value of the bay and watershed separately. Several studies have focused on factors influencing the health of the coral reef ecosystem. However comparison between these studies is difficult because they have been conducted by different researchers using a variety of methods. There have been few attempts to synthesize and critically analyze all available information, including land-use and marine data. This has made it difficult for resource managers and scientists to identify research gaps and priorities in the bay and to focus management efforts.

The synthesis and critical analysis of available data and information on land use, runoff, water quality and the health of the coral reef ecosystem at Honolua Bay was identified as a priority project in Hawaii's Local Action Strategy to Address Land-Based Pollution Threats to Coral Reefs (LBPLAS). This report is limited to available literature for Honolua Ahupuaʻa published between 1970 and June 2007.

Trends in Land-Use

Until recently land-use within the Honolua Watershed had not changed considerably for 30 years. The main changes since 1976 have been a decrease in agricultural land with the end of pineapple cultivation (27% to 7% of total area), a 16% increase in the total area covered by forest, and a 5% increase in the area used for residential development.

It is likely that soil loss from pineapple fields decreased dramatically in the 1970's with the introduction of BMP's, and continued to decrease with the improvement of pineapple farming practices and installation of 22 BMP's between 1994 – 1996. Another reduction likely occurred in 2003 with the decrease in pineapple, and in 2006 when pineapple cultivation ended. However development activities also began on Honolua Ridge in 2004 and were a potential source of eroding soil.

Most of the watershed is forested (~83% or 2,509 acres) and approximately 74% (2,248.5 acres) of the entire watershed is protected through inclusion in the Pu'u Kukui Watershed Preserve (1,197 acres) and Makai Conservation Area (1,052 acres). Residential development comprises 7.9% (240 acres) of the watershed and 2.5% (76 acres) is golf course. 203 acres (6.7%) are zoned for agriculture. Thus any future land-use changes will occur in the land zoned for agriculture. There are no current plans to expand residential developments or golf courses however this could be proposed in the future. New agricultural uses, such as organic farming or grazing, are not currently planned but could also be proposed. It is likely a portion will be designated for parkland.

Management efforts should focus on restoring the lower watershed that was previously utilized for pineapple cultivation. Priority should be given to revegetating denuded/exposed areas that are eroding such as old pineapple roads, unpaved roads and trails, and badlands. ML&P with assistance from the community has already started revegetating an old pineapple field. Similar collaborative projects should be encouraged.

A watershed plan, that incorporates a unified vision for the Honolua Watershed, is urgently needed to better manage the area. Urgent action is needed to ensure the sustainable use of Honolua Bay for future generations.

Trends in Water Quality

MRC reported that water quality in Honolua Bay was relatively consistent since their monitoring program began in 1990 (MRC, 2007). They observed that the

Bay was consistently stratified both vertically and horizontally during that 16 year period. An upper layer of low salinity, high nutrient water was consistently present. This surface layer was influenced by groundwater, stream flow and inputs from land. In contrast the un-mixed lower layer of saltwater was not affected by freshwater input. Three zones were consistent within the bay: an inner zone with low salinity and high nutrients (Si, NO_{3-}, PO_4^{3-}), a central zone with elevated nutrients (Si, NO_{3-}, PO_4^{3-}) and an outer well mixed zone with oceanic conditions (low nutrients).

The geometric means of samples collected at all stations during the nineteen surveys showed that water quality parameters were generally in compliance with State water quality standards for wet embayments. The only exceptions were NO_{3-}, turbidity and Chl *a* in near-shore waters. It is likely that there were changes in nutrient and sediment delivery to Honolua Bay even though water quality parameters have shown little change over the last 16 years. Changes in water quality parameters were difficult to detect because monitoring was undertaken only once a year and at irregular intervals, presenting a brief snapshot of water quality condition. Water samples were collected when freshwater was generally not flowing from Honolua Stream, at low-tide during periods of mild trade-winds and when there was little swell. Thus sampling conditions may not have been representative of the average conditions in the Bay. In addition the small number of samples (19 total over 16 years) makes it difficult to establish compliance with water quality standards. Routine monitoring is needed to assess compliance with water quality standards and changes in water quality conditions.

Because of the vertical and horizontal stratification within the bay monitoring could be limited to near-shore surface waters of the inner bay and Honolua Stream. At a minimum monitoring must occur during the summer and winter months, to capture dry and post-flood conditions. Replicate samples should also be analyzed to account for variability in water quality. It is recommended that bacteria levels are routinely monitored to ensure water quality meets human health and safety standards, and total suspended solids are analyzed.

Groundwater needs to be sampled periodically to determine background nutrient and contaminant concentrations. Long-term in-situ turbidity monitoring should also be implemented to assess the variability in sediment runoff and help quantify the impacts of sediment runoff on coral reef condition. This monitoring should be integrated with coral reef monitoring programs.

Near-shore water quality and bacteria monitoring should be incorporated into DOH's existing beach water quality monitoring program. Additional monitoring and research should continue to be supported by ML&P and other agencies. The use of volunteer monitoring programs must also be considered as both an outreach and data collection tool. Regardless of who leads the monitoring program, any future water quality monitoring must be subject to critical review to ensure that sampling and data collection support any water quality status/improvement claims.

Trends in Coral Reef Condition

Coral cover in Honolua Bay has generally decreased since the first surveys were conducted in 1974. It is difficult to compare coral cover data between studies because of differences in survey methods and survey sites. Because of this discrepancy only general trends were compared between different studies.

All studies concur that there are differences in species composition between the north and south reef. The north reef is dominated by *Porites* sp. while sediment resistant *Montipora* sp. are dominant on the southern reef. There is also agreement that sediments and wave action influence coral cover. High turbidity and sediment deposits in the inner bay have been observed consistently since 1974.

MRC did not observe any significant difference in coral cover between 1990 and 1992. They found that coral cover significantly decreased between 1992 – 2002 and increased slightly between 2002 - 2006. Because monitoring was infrequent MRC could not determine if there had been a gradual decrease in coral cover between 1992 – 2002 or if a single runoff event in 2002 caused the mortality.

The CRAMP data from 1994 – 2007 shows a steady decrease in coral cover during 1994 – 1999, stabilization occurring from 2000 – 2004, and then a decrease again in 2005 - 2007. This differs to MRC's observed increase in total coral cover from 2002 – 2006. This slight increase was caused by a significant increase in coral cover on only 2 transects that were not impacted by sediment runoff in 2002. Conversely coral cover decreased significantly on the shallow transect located nearest the shore on the southern inner reef. Cover did not change significantly on the other 5 transects.

Although there are differences between CRAMP and MRC data, the general trend is the same: coral cover has decreased since their monitoring programs started in 1994 and 1990 respectively. It appears that the large decrease in coral cover observed by MRC in 2002 was cumulative rather than caused by a single runoff event. This emphasizes the importance and strength of regular coral reef monitoring.

In addition to the changes in coral cover Brown (2004) also found that there was low coral recruitment success on the northern reef flat. The low rates of recruitment, low growth and high mortality shown by his short-term studies indicated that future disturbances could further degrade the reef structure. He also predicted the southern reef flat was undergoing a “slow steady decrease in several abundant coral species” and that the remaining species showed no evidence of increasing cover. Unfortunately his prediction may be occurring on the reef flats in Honolua Bay.

It is apparent that erosion of soil and subsequent sedimentation events have caused declines in coral cover, impacted coral recruitment success, and are affecting the long-term condition of Honolua’s reefs. In addition other anthropogenic variables, such as chemical pollutants and increasing human use, are likely contributing to the long-term decline in coral cover. Honolua’s coral reefs have adapted to the bay’s wave action, water circulation patterns and influx of stream and ground-water. However human activities are altering the reefs resilience to both natural and anthropogenic stressors. In order to stop this long-term decline in coral cover, management efforts must focus on reducing anthropogenic sources of stress.

The lack of quantitative data makes it difficult to determine the specific cause(s) of the long-term decline in coral cover. The continuation of long-term coral reef monitoring is critical. Future monitoring should utilize standard survey methods, such as the CRAMP protocol, to reduce discrepancies between long-term studies. The CRAMP protocol has been validated and is utilized State-wide and should be continued in Honolua Bay. If possible monitoring should be expanded to include at least one deep site on the reef slope (similar to other CRAMP sites). This would provide a better understanding of Bay-wide trends in coral condition. Alternatively MRC’s monitoring program could be used to supplement CRAMP’s limited survey sites. However this would require the use of comparable methods, including permanent quadrats by MRC.

As well as long-term benthic monitoring, long-term in-situ turbidity monitoring is urgently needed to help quantify the impacts of sediments on Honolua’s coral reefs. It is also critical that coral recruitment rates continue to be monitored regularly.

Honolua Bay and has some of the highest fish assemblage characteristics (species diversity, species richness, number of individual and biomass) of reefs in the MHI (Friedlander *et al.* 2003). Based on the data reviewed in this report it is difficult to determine how the fish population has changed over time. None of the available reports assessed changes in the fish population and it is difficult to compare between studies because of differences in survey methodologies and changes in fish taxonomy. Long-term data has been collected by Friedlander/ CRAMP/DLNR-DAR (from 1998) and MRC (from 1990) and needs to be analyzed. This analysis was beyond the scope of this project and is recommended for future work.

Information Gaps

Information gaps for the marine and terrestrial ecosystem in the Honolua ahupua'a were identified during this review. Certain components of the ahupua'a have either not been studied or data was not accessible for review. Perceived information gaps are listed in groups below:

Stream Hydrology and Biology Gaps:

- Comprehensive survey of stream flora and fauna
- Quantity and quality of stream flow
- Watershed scale hydrological studies and modeling
- Stream monitoring program
- Effects of stream diversion on stream and marine biota

Marine Ecology Gaps:

- Comprehensive list of marine invertebrates (last surveyed in 1979)
- Comprehensive data on prevalence and occurrence of coral and fish disease
- Marine vertebrate surveys
- Comprehensive list of marine macroalgae
- Analyses of long-term fish data sets
- Cause(s) of coral cover decline
- Biological impacts of sedimentation and turbidity
- In-water monitoring of recreational impacts on coral reefs

Water Quality Gaps:

- Comprehensive long-term water quality data
- Long-term in-situ turbidity data at coral reef
- Location, quantity and quality (nutrients and contaminants) of groundwater input

- Fluxes of freshwater and nutrients from groundwater vs stream flow
- Quantity and quality of stream flow
- Integration of water quality and coral reef monitoring

Geospatial Information Gaps:
- GPS locations of early coral reef and fish surveys (many sites were identified by landmarks in the field)
- Detailed land-use maps

Recommendations

This study highlights the multitude and diversity of studies conducted in the Honolua Ahupuaʻa over the last 37 years and identifies gaps in knowledge for both the marine and terrestrial environment. The following recommendations are aimed at improving management of marine and terrestrial resources within the ahupua'a to ensure their sustainable use for future generations. Key recommendations include:

- Develop an integrated coastal area management plan
- Implement regular water quality monitoring, including:
    - Incorporate near-shore water quality monitoring, including total suspended solids, of Honolua Bay into the State's water quality monitoring program,
    - Incorporate bacterial indicator monitoring into DOH's beach monitoring program
    - Monitor the quantity and quality of groundwater,
    - Implement long-term turbidity monitoring, and
    - Monitor stream flow.
- Continue long-term coral reef monitoring (benthic, coral recruitment and turbidity)
- Support studies that address identified gaps in knowledge

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Acknowledgements

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1.0 Introduction

1.1 Background

Honolua Bay is a popular recreational area for locals and tourists alike and offers some of the best snorkeling and surfing conditions on Maui. It is considered to have one of the most diverse, unique and abundant reef formations on Maui and provides habitat for atleast one species of rare coral, and is a resting ground for the green sea turtle. Honolua bay and adjoining Mokuleia Bay are designated a Marine Life Conservation District and protected from fishing and harvesting.

The watershed has a long history of diverse land uses that have influenced the condition of the Bay. These include grazing, agriculture, development activities, and the introduction of feral ungulates in the upper watershed. Until recently pineapple cultivation was the major land-use in the lower watershed. Public concern over perceived increases in sediment and chemical pollution associated with agricultural and development activities grew in the 1990’s and continues today. Now that agriculture has ended, the community is very concerned about the future of watershed and associated impacts on Honolua’s reefs. In addition up to 600 snorkelers visit the Bay daily and there are no formal management measures or visitor facilities.

The diversity of Honolua's reefs and concerns about its health has lead to a plethora of research and monitoring projects in Honolua Bay and the adjacent watershed. Studies have assessed the economic, cultural, and biological value of the bay and watershed. Several studies have focused on factors influencing the health of the coral reef ecosystem. However comparison between these studies is difficult because they have been conducted by different researchers using a variety of methods. There have been few attempts to synthesize and critically analyze all available information, including land-use and marine data. This has made it difficult for resource managers and scientists to identify research gaps and priorities in the bay and to focus management efforts

The synthesis and critical analysis of available data and information on land use, runoff, water quality and the health of the coral reef ecosystem at Honolua Bay was identified as a priority project in Hawai`i's Local Action Strategy to Address Land-Based Pollution Threats to Coral Reefs (LBPLAS). The LBPLAS provides an overall framework to document the significant ongoing efforts in the state to address land-based pollution threats to coral reefs as well as to guide the development of new priority actions. The overall goal is to "reduce land-based pollution to improve coastal water quality and coral ecosystem function and health." This study was undertaken as part of the LBPLAS and was funded by a NOAA coral management grant to the DLNR-DAR.

1.2 Report Purpose and Scope

The purpose of this report is to:

1. Identify information gaps, areas of concern, and trends in coral reef ecosystem health related to water quality, runoff and land use change in Honolua Bay.
2. Develop a technical report that can be used by scientists and managers to guide future research and monitoring efforts in Honolua Bay.

This report is limited to available literature for Honolua Ahupuaʻa published between 1970 and June 2007. Ahupuaʻ*a* are watershed areas that encompass water source areas in the mountains and extend offshore to include coral reefs and coastal resources. Traditionally, each ahupuaʻa contained nearly all the resources Hawaiians required for survival (Kamehameha Schools Press 1994). For the purposes of this report, the ahupua'a includes Honolua Bay and its adjacent watershed.

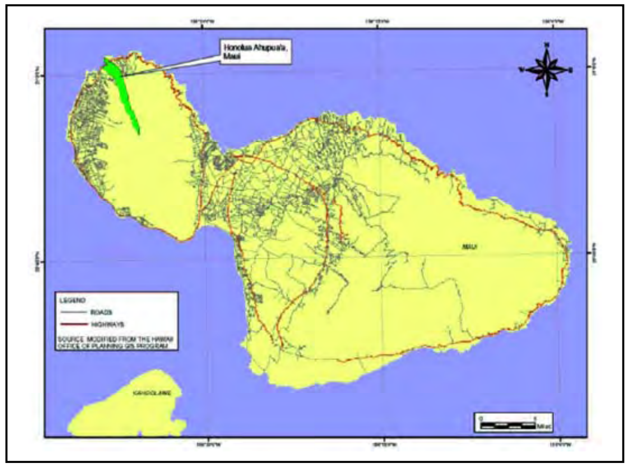

Figure 1. Location of the Honolua ahupua'a (shaded in green) on the NW tip of Maui. Source: U.S. EPA *et al*. 2004).

The Honolua watershed is located approximately 10 miles north of Lahaina on the northwest tip of Maui (Figure 1). The watershed covers approximately 3028 acres or 4.7 square miles (CRAMP, 2007) and includes the drainage area of Honolua Stream, Papua Gulch, and Pahiki Gulch. Honolua Stream is an interrupted perennial stream, approximately 7.5 miles long with an estimated flow of about 5 million gallons per day at the upper elevations (United States Environmental Protection Agency *et al.* 2004). The stream flows into the southern end of Honolua Bay, a 26.5-acre, semi-enclosed embayment bordered north and south by basaltic cliffs.

2.0 Land Use

The Honolua ahupua'a has a long history of diverse land-uses dating back hundreds of years. Evidence of extensive terraces within Honolua Valley indicate that taro was cultivated during the time of the Hawai'ian Kingdom (pre 1850's) (Bishop Museum, 1973). Although there is no available information about the specific land practices used during this time, they are believed to have been less intensive than European land-uses (Muneikiyo, 1992). The type and intensity of land-use has changed dramatically since European settlement. A time-line of important activities is presented in Table 1 and described below.

2.1 Historic Land Use

2.1.1 Cultural Setting

The Honolua watershed is in the traditional Hawaiian land division of Honolua Ahupua'a, and within the traditional cultural district (moku) for Ka'anapali (SCS, 2006). Honolua Valley is 1 of 5 valleys in the former Ka'anapali district that drain the western slopes of West Maui (SCS, 2006). "In traditional Hawaiian times, the five valleys provided West Maui with rich, substantial lands amenable to the construction and use of large agricultural systems. Hawaiians in the area developed extensive irrigated taro terraces (lo'i) and drainage systems ('auwai) that supported a large population" (SCS, 2006). "Inland resources such as taro, sweet potatoes, etc. were brought to Ali 'i residences at the coast from nearby plantations. Extensive cultivation of dryland taro and sweet potatoes, supplemented by coastal fishing, supported a sizeable ancient Hawaiian population. Throughout all of Hawaii, coastal lands were utilized for chiefly residences and Honolua was no different. Oceanfront areas provided easily accessible resources such as elaborate offshore and onshore fish ponds as open-ocean, or deep-water fishing. Surfing was very popular among the elite and was known as the sport of kings. The project area's coastline provides paramount surfing for coastal locales, now infamous throughout the entire world." SCS, 2006.

Honolua Bay is one of the 6 famous Hono-a-Pi'ilani, or the bays acquired by Chief Pi'ilani (Bartholomew, 1995). It also is significant for Hawaiian Canoe Voyaging and was the departure point for Hokule'a voyaging canoes maiden voyage to Tahiti in 1976.

Several archaeological and historical sites were identified by Bishop Museum staff in 1974 and re-surveyed by Scientific Consultant Service Inc. (SCS) in 2006. Thirteen sites have been identified in Honolua including 2 Heiau,
boulders with grinding surfaces, house platforms/burial mounds, agricultural terraces/houses platforms, and midden (Belt and Collins, 1979). All sites were assessed as being historically significant under Criteria D (site has yielded or has the potential to yield information important in prehistory or history) and are being preserved and monitored (SCS, 2006).

Table 1. Timeline of significant land-use changes and historical dates..

Date	Activity
<1850	Traditional Hawaiian Agriculture, extensive taro loʻi and terracing by native Hawaiians (pre-European contact)
1880's	H.P Baldwin acquires Honolua Ranch Land and begins cattle and coffee production
1912	First 20 acres of pineapple planted, work starts on Honolua Ditch, Honolua plantation office moved to Honokahau
1913	Honolua Ditch completed
1914	Honolua Ranch headquarters and Honolua Village relocated from Honolua Valley
1924	Honolua Ranch renamed to Baldwin Packers Ltd.
1929	Baldwin Packers includes 2500 acres in pineapple cultivation, 300 acres in ranching (including other watersheds)
1932	10 acres of aloe planted by D.T. Fleming
1938-1940	Mango, avocado, citrus, lychee and macadamia nut trees planted by Fleming on Baldwin Packers, and watermelon planted on ranch land.
1946	Ranching discontinued, and tsunami destroys remaining community in Honolua Valley
1954	Feral pigs introduced to West Maui for sport
1955	Aloe experiments end
1962	Baldwin Packers merges with Maui Pineapple Company
1969	Cameron's become sole owners and change company name to Maui Land & Pineapple Company. MLPC becomes publically traded.
Late 1960's	Pineapple BMP's introduced
1976	Kapalua Resort developed on 30 ha (includes 3 golf courses, 3 hotels, residential area)
1978	Honolua and Mokulea Bay declared a MLCD
1994-1996	22 BMP's installed
2003	MLPC starts phasing out pineapple in Honolua
2004	Honolua Ridge Phase I lots go on sale July
2004	Diversion of Honolua stream ends
2006	Pineapple farming ends in the Honolua
2007	Development plans for Honolua and Lipoa Point introduced to Maui General Planning Advisory Committee
2007	Maui County planning to purchase Lipoa Point from MLPC

2.1. 2 Historical Ranching and Plantation Era (1880- 1970)

The history of Maui Land & Pineapple Co. and Honolua Ranch is described in the book "Plantation Days" by Cameron & Keane (1987) and is summarized below.

H. P Baldwin acquired most of Honolua Ranch through a series of land-grants and purchases by the end of the 19th century. The first ranch manager, Richard Searle, ran the cattle operation and planted coffee in the mountains. The ranch continued to grow coffee in the early 1900's, which was good quality but made limited profits because of the low market price. D.T Fleming became the ranch manager in 1911 and planted the first 20 acres of pineapple in 1912. In the same year the Honolua plantation office was moved from near Honolua Bay to Honokahau. Work also began on Honolua Ditch to replace the aging wooden flumes of the 1902 Honokohau ditch. The ditch was completed 18 months later and improved water collection from the Honolua, Honokahua and Honokahau valleys. The ditch was 7 miles long, including 6.4 miles of tunnels. It's capacity was 70 million gallons of water per day with an annual average of 25 million gallons.

Cattle ranching continued for several years but was slowly replaced by pineapple crops. In 1924 the Ranch was renamed to Baldwin Packers Ltd. to reflect the emphasis on pineapple cultivation. By 1929 there were 2500 acres in pineapple and only 300 acres used for ranching. In 1932 D.T. Fleming planted 10 acres of aloe and conducted experiments for 20 years in the hope of developing a marketable aloe product. Between 1938 – 1940 Fleming tried to diversify agricultural operations and planted mango, avocado, citrus, lychee and macadamia nut trees on Baldwin Packers land, and watermelon on ranch land. None of these crops were consistently profitable, and were removed. Ranching was discontinued 1946 and aloe trials ended in 1955. In 1962 Baldwin Packers merged with Maui Pineapple Company.

Between 1900 – 1950 thousands of tree seedlings, including hardwood trees like teak, mahogany and eucalyptus as well as exotic fruit trees were planted on Honolua Lands. Ironwood was also planted for windbreaks and as fuel for domestic use. Many of the seedlings died because of drought and wind damage, but portions of an old arboretum still exists in the mountains. Fleming was also responsible for planting the Cook and Norfolk pines that line Kapalua.

Feral pigs were introduced to West Maui for sport in 1954 and caused severe damage to watershed areas (Munekiyo, 1992). The Natural Conservancy in cooperation with ML&P assessed the upper watershed in the 1970's and 1980's and identified that feral pig activities were a threat to native vegetation and a source of soil erosion (EPA *et al*. 2004). In 1988, The Nature Conservancy and ML&P established a conservation program to reduce the numbers of feral animals. The partnership was expanded in the 1990's to become the West Maui Mountain Partnership to include other private land owners, DLNR, and other government agencies. Implementation of strategic fencing, pig hunting, and snares has caused a tenfold decrease in pig numbers over the last 10 years (ML&P 2003).

2.2 Recent Land-Use

2.2.1 Pineapple and Resort Development

By 1969, the Maui Pineapple Company had become a publicly traded entity and in 1975 expanded by incorporating the Kapalua Land Company as its dedicated resort branch (ML&P, 2006). Approximately 401 acres of pineapple was cultivated in 5 fields in the early 1970's and did not change significantly thru the 1990's (Nohara, personal communication).

Land-use patterns in 1976 were estimated as 67% forest, 27% agricultural land, 4% grassland, and 2% urban use (Maui County 1976). The first golf course was established in 1975 with additional courses opening in 1981 and 1991, all located south of Honolua at the primary development site at Kapalua. All three of the existing courses are certified by the Audubon Society as Cooperative Sanctuaries, indicating they are environmentally managed. The first hotel was established in 1978 and coincided with the declaration of Honolua and Mokuleia Bays as Marine Life Conservation Districts.

In 1992, MLP still leased 247 acres in 5 separate leases to former ML&P employees for cattle grazing, although only a small section of the land was considered grazeable and only 8 cattle were located in the watershed in March, 1992 (Munekiyo, 1992). A 2.12-acre area was also leased along Honolua stream for a nursery operation (elevation 80 feet), and approximately 0.5 acres of corn cultivation next to the nursery. A small farm specializing in poultry and swine was located at the confluence of the Honolua stream and Papua Gulch (Muneikiyo, 1992).

During the 1990's, public concern grew over perceived increases in sediment and chemical pollution associated with agricultural and development activities (Munekiyo, 1992). However, during this time (between 1988 and 2004), the amount of land used for pineapple farming continued to remain relatively constant (Nohara, personal communication). The area of pineapple planted at the last planting cycle in the mid to late 1990's was approximately 407 acres, an increase of only 1.6% from the 1970's. A major land-use change occurred in 2005 as ML&P began phasing out pineapple. ML&P was planning to convert Honolua from an agricultural area to an urban resort styled development, including residences, golf course, and hiking trails. The proposed land-use change caused much concern and division within the local community, with some groups fearing a loss of the traditional rural atmosphere, while others were opposed to anything less than full conservation zoning. This concern led to ML&P removing its plans for a golf course and residential area in 2007.

2.2.2. Existing Land-Use

The Honolua watershed contains both State Conservation District and Agriculture District lands. The majority of Honolua watershed is owned by Kapalua Land Company, a subsidiary of ML&P. There are also several privately owned "Kuleana" land parcels.

Current land use is shown in Table 2 and Figure 2. Most of Honolua Watershed is forested (~83%) ~7% is zoned for agriculture, ~8% is residential (Honolua Ride and part of Plantation Estates), and ~2.5% is covered by the Plantation Golf Course. The upper sections of the watershed are within the State Conservation District, which is managed by various reserves including the West Maui Natural Area Reserve, Pu'u Kukui Watershed Management Area, and the West Maui Forest Reserve (United States Environmental Protection Agency *et al.* 2004).

Table 2. Current Land Use in Honolua Watershed

Land-use	**Size (acres)**	**% of watershed**
Forest	2,509.03	82.83
Agriculture	203.38	6.71
Residential	240.17	7.93
Golf	76.46	2.52
Total Watershed Area	3,029.04	100

ML&P dedicated 8,661 acres in the upper watershed to establish the Pu'u Kukui Watershed Preserve in 1998 (ML&P 2006). 1,197 acres of the Preserve are within the Honolua Watershed. Roughly 74% of the watershed is protected through inclusion in the Pu'u Kukui Watershed Preserve (1,197 acres) and Makai Conservation Area (1,052 acres) (Table 3). ML&P has recently designated 28 acres of agricultural land (Field 52) for restoration through a community tree planting project.

Table 3. Area of Honolua Watershed designated for preserves and conservation.

Protected Areas	Size (acres)	% of watershed
PKW Preserve	1,196.90	39.51
Makai Conservation Area	1,051.60	34.72
Total Watershed Area	2,248.50	74.23

The Honolua Ridge development, which is part of Kapalua's Plantation Estates, includes 25 agricultural home-sites ranging from 3 - 25 acres and covers roughly 214 acres. Building size is regulated by Maui County and State land use laws for agriculture zoning. There has been concern about the standards of infrastructure development, the drainage system and grading during the development (Pignataro, 2007).

ML&P is developing plans to better manage the use of the bay and watershed, including hiking trails and experimental tree plantations with space donated to public groups for use (Churchill, personal communication, 2006). Numerous public outreach programs and development ideas are in development that will make it easier for the users of the bay to enjoy the area while minimizing the long-term impacts of such uses (Nohara, personal communication, 2006).

Development plans for a golf course and residential development at Lipoa Point, which were released in March 2007, have been removed by ML&P. Maui County is currently negotiating with ML&P to purchase Lipoa Point and preserve the area for public open space.

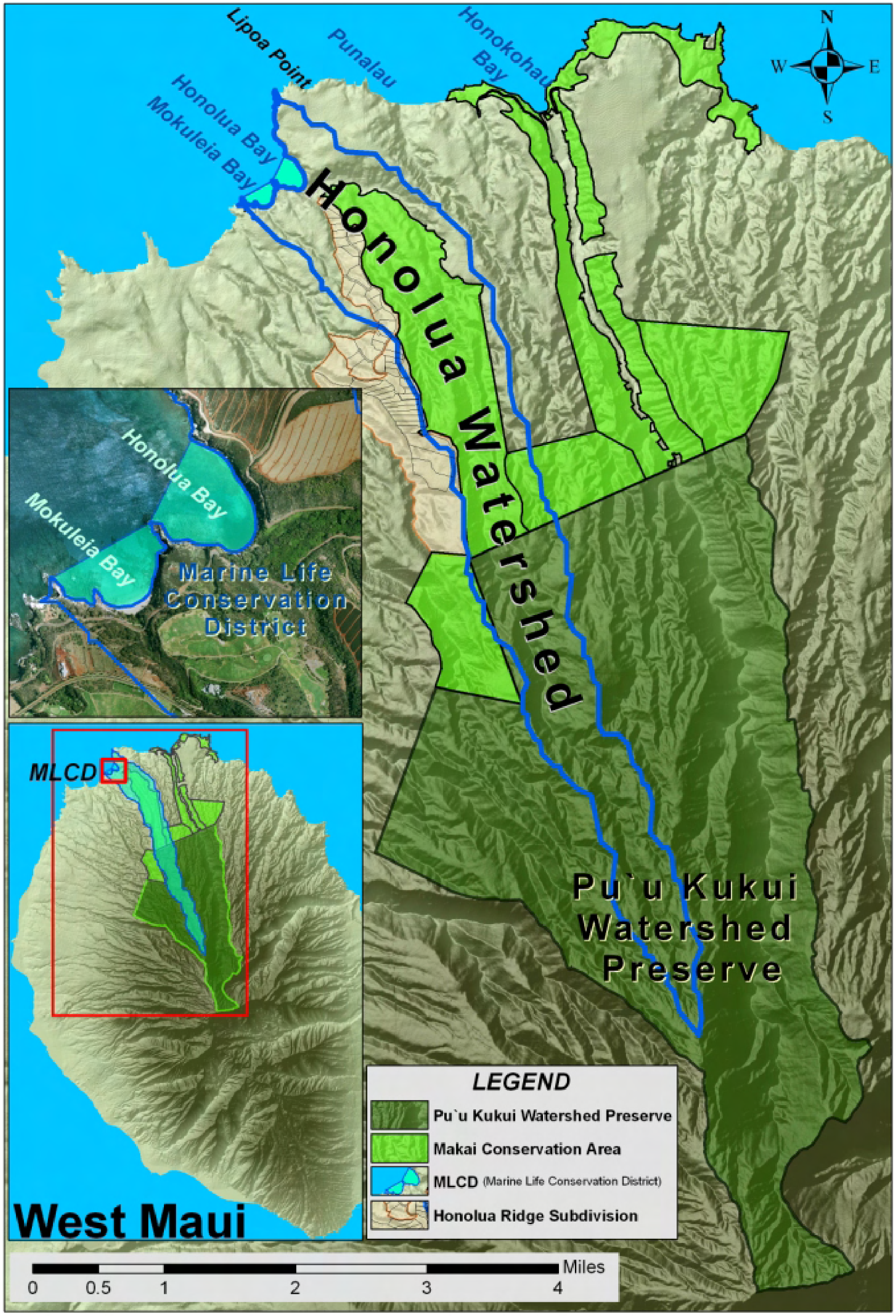

Figure 2. Current land-use in the Honolua Watershed. The blue line denotes the watershed boundary. Map courtesy of ML&P.

2.3 Agricultural practices

Erosion control measures and cultivation techniques have improved dramatically since pineapple cultivation began in Honolua in 1912. Before the installation of erosion control measures in the 1960's, soil and mature plants were lost during large rainfall and flood events (Cameron & Keane, 1987). Over the last 30 years, the plantation managers have made conscientious efforts to be environmentally pro-active (Nohara, personal communication). ML&P was a pioneer on Maui for implementing soil conservation measures and was recognized as an outstanding cooperator by the West Maui Soil and Water Conservation District in 1976 (Munekiyo, 1992). ML&P has also worked closely with various State and Federal entities including the USDA-NRCS, the Hawai`i State Department of Health, and the U.S. Environmental Protection Agency, to improve their agricultural practices. These collaborations have facilitated the creation and implementation of numerous Best Management Practices (BMP's) and cultivation techniques that have attempted to minimize negative impacts associated with agriculture.

There were numerous improvements in the methods used to prepare soil prior to pineapple planting. This has included significant changes in the choice of pre-plant fumigants and nematocides. In 1978, the EPA banned use of 1,2-Dibromo-3-Chloropropane (DBCP) on the mainland. The chemical was originally created to combat nematodes on pineapples in Hawaii and was in widespread use around the state and the mainland U.S.A (USEPA, 2007). Hawaii received extensions until 1986 when the EPA revoked all user permits (USEPA 2000). Telone (1,3-Dichloropropene), was then utilized for a short time before the advancement to Methyl Bromide. Methyl Bromide was used for only a short period before being restricted by the government. ML&P then reinstated the use of Telone as the fumigant of choice (Nohara, personal communication) and was used in Honolua until pineapple cultivation ended in 2006.

In addition to changes in pre-plant fumigants and nematocides, agricultural land-use practices also improved, reducing soil erosion within the watershed. From 1976 to 2004, all 5 pineapple fields in Honolua were prepared similarly and the size of the fields did not vary significantly between planting cycles (Nohara, personal communication). However, the amount of soil conserved through the implementation of NRCS advocated soil conservation practices increased dramatically, and was within Maui County recommended soil loss tolerances.

The soil loss tolerance indicates a soils ability to retain its unique characteristics for plant growth after a certain amount of erosion. If a soil loss tolerance is exceeded due to erosion, the soils become less efficient in growing crops. Soil loss tolerance is a criterion used in the Revised Universal Soil Loss Equation (RUSLE), a model co-developed by the USDA-NRCS, which determines soil loss based on various characteristics in an area. The value will vary greatly depending upon the soil types within the watershed. The Honolua watershed has a mix of soils and most are moderately deep and well drained (Muneikyo, 1992). The water quality management plan for Maui County states that appropriate BMP's should maintain erosion rates at or below 10 tonnes/acre/year, although the rates for a given site will vary with soil type (Munekiyo, 1992). Tolerance values for the Alaeloa and Honolua Soil Series, the two soil series utilized for pineapple cultivation within Honolua, were identified at 5 tons per acre per year (USDA, 1981 in Munekiyo, 1992).

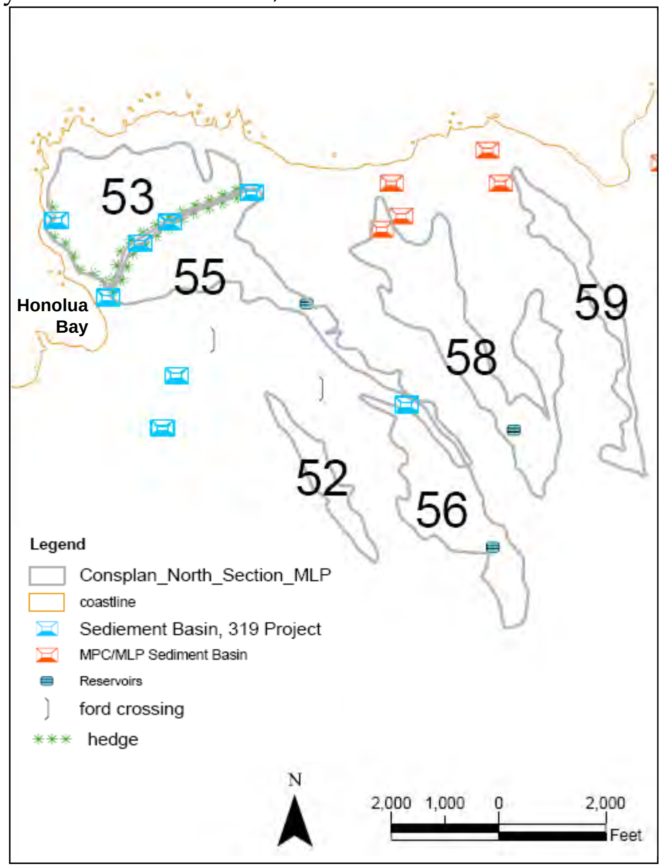

Figure 3. Soil conservation measures implemented by MLPC. Source: USDA-NRCS, 2007.

Soil conservation measures included: crop residue use, contour farming, cross slope block farming, chiseling and subsoiling, diversions, terrace, conservation cropping sequence, and cross ditching (Munekiyo, 1992). ML&P with the assistance of the DOH, EPA and NRCS, also constructed numerous soil conservation structures in various strategic locations around the Honolua watershed between 1994 and 1996 (ML&P, 1999). Some of these structures and techniques included sediment retention basins, revegetation of unused areas, terraces, and drainage improvements (Figure 3). These practices were visually monitored and shown to reduce erosion and runoff (ML&P, 1999). All structures are being maintained during the transition from agriculture to residential development. Additionally, a fence along the conservation district border was installed in 2004 to prevent the encroachment of wild ungulates (United States Fish & Wildlife Service, 2004).

2.4 Watershed Planning Initiatives

Documented watershed planning initiatives are summarized below. Determining the status and effectiveness of these initiatives was beyond the scope of this project and is recommended as a future project.

1976 Honolua Watershed Work Plan

The first watershed work plan was prepared in 1976 by the West Maui Soil and Water Conservation District and County of Maui with assistance from USDA conservation service and forest service. The primary objectives of the plan were "to provide effective land treatment on watershed land and to prevent floodwater ad sediment damage in the flood plain and discoloration of the ocean along the coast." (Maui County, 1976). It was developed in response to Maui County's development and adoption in 1968 of a General Plan to promote orderly growth and the natural landmarks and environment in the district. The Lahaina District was experiencing an economic boom from the developing tourism industry during that time.

The plan outlined improvements for the protection and development of 23,980 acres of the watershed that would be installed over 5 years. Improvements included land treatment measures such as soil and water conservation practices to reduce runoff and sediment production, maintaining favorable soil conditions, productivity and cover for soil protection on grasslands and forest land (Maui County, 1976).

Priority was given to the installation of land treatment measures to control runoff from croplands. Additional focus was placed on reducing erosion from gulches and other areas used for pasture thru improved pasture management. Structural measures included 3,900 feet of open channel, 8 de-silting basins and 4,290 feet of concrete-line floodwater diversions (Maui County, 1976).

1979 Honolua Bay Study

In 1979 Belt and Collins prepared the "Honolua Bay Study" for ML&P. The purpose of the plan was to consider future uses for the area and prepare a land and water use plan, focusing on possibilities for recreational and educational activities. It would also provide the basis for future policy on use of the area by ML&P and others interested in the Bay. The study included an analysis of the natural and man-made environment. The Land- use and water plan had 3 major components: 1. Conservation and use of the marine resources, 2. Public recreation area, and 3 Conservation of historic and archaeological sites.

The Land and Water Use plan designated the entire bay as a marine conservation area, in accordance with its designation as a MLCD. It recommended the establishment of a boat channel from the boat ramp to the water outside the bay to mitigate possible user conflicts. The channel would be located between the two reefs and confine boats with outside destinations to the channel. This separated them from the reef areas used by the majority of swimmers, surfers, snorkelers and divers. Belt and Collins (1979) anticipated the Bay's primary recreation use would be viewing marine life, with swimming a secondary use. Boating was another potential use if it was considered compatible with marine conservation. The Bay could also be a venue for surfing contests because of the excellent winter surf over a limited area.

The plan included a 9.5 acre public beach park, located on the Kapalua side of the valley floor, delineated by Honolua stream, Honoapiilani Highway and about half of the cobble beach area. The specific type and location of park facilities would be determined by the appropriate government jurisdiction. However only a few facilities, including a single structure with toilets and changing rooms, several picnic tables and barbeque pits with a lawn-like grass for lounging would be required. It was though that the beach area would not be intensively used because Honolua did not have a sandy beach.

A public parking area was outlined on the mountain side of the river, separate from the recreation area with convenient road access to Honoapiilani Highway. The parking area could hold 25 vehicles with boat trailers, and could be developed in increments based on future needs. Pedestrians would access the recreation area by crossing the river bed, via a walkway created with big stones.

The plan also included access from the parking lot to the boat ramp for boat launching. Boating facilities were proposed for small boats (<20 ft length), and the boat ramp capacity was 30 to 40 boats per day. It recommended resurfacing and other requirements to meet the State's standards for a boat launching ramp.

A small pier adjacent to the ramp was also included in the plan. Belt & Collins recommended that the ramp be built on pilings, to avoid deflection of normal water movement, and that the piers design included a surface that could be removed during the winter swells.

The plan included the conservation of 3 archaeological sites and 1 historic site. It was recommended that the 3 archaeological sites by preserved and made accessible via trails that included information signs. In addition to signage at each site a centrally located comprehensive exhibit explaining all aspects of the area's history should be developed.

1992 Honolua Bay–Mokuleia Bay Special Project Plan and Preliminary Draft Environmental Assessment (Special Project)

The Special Project was prepared by Munekiyo consultants for the West Maui Soil and Water Conservation District in 1992. The overall objective of Special Project was to propose measures that would enhance the MLCD by effectively reducing non-point source pollution. The specific objectives were:

- Inventory and identify sources of non-point pollution with the Honolua Bay and Mokuleia Watersheds;
- Identify land treatment measures which could be utilized in reducing sediment introduction to the MLCD;
- Identify measures for reducing introduction of chemical materials associated with agricultural and urban activities into the MLCD; and
- Develop an implementation program that promoted long-term integrity of the MLCD.

The area was divided into 5 water sub-areas to enable management alternatives that addressed site specific erosion. Structural and non-structural land were proposed. The Special Project defined existing soil conservation measures utilized by ML&P and recommended additional measures. These included establishing vegetation on the 17 acres of "badlands" within the Papua Gulch drainage basin, and constructing 3 sediment basins. The proposed basins were located within: Papua Gulch above its confluence with Honolua Stream; Pahiki Gulch on the mountain side of Honoapiilani Highway; and along the Honokohau Road extension in Plantation Estates II Subdivision. In addition Munekiyo *et al.* recommended that ML&P evaluate alternative measures for trapping sediment from the mountain portion of Field 52 (in Honolua Stream Drainage Basin), such as a small sediment basin or sediment fence. Field design modifications were also recommended.

Management recommendations focused on non-point sediment sources and did not address water chemistry impacts associated with land activities, because there was insufficient baseline data for a resource management analysis. Establishing an on-going data collection and monitoring program, including field edge monitoring, to determine nutrient and pesticide budgets was recommended. Data could then be used to develop detailed management recommendations for water quality concerns.

The Special Project also included an analysis of the potential impacts of installing the proposed measures. This is included short-term construction impacts, impacts on water quality; flora and fauna, cultural and historic resources, agricultural resources, visual resources, recreational resources, and public services and infrastructure. Refer to the Special Project for more details.

2003 Honolua Ecosystem Restoration Project – Preliminary Restoration Plan

The Preliminary Restoration Plan (PRP) was prepared by the U.S Army Corps of Engineers under Section 206, WRDA 1996 (PL 104-303, Aquatic Ecosystem Restoration). The main purpose of the PRP was to "restore and improve the quality of the terrestrial and near shore marine environment, which is heavily impacted by upland uses". This would "restore degraded terrestrial ecosystem structure, function, and dynamic processes to a more functional and natural condition. Natural ecosystems of this watershed have been impacted by urbanization, modification to support the agricultural industry, and introduced vegetation and wildlife." (USACE, 2003).

Major project features for consideration included large sediment retention basins, wetland creation, estuary enhancement, stream flow restoration, badlands re-vegetation, mid-level landscape restoration, stream corridor protection and grassed filter strips. The development of restoration alternatives were also recommended, including: native plant reintroduction in denuded, erosion-prone, and alien species impacted areas; out planting irrigation and management; stream flow restoration; wetland re-creation; sedimentation basin construction below agricultural areas; and estuary improvement. It was estimated that the approximately 20 acres of land would be required for sediment basin installation, and additional land could be needed for stream corridor preservation, re-vegetation and other actions. The acquisition of land would be the responsibility of the projects local sponsor (DLNR-DOFAW).

Implementing the PRP was expected to benefit the ecosystem by reducing the amount of sediment discharged into Honolua Bay, therefore improving water quality and marine habitats for corals, fish species and turtles. Re-vegetation of riparian and former agricultural lands would reduce further erosion and runoff of sediments into the aquatic and near shore environment and could expand habitat for native terrestrial species. Reducing sediment and stream flow restoration was expected to reestablish aquatic habitat for native aquatic species (USACE 2003).

Although this PRP had the support of DLNR-DOFAW, the West Maui Watershed Partnership, WMSWCD, and ML&P, the request for federal appropriations to fund it was not successful.

2003 Hawaii Tourism Authority Natural Resource Assessment

The Hawaii Tourism Authority (HTA) completed a Natural Resource Assessment of Hawaii's most visited natural resource areas, including Honolua Bay, in 2003. The main objective of the Natural Resources Assessment was to "provide a long-term plan for the expenditure of the monies set aside for improving natural resource sites frequented by visitors by Act 250, SLH 2002."(HTA 2003). The assessment was conducted "to establish a baseline for the quality of natural resource sites in general throughout the state, as well as to identify specific sites in greatest need of improvements in order to prioritize future projects and initiatives." Sites were selected based on a comprehensive review of travel guides and other sources of information used for vacation planning, meetings with HTA's Natural Resources Advisory Group (NRAG), consultation with additional agencies and organizations responsible for recreational and natural resource management, and public input. The final list of sites assessed included: 30 sites on Oahu, 19 sites on Maui, five sites on Molokai, six sites on Länaii, 27 sites on Kauai, and 23 sites on Hawaii Island." (HTA, 2003).

Honolua Bay and Mokuleia MLCD was considered a high priority site because of the volume of visitors and the sensitivity of the MLCD's natural resources. The assessment identified "serious problems with the high volume of visitor use observed at the site" (HTA, 2003). Lack of parking was identified as the most serious impact. Because of limited parking, Honolua Bay visitors park along the shoulder of the Honoapi'ilani Highway, and walk along or across the highway to reach the trail entrance. The assessment suggested a possible solution would be working with ML&P to establish a small parking area within walking distance of the Bay.

The lack of comfort facilities was identified as another significant issue, which negatively impacted both site users and the quality of the natural resource. The assessment suggested installing a portable toilet with directional signage as a temporary solution until something more permanent could be implemented.

Other need improvements included: repairing the surface of the two paths from the highway down to the gated site entrance; posting directional and/or entry signage for the sites; and posting interpretive signage about the cultural and historic significance of the bay and the meaning of the place name "Honolua".

2004 Hawaii's Land-based Pollution Threats to Coral Reefs Local Action Strategy

The land-based pollution LAS is one of six strategies developed in Hawaii to protect the State's coral reefs. The other strategies address recreational impacts to reefs, fisheries management, climate change and marine disease, aquatic invasive species, and lack of awareness .The strategies were developed through an initiative of the U.S. Coral Reef Task Force, which identified priorities for future work by Federal and State Agencies to protect coral reefs in the U.S. In Hawaii a committee of federal and state resource agencies developed the LBP LAS in 2004 with assistance from Tetra Tech EM Inc.

Table 4. Summary of LBP LAS Actions in Honolua, Maui

Proposed Action: Innovative Wastewater and Storm-Water Management System Workshop and Design Recommendations for Public Restroom Facility and Parking Lot in a Sensitive Coastal Environment (**Priority Action 1A**; Honolua, Maui)
Proposed Action: Soil Erosion and Surface Water Runoff Control for Land Use Transition from Pineapple Cultivation to Resort, Residential, and Recreational Development (**Priority Action 1B**; Honolua, Maui)
Proposed Action: Technical Assistance for Stormwater Management for Residential and Golf Course Development at Honolua (Honolua, Maui)
Proposed Action: Honolua Ecosystem Restoration Project (Honolua, Maui)
Action 1.1 Soil Erosion Control Best Management Practices and Monitoring for Pineapple Cultivation (Honolua, Maui)
Proposed Action: Synthesis and Critical Analysis of Available Data and Information on Land Use, Runoff, Water Quality, and the Health of Coral Reef Ecosystem at Honolua Bay (**Priority Action 2A**; Honolua, Maui)
Proposed Action: Carrying Capacity Study for Managing Public Use of Honolua Bay (**Priority Action 2B**; Honolua, Maui)
Proposed Action: Wave Energy and Sediment Suspension Gradients along Northwest Maui (Honolua, Maui)
Proposed Action: Spatial and Temporal Variability in Historic Near-Shore Sedimentation Recorded in Coral Skeletons
Action 2.1 Study of Anthropogenic and Natural Stresses on Coral Reefs (Honolua, Maui)
Action 2.2 Hawai`i Coral Reef Assessment and Monitoring Program (Honolua, Maui)
Action 2.3 Study of Long-Term Variability of Currents, Temperature, Salinity and Turbidity off Kahana, Northwest Maui (Honolua, Maui)
Action 2.4 West Maui Coastal Circulation Experiment (Honolua, Maui)

The overall goal of the LBP LAS is to reduce land-based pollution to improve coastal water quality and coral ecosystem function and health. The Local Action Strategy is watershed-based and incorporates the traditional land and natural resource management system, known as *ahupua`a*. A collaborative planning process, with significant public input, was used to develop the overall goals, objectives and measures of success for Hawaii's LAS. Three priority *ahupua`a* in the main Hawaiian Islands-Honolua, Maui; Kawela to Kapualei, Molokai; and Hanalei, Kauai- were selected for focused action. The priority actions for the Honolua ahupuaʻa are listed in Table 4. The LAS was originally written as a 3 year plan but has now been expanded to 5 years. Hawaii's local action strategies are administered by the Department of Land and Natural Resources Division of Aquatic Resources (DAR). For more information refer to the LBPLAS (USEPA et al., 2004) or visit www.hawaii.gov/health/environmental/water/cleanwater/.

2004 and 2007 USACE West Maui

In 2004 and 2007 the USACE requested federal appropriations for Fiscal Year 2004 and 2008 to perform a reconnaissance study and develop a watershed plan for West Maui. The 2004 request was not successful, hence the recent request.

The justification for the request was that "West Maui is one of the fastest growing areas in the State of Hawaii. Unfortunately, it is also a hotbed of disputes over limited water resources. Unless these problems are addressed in a sustainable and comprehensive manner, they will only get worse. For over a hundred years, many of the streams in this area have been diverted to support plantation agriculture. This had reduced the amount of water recharging underground drinking water supplies, while also limiting the water available to reduce pollution and support public uses, including agriculture, recreation, estuaries, fisheries, and Native Hawaiian rights and practices. West Maui also boasts major tourist attractions, which help to support the State's economic base. Protection and restoration of these natural and cultural treasures is necessary to preserve the islands' quality of life for residents and visitors alike. The West Maui Watershed has been identified for special conservation and preservation activities due to existing near-pristine forestlands and near-shore coral reefs. Unfortunately, many streams and coastal waters do not currently meet State water quality standards. Lack of improvements in stormwater management practices and protection measures may contribute to increased sedimentation and pollution, further degrading water quality and related riverine and coastal ecological systems. Additional flood damage reduction and erosion control measures will also be investigated. The reconnaissance study will identify water resource problems to be addressed by the Corps of Engineers, as well as various plans and programs that can be implemented by local, State and federal partners." (USACE, 2007).

Although the project was fully endorsed and supported by The State of Hawai`i Department of Land and Natural Resources, along with stakeholders such as the State Office of Hawaiian Affairs, County of Maui, West Maui Soil & Water Conservation District, Kaanapali Development Corporation, and ML&P, the federal appropriation request was not successful. Another request will be submitted next year.

3.0 Marine Use

There is sparse literature about the historical uses of Honolua Bay. Sometime before 1955, The Honolua Ranch Manager, D.T. Fleming, began a commercial fishing operation and Honolua Ranch purchased nets and boats and installed an icehouse in Honolua Bay (Cameron & Keane 1987). A normal catch of akule fish was reported to be 4 or 5 tones, and could be as large as 12 tons (Cameron & Keane, 1987). Apparently if an Akule school was spotted, pineapple workers would leave their jobs and meet at the Bay to help haul in the catch (Cameron & Keane, 1987). The fishing operation was initially profitable but the akule schools were sporadic and the size of the catches continued to decrease, until 1955 when the Ranch Manager recommended the closure of the business (Cameron & Keane, 1987).

The uses of Honolua Bay have changed considerably since its designation as a Mare Life Conservation District (MLCD) in 1978. The purpose of the designation was to conserve and protect the marine resources found within the area, and encourage recreational public use (Hawai`i State Department of Land & Natural Resources, 1976). Prior to this designation, fishing (both spear and gill net) and coral harvesting were common practices. There are now prohibitions on taking any marine life from within the Bay or removing coral or sand.

The Bay is considered to have high human use compared with other portions of Maui (Holland, 2003). The area is currently utilized by large numbers of visitors who access the bay from the land or water via tour boats. In 1998, the highest human use was recorded between 11am and 2pm during the summer months with 600-700 visitors entering the bay (Holland, 2003). Commercial tour boat operators brought up to 250 snorkelers per day (Holland, 2003). The low use by SCUBA divers has likely protected the more fragile coral species that occur at depth and are more difficult for casual snorkelers to access (Holland, 2003). To ensure the protection of these fragile species, the State of Hawaii's Planning Department has discouraged the promotion of the bay as a dive site.

The Bay is also a popular with surfers during the winter swell. Although direct contact with the substrate and coral is minimal, access to the surfing zone is via an undeveloped path originating from an unpaved parking area at Lipoa Point. These undeveloped areas are a potential source of soil entering into the bay. The owners of the parking area (ML&P) are aware of this potential degradation and were including the control of erosion from these sites into their development plans (Churchill, personal communication). However these plans have been postponed until land-ownership is resolved.

3.1 Management Framework

Honolua Bay and adjacent Mokuleia Bay were designated a Marine Life Conservation District (MLCD) in 1978, prohibiting all types of fishing. The MLCD includes approximately 45 acres of coral reef habitat.

In 1990, a resolution was passed by the Fifteenth State Legislature declaring Honolua Bay as environmentally threatened by non-point source pollution (State of Hawai`i 1990). This drew attention to the bay's fragile ecosystem resulting in the development of Special Project Plan and Preliminary Draft Environmental Assessment (Munekiyo, 1992) and the initiation of long-term coral reef and water quality monitoring projects by Marine Research Consultants (MRC) and Pacific Whale Foundation (PWF).

In 1997, the bay was incorporated into the Hawai'ian Islands Humpback Whale National Marine Sanctuary (HIHWNMS). This added a greater level of security and environmental protection to the site, above the original 1978 MLCD designation.

3.2 Visitor Use

Human Activities in Marine Protected Areas – Impacts on Substrates

Holland and Meyer (20003) measured the impact of SCUBA diving and snorkeling on substrates at four Hawaii Marine Protected Areas, including Honolua-Mokuleia MLCD. They observed visitor behavior by following 234 divers (205 snorkelers, 25 SCUBA and 4 SNUBA divers) for 129 hours, over a combined distance of 114.6km at the four MPA sites. Divers made a total of 1,340 substrate contacts within MPA boundaries: 1,153 (86%) were with inert substrates (sand and uncolonized rock), 187 (14%) with live substrates (coral, coralline algae and sessile invertebrates, 8 (0.7%) substrate contacts causing visually obvious damage to corals (4 tissue abrasions, 4 skeletal breakages) (Holland & Meyers, 2003). These rates were low compared to rates reported from other geographic areas, despite comparatively high annual visitor numbers (Holland & Meyer, 2003).

Holland & Meyer concluded that the distribution of recreational activities and composition of benthic assemblages were the two main factors determining human impact on substrates in Hawaii MPAs. Although snorkeling occurred frequently at all four sites, live corals were sparse in the shallow areas where most snorkeler substrate contacts occurred. The relatively low numbers of SCUBA divers at 3 of 4 sites probably limited the amount of coral damage. The authors suggested that any significant increase in the number of SCUBA divers would likely cause higher rates of damage to mechanically fragile coral species, such as *Porites compressa,* that are common at these sites. They recommended a mandatory single pre-dive briefing on all commercial snorkel and dive tours, because they significantly reduced diver coral damage in other areas. They also suggested that "finding effective methods for briefing shore-based snorkelers & SCUBA divers could further reduce impact on corals at Hawaii MPA sites."

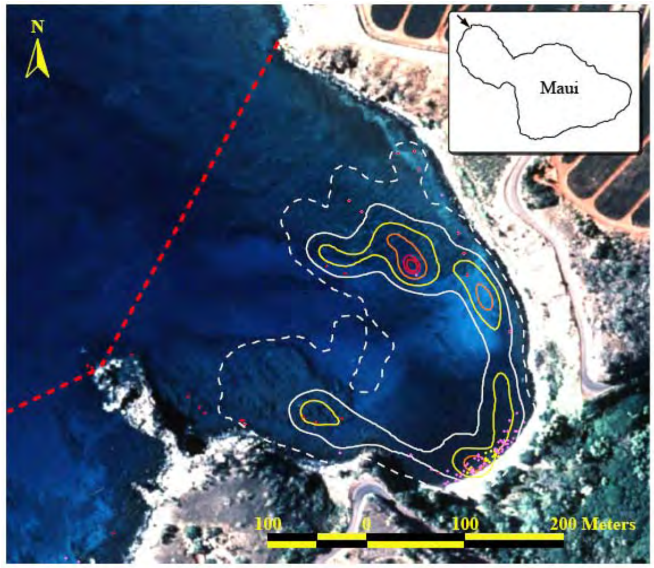

Figure 4. Habitat utilization distribution and substract contact points for snokelers and SCUBA divers at Honolua Bay. Contours outline activity probability surfaces; white dashed contour = 95%, white solid contour = 75%, yellow contour = 50%, orange contour = 25%, pink contour = 10%, red contour = 5%. Colored points are diver substrate contact locations; pink points – uncolonized rock, yellow=sand, red=live coral. Red dashed line=MLCD boundard. Inset= location on Honolua bay on the island of Maui. Source: Holland & Meyer (2003).

Meyer and Holland's observations from Honolua Bay are summarized below.

Snorkeling and SCUBA activities in Honolua Bay were concentrated over the reefs around the sides of the bay and least concentrated in the sandy central area (Figure 4). 98 % (41 of 42) of observed snokelers remained inside the MLCD boundary and 95% of all activities occurred in 55% of the total MLCD area (Figure 4). The most intensively used area was a 6,800 m^2 area on the northern reef, representing only 14% of the total reef area and 6.3% of the entire Honolua Bay section of the MLCD. 57% (24 of 42) of snorkelers visited this reef area, and only 38% of (16) snorkelers visited reefs on the south side of the Bay. Habitat in this area consisted of massive lobe corals interspersed with sandy channels, and was not found elsewhere in the MLCD.

Shore-based and boat-based snokelers were concentrated in different areas. Shore-based snorkelers entered the water from the boulder shoreline and typically snorkeled around the edges of the bay to reach north and south reef areas. Boat-based snorkelers entered from the vessels moored in the sandy central area of the inner cove and snorkeled directly across to the most heavily used areas of reef.

Most (73%) substrate contacts were clustered along the boulder shoreline where snorkelers entered and exited the water. The few other non entry-related substrate contacts observed typically occurred in shallow (<2m) depths around the bay perimeter and on top of reefs. Boat-based snorkelers made only 9% of all substrate contacts observed at Honolua Bay. Only 7% of substrate contacts occurred in the most intensively used areas of reef habitat. Contact with live coral (12.9% of total contacts) occurred around reef perimeters in Honolua Bay.

2007 Recreational Carrying Capacity Evaluation of Honolua Bay

Tetra Tech EM Inc. was contracted by Kapalua Land Company in 2006 to undertake a recreational carrying capacity evaluation of Honolua Bay. The need for this evaluation was identified as an action in the LBBLAS (2004). The evaluation is under final review and has not been publicly released. The Executive Summary from the final draft is copied verbatim below.

"Ocean recreational overuse is considered one of the six primary threats to the health of coral reef ecosystems in Hawaii and the U.S. Ocean recreation is increasing in Hawaii as a result of population growth and the demand for new products and destinations in a mature tourism market. Honolua Bay in west Maui is a popular ocean recreational area. Kapalua Land Company, Ltd. contracted Tetra Tech EM Inc. to evaluate the recreational carrying capacity of Honolua Bay. The overall objectives of the study were to quantify current levels of ocean recreational use at Honolua Bay, evaluate the recreational carrying capacity of the area, and recommend capacity management scenarios for sustainable ocean recreation. Key questions addressed in this evaluation include:

- Are current types and levels of recreational use causing unacceptable environmental and social conditions at Honolua Bay?
- What are the potential driving forces and future trends that should be considered in managing recreational use at Honolua Bay?
- What capacity management actions are needed to minimize current and potential future impacts to the Honolua Bay area?

A total of 16 recreational use surveys were completed between December 2005 and July 2006 to establish current types and levels of recreational use at Honolua Bay. These surveys provided data on maximum and average levels of snorkeling, surfing, and other recreational activities, visitor counts from land- and sea-based access points, the number of vehicles parked along the highway to access Honolua Bay, the number of commercial tour boats using the bay, and other information about visitor satisfaction with the recreational experience. Information and data from previous studies conducted at Honolua Bay were reviewed and used to characterize biophysical conditions and trends, recreational use impacts on coral reefs, and recreational use trends.

Honolua Bay maintains many distinctive features as an ocean recreational area. Few marine areas in Hawaii are characterized by calm, safe conditions for visitors to enjoy snorkeling and SCUBA diving. The bay is already designated as a Marine Life Conservation District and fishing and other extractive activities are prohibited. Land-based access to the bay provides a unique combination of an easy hike through a "wilderness setting" and a safe snorkel. The coastal bluffs surrounding the bay provide outstanding scenic vistas and support endemic vegetation. Crowding and resource use conflicts are not yet a major concern at this time but could become problems in the future. In order to preserve these and other significant features, improved area management is needed to minimize recreational use impacts and to proactively address future threats.

Recreational use is currently contributing to environmental and ecological stress in the Honolua Bay area largely due to the absence of area management and not necessarily to the overall number of visitors. Key recreational carrying capacity issues at Honolua Bay include the following:

- The numbers of visitors to the area will likely increase as land-based and sea-based commercial tour operations respond to increased demand for ocean recreational experiences. Under current conditions, this increase could result from intensification of commercial tour operations through potential increased use by large capacity commercial vehicles and number of permits or vessel capacity of commercial tour boat operations.

- Coral breakage is likely to continue or increase from snorkeling and SCUBA diving. This trend will continue without consistent pre-dive briefings and a lack of supervision during a dive. Coral cover in the bay, already experiencing a long-term decline, cannot be subjected to any additional stress, although limited, from ocean recreational activities.
- Mooring buoys, although planned have not been installed. Repeated anchoring by vessels in the bay may degrade benthic environment including both soft and hard bottom communities. Mooring buoys will need to be sited near but away from coral reef areas to accommodate high damage rates characteristic of the first 10 minutes of a dive.
- Illegal fishing is reportedly occurring within the bay. A decline in the abundance or change in the composition of the reef fish assemblage could increase the vulnerability of coral reefs to marine invasive algal species.
- Coastal bluffs serve as outstanding scenic vistas and habitat to endemic terrestrial vegetation in the area will continue to be altered by development unless these areas are set aside as open space and protected.
- Health and sanitation problems will continue and likely increase as a result of land-based visitors. A range of low impact solutions can be developed to address these problems from signage to facilities..
- Site conditions pose safety concerns for visitors including roadside parking, absence of emergency communication facilities, slippery boat ramp, and aggressive reef fish behavior as a result of feeding.
- Sediment runoff from rain events will likely continue to impact water quality in the bay.

Development of any supporting facilities should adopt low impact design considerations to minimize additional water quality degradation from surface water runoff or groundwater discharge. Current levels of recreational use could be sustained with improved area management designed to minimize the impacts of visitors on the marine and terrestrial environment and health and safety concerns. Four recreational capacity management scenarios are described for Honolua Bay. Specific management measures defined in each scenario will require action on the part of a range of stakeholders including government, public, and private sectors. These scenarios are as follows:

Scenario 1: Maintain recreational uses at 2006 levels with improved area management

Scenario 2: Maintain recreational uses at 2006 levels with improved area management including a parking area

Scenario 3: Maintain recreational activity at 2006 levels with improved area management including a parking area and other supporting infrastructure

Scenario 4: Revise recreational levels and access from 2006 levels based on long-term ecosystem monitoring

Scenario 1 is recommended as a necessary first step in managing recreational capacity and impacts at Honolua Bay. Scenario 1 describes a set of largely non-structural actions for improved area management of Honolua Bay. These management actions, which include: maintaining recreational use at 2006 levels through land- and sea-based access controls, providing on-site management, improving education and outreach activities, and establishing a long-term ecosystem monitoring effort, need to be put in place as a foundation for considering scenarios that propose supporting infrastructure. Furthermore, some management actions require coordinated implementation by several responsible entities.

A transparent process for involving local stakeholders should developed and implemented to identify recreational use issues and concerns and potential solutions as well as to define the values to be protected and management goals for the area. An integrated coastal area management plan is needed to guide the coordinated actions of multiple responsible entities and to set forth a comprehensive and multisectoral set of actions to achieve these goals for both watershed and marine areas. Lastly, information management is a critical component of the sustainable use and management of Honolua Bay. Information and data needs to be consolidated in a geographic information system to enable access to and analysis of all datasets to inform management decision-making." Tetra Tech EM (2007).

4.0 Terrestrial Ecosystems

4.1 Climate

Lahaina's climate is relatively uniform year round due to its tropical latitude, and position relative to storm tracts, the Pacific anticyclone, and the surrounding ocean (Munekiyo, 1992). Variations in local climate are largely caused by local terrain. Average temperatures in Lahaina range between 60 degrees and 88 degrees fahrenheit, with August historically the warmest month, and January and February being the coolest. The winds in the Lahaina area are seasonal. The north-easterly tradewind occurs 90% of the time during the summer and 50% in Winter. Wind patterns also vary daily, with tradewinds generally being stronger in the afternoon. During the day, winds blow onshore toward the warmer land mass. In the evening, the reverse occurs, as breezes blow toward the relatively warm ocean.

Rainfall at Lahaina is highly seasonal, with most precipitation occurring between October and April when winter storms hit the area. The leeward side of the West Maui Mountains receives most of its rainfall in late afternoon and early evening after sea breezes take moisture upslope during the day(Munekiyo, 1992). Rainfall within Honolua Bay varies with elevation, from about 30 inches per year at sea level to 150 inches per year at 2,000 feet (Figure 5). The lowest yearly rainfall recorded was 29.528 inches (750mm) and highest was 236.220 inches (6000mm) (CRAMP, 2007).

ML&P operated several rain gauges in the Honolua pineapple fields since the early 1900's. These gauges have not been operational since pineapple cultivation ended in Honolua. Figure 6 shows the total yearly rainfall for field 56 (north upper watershed around 400 feet elevation). Although the amount of rainfall varies within the watershed, rainfall trends are similar between fields.

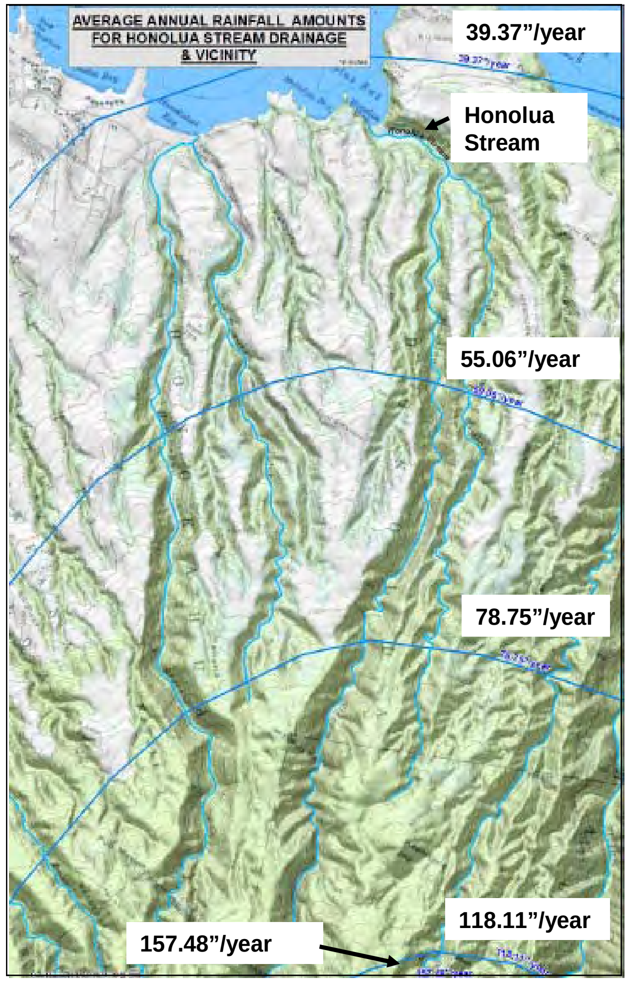

Figure 5. Average Annual Rainfall Amounts for Honolua Stream Drainage & Vicinity. Adapted from ML&P 2006.

Total rainfall also varies regionally because of drought conditions that Hawaii often experiences. Maui County experienced severe drought in 1971, 1977-78, 1980-81, 1996, 1998-89, 2000-02, 2003, and 2006- 07 (Commission on Water Resource Management, 2007).

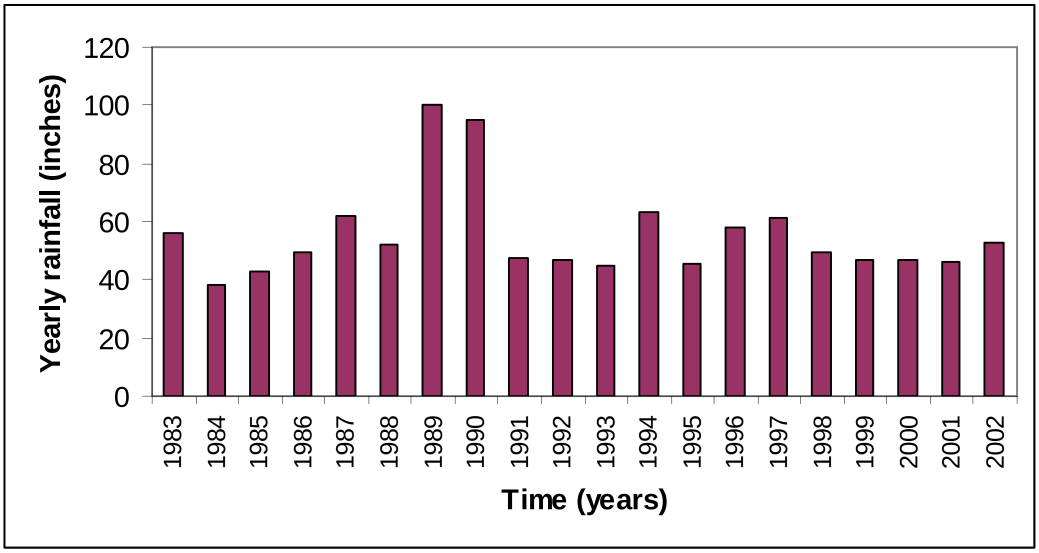

Figure 6. Total rainfall from Field 56 in the Honolua Watershed from 1983 -2003.

4.2 Geology

West Maui has three principal volcanic formations:

1. Wailuku Volcanics, consisting of primitive basalt and olivine basalt, is the oldest, most widespread and hyrogeologically important formation,
2. Andesitic-trachytic rocks of the Honolua volcanic series, covering the Wailuku formation in many areas, and
3. Lahaina volcanics, the youngest formation limited to the Lahaina area. (Yuen, 1990).

Alluvial deposits also play an important role in controlling groundwater occurrence and behavior in addition to the volcanic formations (Yuen, 1990). The most important sedimentary formation is the "old alluvium", a moderately indurated agglomeration of clay and gravel (Yuen, 1990).

4.3 Soils

The soils present in the Honolua watershed cover three soil associations. At the lower elevations below the 400 ft contour the soils are composed primarily of the Waiakoa-Keahua-Moloka'i association (Muneikiyo 1992). This soil association is characterized by well drained sub-soils with fine texture (Muneikiyo 1992). Between the 400 and 1,000 foot contours the soil association is the Honolua-Olelo, which is normally identified with well-drained soils found in intermediate uplands (Muneikiyo 1992). This soil association consists of deep, gently sloping to moderately steep, well-drained soils and is normally found on intermediate uplands. The third soil association type found in the area consists of the Hydrandepts-Tropaquods. This type is found in the upper reaches of the Honolua watershed and is identified with soils that have a fine texture and are well-drained (Munekiyo, 1992). Refer to Figure 7 for the specific soil types found in the Honolua watershed.

4.4 Topography

The Honolua Watershed has extremely variable topography, ranging from approximately 5 percent slope at the base of Honolua Valley to greater than 30 percent on the valley walls (Munekiyo, 1992). The upper point of the watershed is Pu'u Kukui, the highest peak in the West Maui Mountains (elev. 5,788 feet). The watershed is incised by deep valleys radiating outward from the top of the drainage area to the ocean (Maui County, 1976). Valleys typically range from 600 to 1200 feet deep and 1,500 feet wide in their upper reaches, and to about 80 feet deep and 500 feet wide in their lower reaches. Grades begin at about 16% and flatten to 6% as they approach the ocean. (Maui County, 1976) Honolua Valley is a narrow line valley ranging from 150 to 500 feet in width where Honolua Stream enters Honolua Bay (Munekiyo, 1992). The slope of the valley floor from the Bay extending to the mountains is very slight and the 40 foot contour is over 1,400 feet from the coast, making Honolua Bay vulnerable to tsunami damage (Munekiyo, 1992).

4.5 Flood Characteristics

Flood characteristics of the Honolua watershed are described in Munekiyo (1992) and summarized below:

The entire coastal strip of Honolua Bay is designated Zone "V29" by the Flood Insurance Rate Map. It falls within the area of a 100-year coastal flood with velocity; base flood elevations and flood hazard factors determined. The ocean portion of Honolua Valley, below Honoapi'ilani Highway, is designated Zone "A4", indicating that it falls within a 100-year flood area with base flood elevations and flood hazard factors determined. The area mountain-side of the highway, extending to the confluence with Papua Gulch is Zone "A" falling within an area of 100-year flood (Federal Insurance Administration, 1981 in Munekiyo, 1992).

"Calculations of the hydraulic capacity of sections of Honolua Stream (Belt & Collins, 1979) indicate that when storm runoff increases to about 400mgd, overtopping is likely to occur either just above the confluence of Honolua Stream and Papua Gulch, or about 200 feet downstream of the bridge across Honoapiilani Highway. As the storm discharge continues to increase, a greater portion of the valley floor downstream of the bridge will be flooded. For very large magnitudes of storm discharge, both sides of the valley floor will be inundated for a distance of 600 to 800 feet downstream of the bridge." (Munekiyo, 1992).

4.6 Terrestrial Flora and Fauna

The Honolua watershed contains a mix of rare and invasive plant species. The upper watershed (above the 1,500 ft. contour) is dominated by native forest including rare plants such as the *Gardenia Remyi*, while a mix of native and introduced ecosystems and alien vegetation such as *Samanea saman* (monkey pod) dominate the lower watershed.

There are no available terrestrial flora and fauna surveys of the entire watershed. A vegetation survey was conducted in the lower section of Honolua Valley by Belt, Collins and Associates in 1979 as part of a larger Honolua Bay study. An environmental assessment of the Pu' u Kukui preserve area was completed my ML&P in 2005. Several research projects have also undertaken in the preserve, with results published in peer-reviewed scientific journals. Hobdy (2007) recently completed a flora and fauna survey of the lower watershed. Following is a summary from these surveys.

Pu 'u Kukui Preserve

The Pu'u Kukui preserve or "Hill of Light" is the largest private preserve in Hawaii. It covers an area of 9,8851 acres of the West Maui Mountains or Mauna Kahalwai, meaning "Shedding of the Waters". 1196.8 acres are within the Honolua Watershed. The preserve was established by ML&P in 1988 and is managed by Maui Land & Pineapple in collaboration with The Nature Conservancy and the State Natural Area Preserve Program.

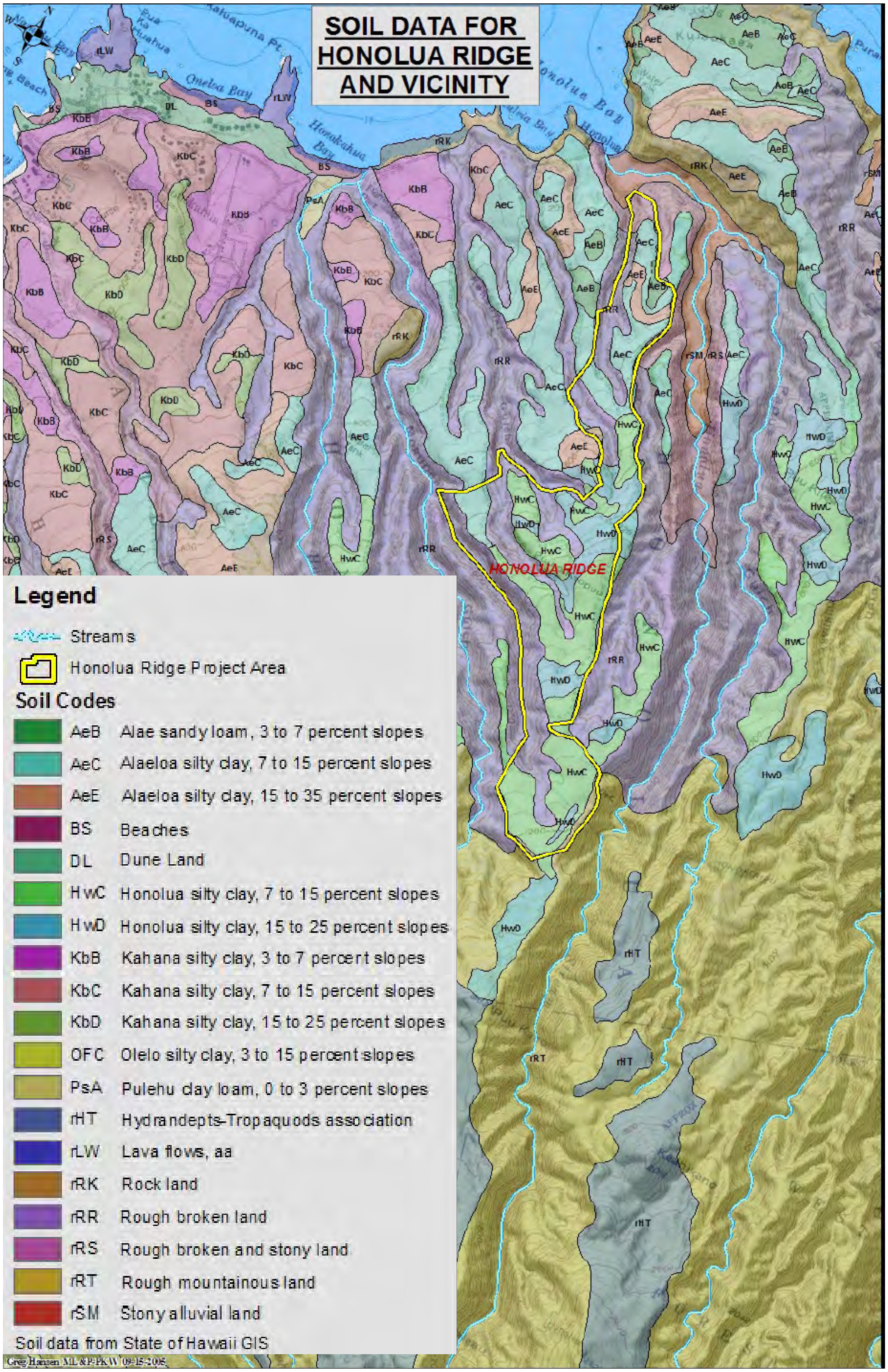

Figure 7. Soil data for Honolua Ridge and Vicinity. Source: Greg Hansen, ML&P, 2005.

The following overview, copied verbatim, was prepared by ML&P (2005) as part of a final environmental assessment for the preserve.

"The Pu`u Kukui Preserve contains 15 terrestrial native natural communities. These natural communities vary from lowland shrub lands to montane forests and bogs. One of these communities is considered rare, as it occurs in fewer than 20 sites worldwide: `Ohi`a (*Metrosideros*) Mixed Montane Bog. Seven of the native natural communities found in the Pu`u Kukui Preserve, including `Ohi`a Mixed Montane Bog, are also found in the West Maui NAR.

The Pu`u Kukui Preserve is home to at least 36 species of rare plants; four other taxa endemic to West Maui also occur here. Eight species of rare plants found in the PKW Preserve are listed as Endangered (E) by the U. S. Fish & Wildlife Service (USFWS). Two other taxa (*Santalum freycinetianum* var. *lanaiense* [`iliahi], and *Clermontia oblongifolia* subsp. *mauiensis* [oha wai]) listed as Endangered potentially occur in the Preserve, but require further study to determine their identity. Specimens have been collected and forwarded to local herbaria but the taxa are problematic taxonomically and still undetermined. Twenty-eight other rare plant species are also listed as either Candidate (C) or Species of Concern (SOC) by the USFWS.

Three native forest birds found in the PKW Preserve's forests are also found in the West Maui NAR: the `Apapane *(Himatione sanguinea sanguinea),* `Amakihi *(Hemignathus virens wilsoni),* `I`iwi *(Vestiaria coccinea).* The PKW Preserve also provides habitat for the Pueo *(Asio flammeus sandwichensis,* Hawaiian Short-eared Owl) - a USFWS Species of Concern, as well as for migratory and sea birds such as Kolea (*Pluvalis fulva*, Pacific Golden Plover), `Ulili (*Heteroscelus incanus*, Wandering Tattler), Koa`e Kea *(Phaethon lepturus dorotheae,* White-tailed Tropicbird), the endangered `Ua`u (*Pterodroma phaeopygia,* Hawaiian Petrel), and the Threatened Newell's Shearwater or A'o (*Puffinus newellii*). Our endangered State Bird, Nene (*Nesochen sandvicensis*) has been observed several times in recent years due to the State's rearing & release program near Hana`ula, and may someday establish a breeding colony near ML&P's Haela`au Cabin on Kaulalewalewa. ML&P' small mammal & predator control program would help facilitate this.

At least seven species of rare native tree snails and two freshwater species *(Partulina perdix, P. splendida, P. tappaniana, Perdicella kuhnsi,* etc.,) have been observed and recorded in the PKW Preserve since management began in 1988. A snail species not seen on Maui for over half a century; *Newcombia cumingi,* was rediscovered in the PKW Preserve in 1994 by Preserve staff. Others species undoubtedly occur, but have remained undetected due to small population size or lack of adequate survey. Other rare invertebrate species include the endemic Hawaiian damselfly *(Megalagrion pacificum);* a candidate endangered species, as well as others. Also, Hawai`i's only endemic land mammal; the endangered Hawaiian Hoary Bat (*Lasiurus cinereus semotus)* has been observed by PKW Preserve staff at various locations throughout the Preserve area.

The Pu`u Kukui Preserve has been divided into 10 Management Units defined by topographical and biological features. The Honolua unit encompasses 1,100 acres stretching from 1,040 to 2,800 feet elevation between Kaluanui (the northwest drainage of Honokohau Stream) and Honolua streams. These streams transport rainwater to ML&P's Honokohau Ditch system's #2 and #3 intakes, respectively. The two landmark peaks of Unit 3 are Keahikauo (labeled as Keahikano @ 2,013 feet elevation on USGS Lahaina Quad.) and the prominent ridge line of Honolua (2,645 feet elevation). Low levels of pig damage still occur in this unit. *Tibouchina herbacea, Clidemia hirta*, and *Andropogon virginicus* (broomsedge) are the principal weed species, with satellite populations of *Cinnamomum burmannii* and *Ardisia elliptica* (Shoebutton, Inkberry). Natural communities include a range of wet and mesic community types. Rare native elements include the plants *Cyanea asplenifolia, Gardenia remyi, Pritchardia forbesiana, Strongylodon ruber*. Animals include several species of *Partulina* tree snails; the Hawaiian Petrel and Newell's Shearwater have been heard in this Unit.; several populations of rare plants and animals occur throughout Unit 3. Three strategic fences have been built by PKW Preserve staff.

Active management by all West Maui landowners is needed to prevent damage to the native forests by feral ungulates (pig, goat & deer) and invading weeds. Nine strategic fences have been built cooperatively by ML&P, the State Division of Forestry & Wildlife (DOFAW), and TNC staff in the PKW Preserve, Kahakuloa (4 fences) and Honokowai (4 fences) sections of the West Maui NAR, and the Kapunakea (1 fence) Preserve. Additionally, new fences have or are currently being constructed in cooperation with NARS and staff of the West Maui Mountains Watershed Partnership (WMMWP); a joint, public/private partnership between majority landowners of mauka conservation lands on West Maui whose intent is to protect and conserve the water and other native natural resources on their respective properties. These kinds of cooperative projects improve the efficiency of management efforts and benefit the entire Kahalawai/West Maui area.

Lower Honolua watershed

Hobdy (2007) surveyed 12 acres of the lower watershed on the NE edge of Honolua Bay, proposed my ML&P for use a surf park. The survey area covered coastal area at sea-level, the coastal bluff and ridge top. He found that vegetation was predominantly non-native and dominated by weedy grasses, shrubs and trees, with only 3 native species among the 22 most common plant species encountered.

The gentle slopes above the bluffs were covered by a weedy grassland with scattered shrubs and trees (Hobdy, 2007). Guinea grass (*Panicum maximum*) dominates with koa haole (*Leucaena leucocephala*), common ironwood (*Casuarina equisetifolia*) and panini (*Opuntia ficus-indica*) also common (Hobdy, 2007).

The steeper bluffs were also dominated by Guinea grass, with swollen fingergrass (*Chloris barbata*), Chinese violet (*Asystasia gangetica*), ʻakulikuli (*Sesuvium portulacastrum*), naupaka kahakai (*Scaevola taccada*) and milo (*Thespesia populnea*) also common (Hobdy, 200).

Hobdy (2007) recorded a total of 80 plant species including:

- 2 species endemic to the Hawaiian Islands: ʻakia (*Wikstroemia uva-ursi*) and pāʼ ū o Hiʼiaka (*Jacquemontia ovalifolia* subsp. *sandwicensis*);
- 9 species indigenous to Hawaii as well as other Pacific islands: ʻuhaloa (*Waltheria indica*), popolo (*Solanum americanum*), ʻohelo kai (*Lycium sandwicense*), ʻihiʼai (*Oxalis corniculata*), ʻilima (*Sida fallax*), naupaka kahakai, ʻakulikuli, mauʼu ʻakiʼaki (*Sporobolus virginicus*) and ʻahuʼawa (*Cyperus javanicus*);
- 2 Polynesian introductions: milo and niu (Cocos nucifera).
- 67 species of non-native agricultural weeds or planted ornamentals.

NB: None of the species are Federally Endangered or Threatened

Hobdy concluded that he steep coastal zone had a diverse and abundant native species that "create a distinctive habitat that along with the dramatic landscape they occupy, should be considered both a scenic and biological asset" (Hobdy, 2007). He recommend that "any proposed trails through the area should be carefully designed to avoid damaging this plant community but also be close enough to allow for viewing and perhaps some interpretive signage. Any intensive development should be restricted to the flat ridge top." (Hobdy, 2007).

Hobdy also surveyed fauna, and found only sign of one mammal species (<u>Mongoose</u> (*Herpestes auropunctatus*)) during two site visits. Although dense vegetation prevented good visibility of ground dwelling animals, Hoby expected a significant population of rats (*Rattus ratus*) and mice (*Mus domesticus*), because of an abundant food supply of seeds and herbaceous vegetation. He also expected feral cats (*Felis catus*) throughout the property.

He made a special effort to look for the native Hawaiian hoary through an evening survey of the area but found no evidence of its activity. The area does not represent ideal bat habitat and there have been no reports of bat sightings in the vicinity (Hobdy, 2007).

He found that birdlife was moderate in both diversity and numbers considering the small size of the property. He recorded 7 non-native bird species during two visits to the area including: Common myna (*Acridotheres tristis*), Zebra dove (*Geopelia striata*) Gray francolin (*Francolinus pondicerianus*), House finch (*Carpodacus mexicanus*), Red-crested cardinal (*Paroaria coronata*), Spotted dove (*Streptopelia chinensis*), and Japanese white-eye (*Zosterops japonica*).

A few other non-native birds might be expected but the habitat is not suitable for any of the native forest birds which are presently restricted to higher elevations in West Maui (Hobdy, 2007). Hobdy did not observe any indigenous seabirds such as the wedge-tailed shearwater or 'ua'u kani (*Puffinus pacificus*) along the coastal bluffs during the survey. The area has suitable habitat and birds would probably attempt to establish burrows if the area did not have heavy human and vehicular use. Any attempts would also likely be unsuccessful due to the predation by mongoose and feral cats (Hobdy, 2007).

Hobdy did not record insects but noted they were common throughout the area resulting in the observed the bird activity. "Although not found on the park site, one native Sphingid moth species, Blackburn's sphinx moth (*Manduca blackburni*), has been put on the federal Endangered species list and this designation requires special focus (USFWS 2000). Blackburn's sphinx moth occurs on Maui although it has not been found in this area. Its native host plants are species of 'Aiea (*Nothocestrum*) and a non-native alternative host plant is tree tobacco (*Nicotiana glauca*). There are no 'aiea on or near the project area but two small tree tobacco plants were seen on the steep bluff. Each of these plants was carefully examined but no Blackburn's sphinx moth or their larvae were observed." (Hobdy,2007).

"The one mammal and seven bird species are all common non-natives. No Endangered or Threatened mammal, bird or insect was found on the park site, nor were any species that are a candidate for such status seen. As a result of this and of the nature and condition of the habitat there is little of concern regarding the wildlife resources on the property and the park plans are not expected to have a significant negative impact on the fauna resources in this part of Maui." Hobdy, 2007.

Honolua Valley
Belt, Collins and Associates surveyed the valley area in 1979. They found monkeypod (*Samanea saman*) was the most significant plant, with the Hawaiian plum (*Eugenia* sp.) being the next dominant. They also observed trees spotted throughout the valley including: ironwood (*Casuarine equisetifolia*), opimua (*Pithecellobium dulce*), Kukui (*Aleruites moluccana*), some eucalyptus sp. and kiawe (*Prospois chilensis*). Several large mangoes (*Magifera indica*), breadfruits (*Artocarpus incisus*), Papayas (*Carica papaya*) were observed on the northern side of the valley. Several palms including the Date Palm (*Phoenix roebelinii*), Chinese Fan Palm (*Livistona chinensis*) and 1 of the Washintonia family, and coconut trees (sp) were also noted. Haole Koa (*Leucaena glauca*) was the main plant in the understory. Numerous Christmas Berry (*Schinus terbinthifolius*) were observed on the slopes of the southern valley. The northern slopes contained many sisal plants (Agave sisalana), Cacus (*Opuntia megacantha*), and night booming cereus (*Hylocereus indatus*). The beach contained several Wili Wili (*Erythrina sandwicensis*), Milo (*Thespesia populnea*), Castor beans (*Ricinus communis*), a variety of common weeds including a large open area of Bermuda grass (*Cynodon dactylon*).

The inland valley had similar vegetation including a grove of acacia (*Acacia koa*) by the stream bed, and guavas (*Psidium guajava*) on the slopes. Kalamoan (*Casia glauca*) was also found along the road side.

They also noted that a variety of wild vines were growing on the larger trees within the forest area. The understory was quite sparse where grazing had occurred but other ground level areas were covered by dense Haole Koa.

5.0 Freshwater Ecosystems

5.1 Groundwater

The Honolua watershed is part of the Lahaina Aquifer Sector, one of Maui's two aquifer sectors. The Lahaina Sector includes four types of aquifers (high-level dike impounded, basal volcanic, sedimentary, minor perched) and six aquifer systems. (Yuen, 1991).

The Honolua aquifer consists of two types of aquifers: high-level dike impounded and basal volcanic (Yuen, 1991). The free basal lens occurs in Wailuku basalt extending for 2 miles inland from the coast, followed by high level dike water to the aquifer boundary (Yuen, 1991). The eastern boundary of Honolua Aquifer follows the ridge separating Honokohua Valley from Honolua Valley. Its south western boundary follows the ridge just south of Kahana Stream to an elevation of almost 4,000 feet, near the headwater of the three major streams in the system: Honolua, Honokohua, and Kahana streams (Munekiyo, 1992). There are also numerous small gulches within the aquifer system. Total average annual runoff is estimated to be 24 inches/year or 28 percent of average annual rainfall. Honolua, Honokoahua and Kahana streams have not cut deeply enough into the underlying lava to tap dike-impounded reservoirs (Munekiyo, 1992). Honolua lavas cover part of the aquifer but are not hydrologically important (Yuen, 1990). Flank lava flows are saturated by the basal lens but widely spaced dikes may reach the coast. Outflow of the basal lens is not impeded by caprock. Yuen calculated a sustainable yield of 8 mgd for basal groundwater, which could be developed as potable water.

5.2 Surface Water

Honolua Stream is characterized as an interrupted perennial stream with an average stream flow of 5 million gallons per day in the upper elevations (EPA *et al*. 2004). Stream flow was gauged by the USGS at 840 ft from 1913 -1917 but has not been gauged since. Honolua stream originates around 3,900 feet elevation on the NW flank of the West Maui Mountains and descends northwesterly for approximately 7.5 miles (SWCA 2006). There are several steep waterfalls in the first mile below the headwaters and the valley is narrow and steep with a wetted stream width varying between 1-9m (SWCA 2006). SWCA (2006) also observed at least 4 large waterfalls in the main stream above 850 feet elevation. An intake structure is located around 800 feet, which diverted approximately 3 million gallons of water daily into the Honokohau Ditch between1903 to 2004 (CWRM, 1990) (Figure 8).

Figure 8. The intake for the Honolua stream diversion.

ML&P voluntarily closed the intake in late 2004 allowing the natural stream-flow to pass downstream (SWCA, 2006). The diversion structure is still operational and stream water continues to flows through it, but all water is returned downstream (Figures 9 -11.) (Schmidt, 2007). The flow of water through the intake diverts flow from a small section (approximately 100 feet) of the stream (Figure 9) (Schmidt personal communication, 2007).

Figure 9. Water flows through the diversion and is piped back to Honolua stream.

There has been debate about the classification of Honolua Stream. It was described as a continuous perennial stream by the Hawaii Stream Assessment (CRWM 1990). Munekiyo (1992) stated that it was "clearly interrupted" because water did not flow below 800 feet elevation due to the diversion of water. SWCA (2006) recommended that the stream be classified as perennial interrupted (as defined by Polhemus *et al*. 1992) because streamflow to the sea appeared to be intermittent under natural (no-diversion) conditions even when flow was perennial in the upper reaches. They suggest that intermittent flow during base flow conditions is caused by the loss of water to Honolua series lavas in the stream bed, below 750 feet elevation (SWCA, 2006). Even though the stream is perennial in the upper reaches, USGS gage data indicates that the lowest natural flow recorded approached zero (SWCA, 2006). Based on the overall decline in surface water discharge since 1913 reported by Oki (2004), SWCA (2006) suggested that flow in the upper reaches may be zero during drought conditions. Based on the intermittent nature of Honolua Stream, ML&P has petitioned the Commission on Water Resource Management to amend the interim instream flow standards for Honolua Stream (SWCA, 2006).

Figure 10. Water from the diversion is returned to Honolua Stream.

Figure 11. Stream flow is diverted from approximately 100 ft of Honolua Stream (left) and returned downstream of the diversion (right).

5.3 Water Quality

Drinking water sources, including groundwater and surface water sources, are regularly monitored by Maui County (see http://mauiwater.org/). There are 2 water systems in West Maui: Lahaina and Honokohau. Until recently water from the Honolua ditch supplied drinking water for the Lahaina water system. Water sources area listed in table 5. The drinking water for both systems meets State and Federal standards. Several primary contaminants are detectable, but are in compliance with State and Federal Standards (Table 6 - 13). Contaminants include Nitrates, Fluoride, TCP 1,2,3 (Trichlorpropane), Chromium, TTHM's (Total Trihalomethanes), HAA's (Haloacetic Acids), Radon, Bromacil, Lead and Cooper. For more information refer to http://mauiwater.org/WQRWESTMAUI.html.

Table 5. Source of Lahaina Drinking Water.

Source Name	**Origin**	**Treatment**
Kanaha Wells 1 & 2	Ground	Chlorination
Waipuka Wells 1 & 2	Ground	Chlorinati on
Kanaha Stream	Surface	Microfiltration, Chlorination
Napili Wells B & C	Ground	Chlorination
Honokohua Well B	Ground	Chlorination
Honolua/Honokohua	Surface	Multimedia/Direct

Table 6. Primary contaminants, with possible health affects, detected in the Lahaina distribution system. Source: 2005 Water Quality Monitoring Results from West Maui. Source: http://mauiwater.org/WQRWESTMAUI.html.

Detected Primary Characteristics	Unit	Highest Level	Range	MCL (Allowed)	MCLG (Goal)	Typical Source of Contaminant	In compliance?
Nitrates	ppm	1.3	ND-1.3	10.0	0	Erosion of natural deposits	Yes
Fluoride	ppm	0.24	0.23-0.24	4	4	Erosion of natural deposits	Yes
TCP (1,2,3-Trichloropropane)	ppt	0.09	<0.04-0.09	800*	N/A	Run off/leaching from soil fumigant	Yes
Chromium	ppm	0.0019	ND-0.0019	100	100	Erosion of natural deposits	Yes

*Regulated in Hawaii but not by EPA

Table 7. Primary contaminants, with possible health affects, detected in the Lahaina distribution system. Source: 2005 Water Quality Monitoring Results from West Maui. Source: http://mauiwater.org/WQRWESTMAUI.html

Contaminant	Unit	Highest Annual Average	Range	MCL (Allowed)	MCLG (Goal)	Typical Source of Contaminant	In compliance?
TTHM'S (Total Trihalomethanes)	ppb	21.4	1.8-49.9	80	N/A	Disinfection by-product	Yes
HAA'S (Haloacetic Acids)	ppb	17.3	ND-38.4	60	N/A	Disinfection by-product	Yes

Table 8. Unregulated substances, which do not have maximum limits but require monitoring, in the Lahaina distribution system. Source: 2005 Water Quality Monitoring Results from West Maui. Source: http://mauiwater.org/WQRWESTMAUI.html

Contaminant	Tested By	Sample Date	Unit	Highest Average	Range	Source of Contaminant
Radon	(1)	2000	pCi/L	87	ND-133	Erosion of natural deposits in groundwater aquifers
Bromacil	(1)	2001	ppm	1.3	0	Run-off/leaching from soil fumigant

Table 9. Lahaina System Lead and Copper rule compliance. Source: 2005 Water Quality Monitoring Results from West Maui. Source: http://mauiwater.org/WQRWESTMAUI.html

Contaminant	Sample Date	Unit	90^{th} Percentile Reading	Action Level	# Samples Above Action Level	In compliance?
Lead	2003	ppb	< 5	15	0	Yes
Copper	2003	ppm	0.16	1.3	0	Yes

Table 10. Source of Honokohau Valley System Drinking Water

Source Name	Origin of Water	Treatment
Kapalua Wells 1 & 2	Ground	Chlorination

Table 11. Primary contaminants, with possible health affects, detected in the Honokohau Valley distribution system. Source: 2005 Water Quality Monitoring Results from West Maui. Source: http://mauiwater.org/WQRWESTMAUI.html

Detected Primary Contaminants	Unit	Highest Average	MCL (Allowed)	MCLG (Goal)	Source of Contaminant	In compliance?
TTHM'S (Total Trihalomethanes)	ppb	7.1	80	N/A	Disinfection by-product	Yes
HAA'S (Haloacetic Acids)	ppb	1.4	60	N/A	Disinfection by-product	Yes

Table 12. . Unregulated substances, that do not have maximum limits but require monitoring, in the Honokohau distribution system. Source: 2005 Water Quality Monitoring Results from West Maui. Source: http://mauiwater.org/WQRWESTMAUI.html

Contaminant	Tested By	Sample Date	Unit	Highest Average	Range	Source of Contaminant
Radon	(1)	2000	pCi/L	87	ND-133	Erosion of natural deposits in groundwater aquifers
Bromacil	(1)	2001	ppm	1.3	0	Run-off/leaching from soil fumigant

Table 13. Honokohau Valley System Lead and Copper rule compliance. Source: 2005 Water Quality Monitoring Results from West Maui. Source: http://mauiwater.org/WQRWESTMAUI.html

Contaminant	Sample Date	Unit	90^{th} Percentile Reading	Action Level	# Samples Above Action Level	In compliance?
Lead	2004	ppb	< 5	15	0	Yes
Copper	2004	ppm	< 0.05	1.3	0	Yes

5.4 Stream Biology

Honolua stream was designated a "Special Area" in the 1990 Hawaii Stream Assessment because of its association with the Honolua-Mokuleia Marine Life Conservation District (Hawaii Cooperative Park Service Unit, 1990 in Munekiyo 1992). This designation means that the stream was identified by Federal, State, County or private agencies as having natural or cultural resources of particular value.

In March and April 2006, SWCA observed native Hawaiian stream animals including migratory fishes and crustaceans and aquatic insects in Honolua Stream above 750 ft elevation. No other biological surveys were found. Thus a detailed summary of the 2006 SWCA report is provided below.

SWCA (2006) found large numbers of endemic O'opu nake (*Awaous guamensis*), O'opu nopili (*Slcyopterus stimpsoni*), O'opu alamo'o (*Lentipes concolor*), the endemic mountain shrimp (*Atyoida bisulcata*), and the introduced Tahitian prawn (*Macrobrachium lar*) in riffles and runs in the stream between 750' and 850' elevation. Many of the o'opu were large suggesting that they inhabit higher elevations at least to the first or second series of waterfalls. SWCA was able to access the stream at only one location above 850; a riffle run complex just above a large waterfall at 2,050 feet. The endemic mountain opae (*A.bisulcata*) was the only amphidromous species present at this elevation. No invasive species (e.g. poecillid fishes and apple snails) were observed in the stream. No listed endangered species were observed during their study; however several breeding pairs for the candidate endangered species *Megalagrion pacificum* (Pacific Hawaiian Damselfy) were found along the stream near an elevation of 2,050 ft. The flow of Honolua Stream at this elevation is not affected by the ditch intake. Their findings suggest that flood flows occur with sufficient frequency to allow upstream migration of native amphidromous species characteristic of unaltered Hawaiian streams. Unfortunately they were not able to locate any baseline aquatic survey data in Honolua stream prior to the late 2004 flow release.

SWCA stated that "empirical evidence suggests that freshets occurred within sufficient frequency over the hundred years between 1903 and 2004 to allow periodic upstream migration of native amphidromous species into the perennial reaches of the stream above the ditch intake near 800 ft elevation. Because the stream itself is short and narrow it's flow volume is slight compared with other Hawaiian streams, limited habitat is available for amphidromous species even under natural conditions. However, since the closure of the intake at Honolua in late 2004, discharge has been more frequent and has enhanced the ability of amphidromous species to invade the stream".

In addition, Hihiwai (*Neritina gransosa*) were not found within the stream, and there was no evidence that hihiwai had inhabitated Honolua Stream in recent years. Native mountain shrimp were found in abundance above high waterfalls at 1,900 ft elevation.

SWCA concluded that "the periodically dry reaches on the stream below 750' elevation, the concrete dam, and the intake grating on Honolua Stream were not permanent barriers for the migration of endemic and indigenous Hawaiian stream animals. The stream above an elevation of 850 ft was undisturbed and provided habitat for native migratory stream animals and endemic aquatic insects. The release of natural streamflows below the ditch intake on Honolua

Stream has restored aquatic habitat; however the exact volume of usable habitat for specific species cannot be quantified without further detailed study. Restoration of natural streamflow in Honolua Stream may result in subtle long-term changes in the ecology of Honolua Bay; however, return to natural conditions is not expected to b detrimental."

6.0 Marine Ecosystems

6.1 Marine Water Circulation and sediment dynamics

ECI (1974) attempted to describe the physical oceanography of the Bay using several sources. Currents were measured by tracking floating objects with surveying equipment, salinity was measured with an American optical refractomter and qualitative temperature measurements were obtained by swimmers. Sediment distribution indicated there appeared to be a seaward flow mainly thru the deep water over the South reef, with a compensating inward flow probably over the northern reef (ECI, 1974). They deduced from salinity measurements that freshwater seeps in at one or more locations and is fairly mixed throughout the Bay. However their qualitative temperature measurements did not support this. They found that cold water was concentrated in the upper 5 feet of the bay waters and 2 locations seemed colder than others: north of the boat launching ramps and over the eastern end of the southern reef. They concluded that "a combination of stream runoff and subsurface seepage may be responsible for inhibiting reef growth in the back portion of the bay".

Brown (1999) examined sediment and water motion in order to understand the causal mechanisms associated with changes in fish assemblages and coral cover. He collected monthly sediment samples for 20 months using sediment traps at both the north and south reefs. Sediment movement was measured using stakes in the central basin. Water motion was measured monthly for 2 years using clod cards, which were compared with the offshore wave record.

Brown (1999) found that:

- Sediment collection rates were higher on the north reef than the south reef throughout the year.
- Sediment collection rates were statistically higher in fall and winter months than spring and summer months at both sites.
- Overall sediment collection rates within Honolua were low compared with other sites along Maui.

- Sediment movement was correlated with water motion and the offshore wave record.
- During low (<4.5m) to intermediate (4.5m – 6m) significant wave height, sediment levels remained constant or gradually entered the bay.
- When significant wave height reached 6m offshore, sediment moved out of the bay in large quantities. This generally occurred during fall and winter months when water motion was statistically higher.
- Sediment did not appear to be the major influence on coral reef structure within the bay compared to water motion. However this may be confounded by scouring activity from the residual sediment, which is restricting coral recruitment and increasing coral mortality, explaining the observed decrease in coral cover.

The United States Geological Survey (USGS) conducted several studies of coastal circulation and sediment dynamics along west Maui, including Honolua Bay from 2001 – 2004 (Storlazzi & Jaffe, 2003; Storlazzi *et al*. 2003, Storlazzi *et al.* 2004). The fourth and final USGS study off West-Maui focused on Honolua Bay (Storlazzi &Presto 2005). The aim was to understand how currents, waves, tides, temperature, salinity and turbidity varied spatially and temporally in the Bay. It also aimed to provide baseline information for future watershed restoration projects proposed by Hawaii's Local Action Strategy for Land-based Pollution. Cruises were conducted during the winter (Feb 03) and late June/early July 2003 during the spawning of the coral *Montipora capitata*.

A MegaDOBIE instrument package was deployed over 9 months, from late June/early July 03 thru winter into mid-march 2004. Two key instruments were utilized for data collection during the spatial surveys: 1. A 600 kHz downward-looking vessel-mounted Acoustic Doppler Current Profiler (VM-ADCP), was used to collect vertical profiles of current velocity and acoustic backscatter data. 2. A Conductivity/Temperature/Depth (CTD) Profiler with an Optical Backscatter Sensor (OBS) collected vertical profiles of water temperature, salinity, density and optical backscatter (a measure of turbidity). A total of 5 km of high-resolution VM-ADCP profile data and 10 CTD/OBS casts were collected during the winter and summer of 2003. These data were collected along shore-normal transects between the 4 m and 50 m isobaths and included CTD/OBS casts at the offshore and inshore ends of each transect line. More than 4800 hourly observations of waves and tides were collected at a fixed location on the 10 m isobath over the course of 9 months between June 2003 and March 2004; more than 93300 observations of turbidity were collected every 4 minutes over this time period. Just over 39500 observations of temperature and salinity at a depth of 10 m were collected over the course of 4 months between June 2003 and November 2003 in Honolua Bay" (Storlazzi and Presto, 2005).

Storlazzi & Presto (2005) found that the tides in Honolua bay were mixed, semi-diurnal with two uneven high tides and two uneven low tides per day; changing just over every 6 hours. The mean daily tidal range was approximately 0.6 m, while the minimum and maximum daily tidal ranges are 0.4 m and 1.0 m, respectively. They found that a rotation of currents generated a semi-permanent eddy in the inner portion of the bay during low wave energy conditions (Figure 12). Mean flow was primarily to the north and northeast around the headland that borders the east side of Honolua Bay; the mean flow in the innermost portion of the bay was to the southwest, towards Honokahua Bay and DT Fleming State Beach (Figure 12). They estimated it could take from 17 minutes to as long as 27 hours, to replace water in Honolua Bay, with an average replenishment time of 33 minutes. This assumed that flow remained constant alongshore, which generally did occur with a range in alongshore current speeds of 0.01 m/sec to 1.84 m/sec with a mean ± one standard deviation of 0.51 ± 0.54. The re-circulating eddy was observed in the innermost portion of the bay 60% of the time during their surveys, thus the replenishment rates are likely an order of a magnitude too large during low wave conditions, as the eddies would help to retain water within the innermost portion of the bay. When large waves impact the bay, the high wave energy gradient would cause these eddies to break down and would likely drive strong cross-shore flows, flushing out the bay over very short time scales (in 1-10's of minutes) (Strolazzi & Presto 2005).

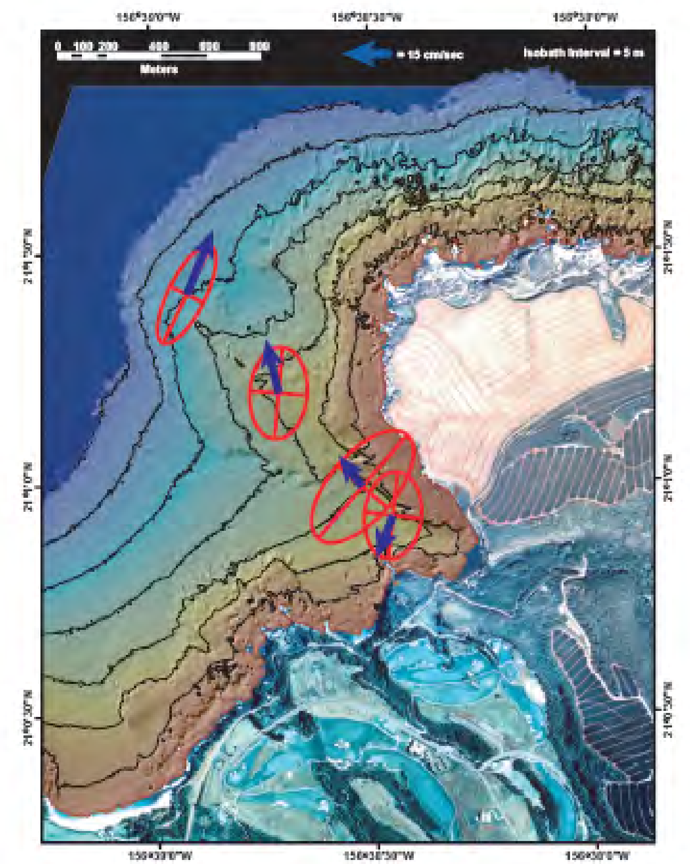

Figure 12. Plot displaying the orientations of net flow in Honolua Bay and its variability. Source: USGS 2005.

The key findings from USGS report were:
(1) There is a persistent eddy in Honolua Bay during low wave energy conditions. Current speeds are greater further offshore and the direction of flow is primarily alongshore. Mean flow offshore is primarily to the north and northeast around the headland that borders the east side of Honolua Bay; the mean flow in the innermost portion of the bay, however, is to the southwest. This suggests significant steering by the coastline.
(2) High turbidity was generally correlated with one of two processes: large wave events that resuspended fine-grained bed sediment and turbid freshwater runoff from the Honolua Stream.
(3) The water in Honolua Bay is generally more saline and cooler further offshore and with increasing depth. These general trends, however, are greatly influenced by the presence of freshwater either from stream discharge or groundwater effluence through the reef."

6.2 Marine Water Quality

Overview

Water quality in Honolua Bay is generally good and meets most Hawaii State Department of Health water quality standards. Near-shore waters to 60' from Honolua to Lahaina are listed as impaired for nutrients, turbidity, and Total Suspended Solids (TSS) in the Hawaii State DOH 2004 list of impaired waters. The listing however is based on visual assessment and prior listings and not current water quality data.

Water quality in Honolua Bay has been monitored semi-continuously since 1990 by Marine Research Consultants (MRC) under contract from Kapalua Land Company (KLC). Prior to 1990 no known water quality data is available. MRC conducted 13 surveys between 1990 and 2006 to determine if land-use activities, particularly agriculture and resort development, were impacting water quality. In 2006 the program was expanded to include near-shore areas off Lipoa Point.

They used identical survey techniques for all water quality surveys with site selection based on having the highest potential for evaluating groundwater and surface water input from land to the ocean. Sampling efforts focused on the Inner Bay, which was expected to be most impacted by land-based inputs. Water samples were collected at 9 nine stations along 2 transects on the north and south side of the Bay (Figure 13). Transects were located within 3 feet of the shoreline and extended approximately 700 ft into the Bay. Samples were collected a 2 depths: surface (10cm from surface) and bottom (within 1 m of the floor), with only surface samples collected at water depths less than 1m. A total of 34 samples were collected during each survey. Water samples were also collected from two potable wells above the Kapalua developments in order to determine the compositions of naturally occurring groundwater that enters the Bay. Freshwater was generally not flowing from Honolua Stream during the surveys, and surveys were generally conducted at low-tide during periods of mild trade-winds and very little swell.

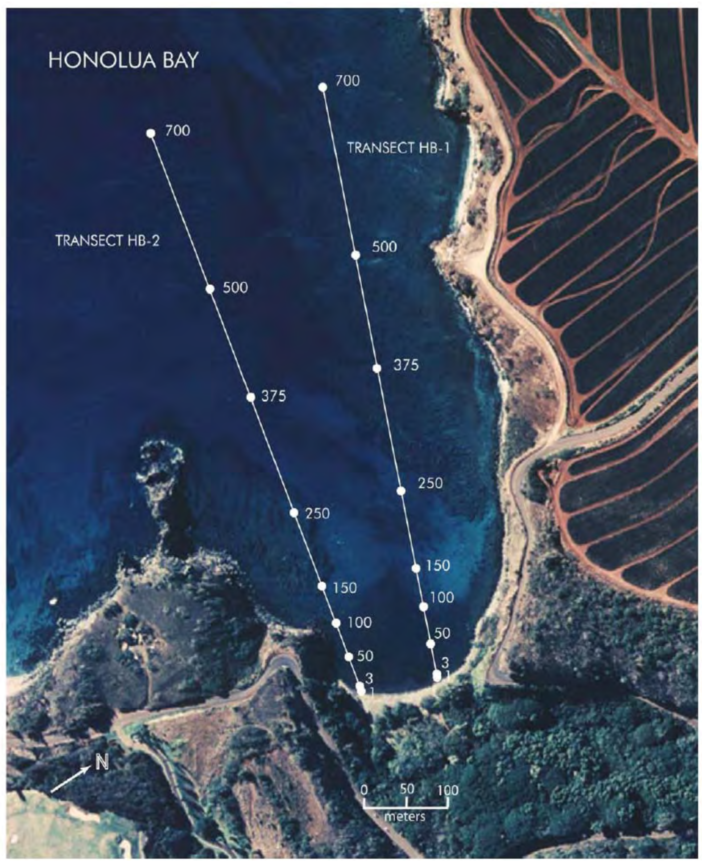

Figure 13. Location of water quality sampling regime used by MRC. Source MRC 2007.

Water quality parameters were evaluated for the 10 specific criteria designated for embayments in Chapter 11-54, Section 06 (Open Coastal waters) of the State of Hawaii Department of Health Water Quality Standards. These criteria include: total nitrogen (TN), nitrate + nitrite nitrogen (NO_3^- + NO_2^-), ammonium (NH_4^+), total phosphorus (TP), chlorophyll a (Chl *a*), turbidity, temperature, pH and salinity. Orthophosphate phosphorus (PO_4^{3-}) and silica (Si) were also reported because they are sensitive indicators of biological activity and the degree of groundwater mixing, respectively (MRC, 2007).

Results:

MRC reported that their water quality data was relatively consistent over the 16 year monitoring period. Water quality was characterized by a highly stratified water column, and three distinct zones (inner, central and outer). Long-term water quality trends were reported by MRC (2007) and key points are summarized below. Refer to the various MRC reports from 1990 - 2007 for a detailed description of individual monitoring efforts.

MRC's long-term data showed a consistent highly stratified water column in Honolua Bay (Table 14). The upper layer was composed of a low salinity-high nutrient lens that originated from groundwater discharge along the sides of the Bay and stream water from Honolua Stream. The remainder of the water column extending to the reef was composed of higher salinity-lower nutrient water than the surface, which was less affected by groundwater and stream runoff.

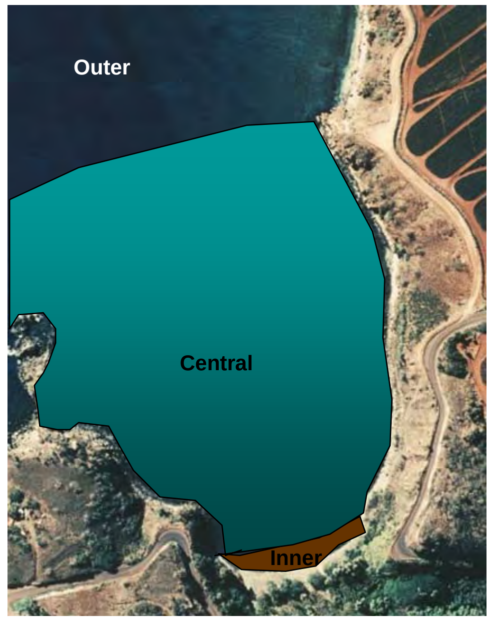

Figure 14. Three distinct water quality zones consistently observed in Honolua Bay: an inner, central and outer zone.

Three distinct zones were consistently observed in Honolua Bay over the entire sampling period (Figure 14). An innermost zone, within about 10m of the shoreline, generally exhibited relatively high concentrations of Si, NO_3^-, and PO_4^{3-} (dissolved nutrients which occur in high concentrations in groundwater) and low salinity relative to other areas. These results reflected the efflux of groundwater and surface water at the inner shoreline.

A second zone (Central Bay) was apparent from about 10m to 500m from the back shoreline seaward to the rocky outcrops that define the mouth of the Bay. Nutrients that are present in groundwater were generally elevated relative to concentrations found in open ocean waters, but were lower compared to concentrations in the near-shore zone.

The third zone (Outer Bay) began in the area seaward of the outer boundaries of the Bay, between 500 and 700m from the back shoreline. Water chemistry reflected coastal oceanic conditions because bay water was generally thoroughly mixed with open ocean water by wind, wave and currents (MRC, 2007).

The water column was also consistently vertically stratified. Nutrient concentrations in the surface layer originated from both naturally occurring groundwater, stream flow, and a component originating from human activities, most likely agricultural leachate.

Table 14. Geometric means (in µg/L) of water chemistry measurements in Honolua Bay collected during surveys conducted since March 1990 (N=19). For calculations of geometric means, detection limits were used for sample data below the detectable limit. Abbreviations as follows: S=surface; D=deep; DFS=distance from shore. Also shown are the State of Hawaii DOH geometric mean water quality standards for embayments under "wet" conditions. Shaded and boxed values exceed DOH geometric mean standards. Source MRC, 2007.

TRANSECT	DFS (ft)	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	TURB (NTU)	SALINITY (o/oo)	CHL a (µg/L)	TEMP (deg.C)	pH
HB - 1 NORTH	1 S	5.00	4.51	2.88	426.7	7.01	97.13	13.14	107.3	0.62	33.644	0.60	25.1	8.14
	3 S	4.30	4.86	2.24	405.5	6.97	96.23	12.31	104.9	0.54	33.734	0.36	25.1	8.14
	50 S	4.06	6.47	2.28	462.1	6.80	94.01	11.97	104.7	0.30	33.637	0.20	25.1	8.15
	50 D	3.18	2.74	1.59	160.3	7.10	93.50	11.30	99.4	0.22	34.466	0.29	25.2	8.16
	100 S	3.36	8.04	1.85	571.8	7.40	92.72	11.47	105.7	0.18	33.385	0.16	25.0	8.18
	100 D	3.04	3.39	1.65	133.8	7.17	91.17	10.59	98.3	0.14	34.547	0.17	25.1	8.18
	150S	3.77	11.52	2.35	536.7	7.02	85.48	11.28	103.8	0.15	33.452	0.15	25.0	8.19
	150D	2.66	2.72	1.74	85.8	7.00	84.63	10.08	92.5	0.12	34.710	0.15	25.1	8.17
	250S	4.08	13.71	1.98	444.5	6.34	81.45	10.93	101.1	0.13	33.634	0.13	25.0	8.18
	250D	2.84	3.73	1.36	79.8	6.94	87.69	10.23	94.3	0.09	34.734	0.13	25.1	8.17
	375S	3.44	8.40	1.68	203.7	6.52	88.39	10.56	101.6	0.13	34.308	0.12	25.2	8.17
	375D	2.74	3.42	1.40	72.7	6.75	87.93	10.05	94.7	0.11	34.734	0.12	25.1	8.18
	500S	2.29	4.21	2.21	119.2	7.15	90.00	9.87	100.1	0.13	34.566	0.12	25.1	8.17
	500D	2.66	2.05	1.70	59.4	7.15	88.12	10.23	93.4	0.10	34.783	0.11	25.2	8.19
	700S	2.27	1.23	1.85	59.7	8.46	91.26	11.28	96.6	0.09	34.759	0.11	25.2	8.19
	700D	2.41	1.08	1.62	46.9	6.98	84.74	9.92	88.0	0.09	34.801	0.12	25.1	8.20
HB - 1 SOUTH	1 S	6.87	11.97	4.33	1123.6	8.22	107.21	16.13	131.1	0.96	30.847	1.78	25.1	8.14
	3 S	5.32	12.82	4.71	904.9	7.29	100.91	14.06	127.9	0.56	31.700	1.13	25.0	8.16
	50 S	4.45	10.79	4.21	626.6	6.93	94.72	11.99	114.2	0.22	32.834	0.29	25.0	8.17
	50 D	3.60	3.22	3.40	273.7	7.36	94.49	11.63	105.1	0.20	33.995	0.42	25.1	8.17
	100 S	3.66	9.44	3.70	487.8	7.08	95.39	11.56	111.6	0.19	33.586	0.20	25.1	8.18
	100 D	3.10	3.40	3.13	122.0	7.25	93.46	10.79	102.2	0.13	34.584	0.21	25.1	8.18
	150S	4.41	17.24	3.26	592.0	7.12	92.42	12.04	116.7	0.14	33.193	0.18	25.0	8.19
	150D	3.65	2.85	2.88	105.6	6.68	91.18	11.00	99.7	0.10	34.474	0.16	25.1	8.18
	250S	4.12	15.12	3.92	506.2	7.14	90.05	11.83	113.7	0.11	33.472	0.12	24.9	8.19
	250D	2.92	2.85	3.74	83.2	7.48	88.95	10.73	97.8	0.11	34.725	0.15	25.0	8.18
	375S	2.93	8.64	4.21	296.5	7.29	89.21	10.98	105.9	0.12	33.969	0.12	25.0	8.19
	375D	2.50	1.33	2.60	70.7	7.32	88.17	10.22	93.3	0.09	34.754	0.13	25.0	8.19
	500S	2.89	2.93	3.27	133.3	7.31	90.38	10.47	99.1	0.11	34.491	0.13	25.0	8.18
	500D	2.34	1.21	2.62	64.3	7.11	87.83	9.94	92.0	0.10	34.767	0.14	25.1	8.19
	700S	2.32	1.66	3.26	86.5	7.95	91.37	10.80	98.5	0.11	34.642	0.12	25.1	8.19
	700D	2.10	0.87	3.09	49.6	7.35	85.84	9.91	91.1	0.08	34.800	0.12	25.1	8.19
DOH WQS		GM	8.00	6.00				25.00	200.0	1.50	*	1.50	**	***

Compliance with DOH Standards

MRC compared their data to DOH water quality standards for embayments under "wet" conditions. Wet criteria apply when the average fresh water inflow is equal or exceeding one percent of the embayment volume per day. DOH standards include specific criteria for three situations: criteria that are not to be exceeded during either 10% or 2% of the time, and criteria that are not to be exceeded by the geometric mean of samples. However these standards are intended for use with large data sets and not single data points. Because only 19 samples were collected from each sampling station, MRC used comparisons with the 10% or 2% criteria to provide an indication of whether water quality was near the stated specific criteria. As these comparisons were not statistically meaningful they are not presented in this report. Refer to MRC (2007) for more details.

The geometric means of samples collected at all stations during the nineteen surveys are shown in Table 14. Samples that exceeded the DOH geometric mean limits for embayments are also shown. Four surface samples from Transect 1, and seven surface samples from Transect 2 exceeded the DOH geometric mean standard for NO_3^- (Table 14). All samples were surface water samples within the inner and central bay zones. The DOH geometric mean standard for Chl *a* was exceeded in the southern shoreline sample from Transect 2. MRC emphasized that all samples exceeding the DOH geometric mean standard for NO_3^- had reduced salinities and were influenced by groundwater. They suggested that the influx of groundwater to nearshore waters could result in samples exceeding the DOH geometric mean of NO_{3-} (MRC, 2007).

MRC also used hydrographic mixing models to interpret the extent of material input from land. This included conservative mixing analyses of their long-term data set (Figure 15). Hydrographic mixing models remove uncertainty caused by comparing concentrations from samples collected during multiple surveys at different stages of tide and wave conditions (MRC, 2007). Concentrations of a dissolved chemical species are plotted as a function of salinity, to examine what nutrients are added and removed from an estuary (Figure 15). Comparing the curves produced by mixing plots with conservative mixing lines (connecting concentrations in open seawater with groundwater) provides an indication of the origin and fate of the material in question (Officer 1979, Dollar and Atkinson 1992, Smith and Atkinson 1993 in MRC 2007). If a water quality parameter displays purely conservative behavior (no input or removal from any process other than physical mixing), data points should fall on or near the conservative mixing line and the linear regression line should be very similar in slope and intercept to this line. Data points will fall above the line if external material is added to the system. Removal of material from the system thru processes such as uptake by biotic metabolic processes is indicated by data points falling below the mixing line.

MRC (2007) stated that their analyses of the long-term data set indicated that there were inputs of NO_3^- and PO_4^{3-} to Bay waters and this was likely the result of leaching of agricultural nutrients to groundwater (MRC, 2007). They also claimed that nutrient input into the Bay had been essentially constant, except for a decrease in NO_3^- into the northern region of the Bay between 2002 and 2006 (MRC, 2007).

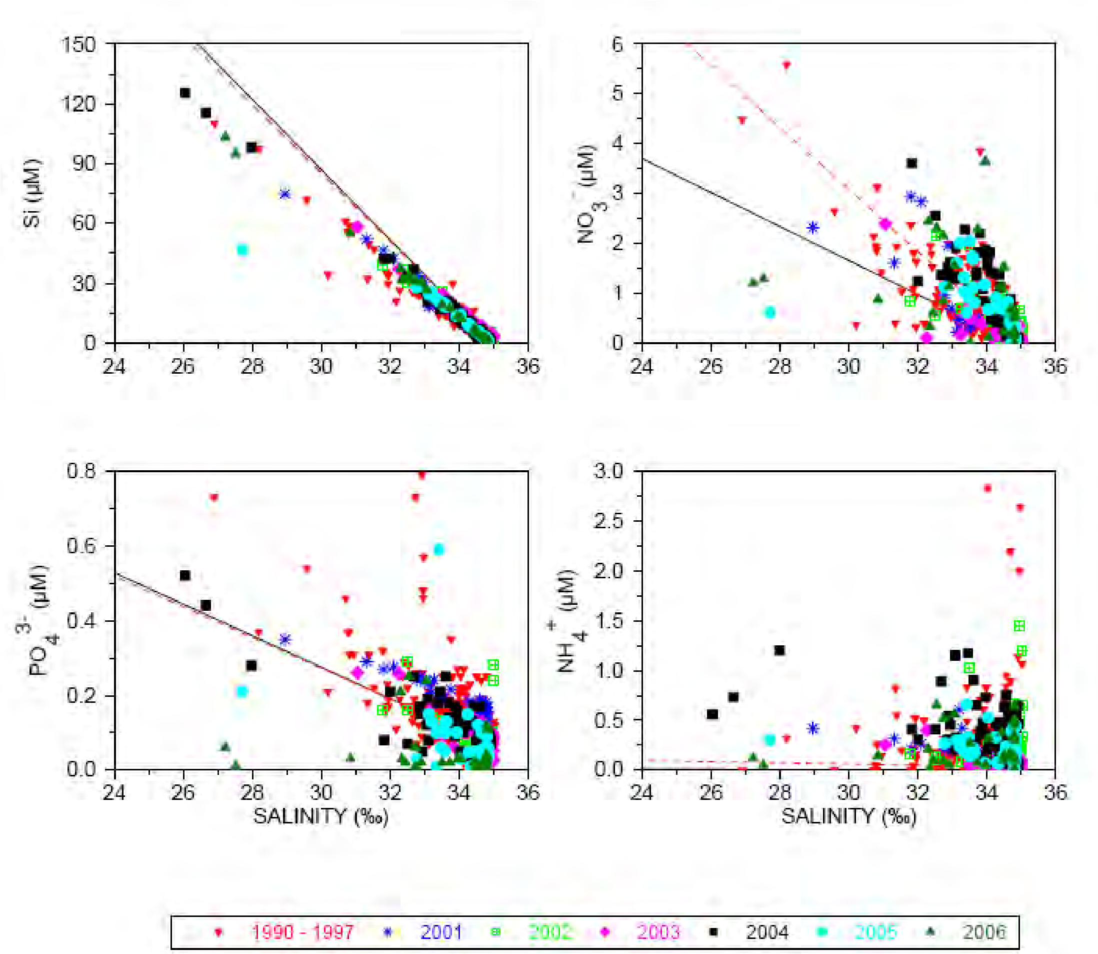

Figure 15. Mixing diagram showing concentration of dissolved nutrients as functions of salinity from samples collected along two transects in Honolua Bay conducted between March 1990 and August 2006. Straight lines in each plot are conservative mixing lines constructed by connecting the concentrations in open ocean water with water from 2 groundwater wells above Kapalua. For transect locations, see Figure 13. Source: MRC, 2007.

6.3 Marine Contaminants

6.3.1 Preliminary Screening for Chemical Pollutants

A preliminary screening for chemical pollutants in sediments and corals in Honolua Bay was conducted in August 2006 by Hawaii's Land-based Pollution Threats to Coral Reefs Local Action Strategy in collaboration with Haereticus Environmental Laboratory. The purpose of this study was to investigate the role of sediments and chemical pollutants in the 10+ year decline in coral cover and recruitment failure at Honolua Bay. The research strategy was to determine bioaccumulation levels of potential toxicants in coral tissues and the health condition of these organisms (biomarkers), while providing scientific evidence for linkages with the chemicals used by key industries in the watershed and marine tourism. The ultimate intent is to reduce risk to the coral ecosystem by improving management of chemical pollutants and/or erosion.

The study intended to answer the following management-related questions:

- Are corals at Honolua Bay exposed to chemical pollutants?
- If yes, what is the origin of the chemicals: vessel antifouling paints, legacy pineapple herbicides/nematicides, or golf course herbicides/pesticides?
- Are corals at Honolua Bay stressed (as evidenced by biomarkers)?
- If yes, are corals stressed by sedimentation (clean sediments) and/or by exposure to chemical pollutants?

Sediment and coral tissue samples returned no positive detections for the 288 target analytes (chemical pollutants) (Downs unpublished data). Chlordane was detected at very low concentrations (pptrillion) in the coral samples, but this was below the standard curve used for detection (Downs unpublished data). Although the target analytes were not detected in this study it is difficult to draw definitive conclusions about contamination levels in Honolua Bay. As samples were collected during a drought it is possible that contaminant levels were lower than average. It is recommended that a more detailed study that is representative of normal environmental conditions be undertaken. This would include sampling during the middle of the "dry season", within the first month of the rains, and half way through the rainy season (Downs pers comm.). Sampling should be combined with a lesion regeneration assay for corals and meticulous transect documentation of coral coverage, density, recruitment. Downs also suggests conducting porewater toxicity tests.

6.3.2 Preliminary analyses of metals and metalloids

Preliminary analyses of metals and metalloids in marine sediments from Honolua Bay were completed in August 2007 by Laetitia Hedouin, Amanda Reichelt-Brushett and Ruth D. Gates from the Hawaii Institute of Marine Biology. This work was funded by the Local Action Strategy to address Land-based Pollution Threats to Coral Reefs, as part of a larger project to develop pollution sensitive bioindicators in corals.

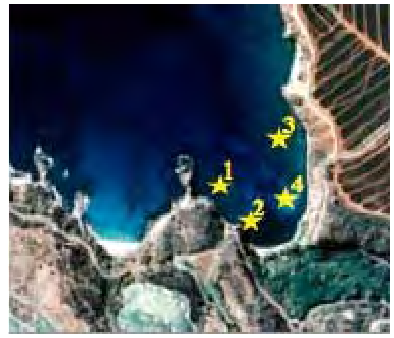

Figure 16. Sample sites for heavy metal analyses. Source: Gates *et al*. (2007).

Sediment samples were collected at 4 stations (Figure 16) in September 2006. Sediment was analyzed for the levels of: Ag, As, Cd, Co, Cr, Cu, Fe, Mn, Mi, Pb, V, Zn. Results were compared to available literature and the 1999 NOAA sediment quality guidelines (Long *et al.* 1995; NOAA, 1999) that define the concentrations of metals and metalloids that have adverse effects on biological organisms. The guidelines list 3 different effect levels: Threshold Effect Level (TEL) represents the concentration blow which adverse effects rarely occur; Effect Range-Low (ERL) corresponds to concentrations above which negative effects are more common, and Effect Range-Median (ERM) corresponds to concentrations at or above which negative effects frequently occur (Gates *et al.* 07). The results of this limited sampling are presented in Table 15.

Table 15. Element concentrations (mean ± SD; mg Kg-1 dry wt) in sediments from 4 stations in Honolua Bay. TEL: Threshold Effect Level; ERL: Effect-Range Low; ERM: Effect-Range Median based on NOAA sediment quality guideline (Long et al. 1995) and NOAA Screening Quick Reference Tables (NOAA 1999). A dash indicates a concentration that was below the limit of detection. Source: Gates *et al.* 07

	Site 1	Site 2	Site 3	Site 4	TEL	ERL	ERM
Ag	0.33 ± 0.03	0.7 ± 0.1	0.12 ± 0.03	0.4 ± 0.1	0.73	1	3.7
As	8.8 ± 1.1	9.5 ± 0.6	4.9 ± 0.5	5.1 ± 0.2	7.24	8.2	70
Cd	0.18 ± 0.03	0.37 ± 0.03	-	0.2 ± .1	0.676	1.2	9.6
Co	41.2 ± 39.7	72.0 ± 5.4	2.1 ± 0.1	60.9 ± 5.2			
Cr	49.5 ± 7.4	198.8 ± 9.3	8.6 ± 0.7	130.3 ± 4.3	52.3	81	370
Cu	7.0 ± 2.2	23.5 ± 2.7	1.0 ± 0.1	17.9 ± 0.8	18.7	34	270
Mn	592 ± 331	667 ± 48	96.6 ± 0.3	799 ± 28			
Ni	200 ± 55	917 ± 73	11.1 ± 1.1	770 ± 68	15.9	20.9	51.6
Pb	0.70 ± 0.05	2.6 ± 0.6	0.7 ± 0.1	2.3 ± 0.6	30.24	46.7	218
Zn	42.2 ± 5.0	139 ± 8.7	11.6 ± 1.0	109.0 ± 6.7			

Gates *et al*. (07) preliminary data indicated that some metals (Nickel, Chromium, Cobalt, Manganese, Arsenic) are found in high enough concentrations to elicit adverse biological effects in marine life (see highlighted values in Table 15). This preliminary study did not examine if metals were impacting the Bay's marine life, or the source of the heavy metals. Other studies in Hawaiian watersheds have shown that elevated metal concentrations were caused by natural erosion and weathering of Hawaiian soils.

They concluded that even though mineralogical processes may be controlling the presence of transition elements such as Ni in sediments, these processes probably didn't account for the extremely high Ni values. They reported that "the presence of such high levels of Ni, Co, Cr and Mn in sediments from Honolua Bay is of concern biologically because bottom sediments enter the food web through ingestion by marine organisms and bioaccumulate through the trophic chain." They recommended that further investigation was needed to determine the source of contamination and if contaminants were biologically available.

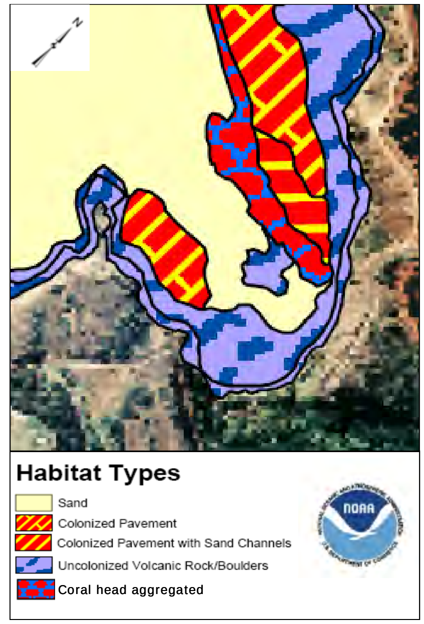

Figure 17. Honolua benthic habitat map, adapted from the Maui Benthic Habitat Map Frame 33, prepared by NOAA.

Hedouin and Gates undertook a comprehensive survey of metal and metalloid contamination in Honolua Bay and other areas in west Maui in September, 2007. They used a biological approach, which determines the degree of contamination in marine organisms from different trophic levels, such as algae, urchins and fish. This will enable a more comprehensive understanding of the bioaccumulation of contaminants in the sediment and in the biological compartments and will allow a better assessment of the long-term implications of contamination. Analyses are being undertaken and results are expected to be available in early 2008.

6.4 Marine Benthic Habitats

Honolua Bay can be divided into 3 broad regions (Figure 17). The regions include a fringing reef extending into the bay and bordering the north and south shorelines, a deeper sandy bottom area between the reefs, and an inner area of silt, sand, and a boulder bottom extending across the inner bay, offshore from the sand and cobble beach at the head of the bay.

The central sandy region is composed of well sorted sands of both terrestrial and biogenic origin (calcareous material).The percentage of terrestrial basaltic sands and silt content decreases from shore. Surface discharge from Honolua stream is intermittent and limited to high rainfall. Groundwater discharge at the coast appears to be continuous and concentrated at 2 points located near the shoreward edges of the fringing reefs on either side of the bay. (ECI 1974).

Benthic habitat types were mapped by the NOAA biogeography program in cooperation with Analytical Labs of Hawaii in 2002. Habitat types for Honolua Bay are shown in Figure 19. The Maui Benthic Habitat Map is in Appendix A.

6.5 Coral community structure

Marine biologists have been studying the ecology and biology of the coral reef ecosystems in Honolua Bay for the past 33 years. Studies have been undertaken by numerous researchers, utilizing differing methodology (Table 16). A summary of the different survey methods is provided in Table 17. A detailed description of the survey methods and results is provided below.

Table 16. List of marine surveys included in this report.

Year	Investigators	What studied
1974	Environmental Consultants Inc.	Marine geological, physical & biological (coral and fish) surveys
1979	Torricer et. al. (UH marine option program)	Fish census, substrate type, macroalgae
1989-1998	Pacfic Whale Foundation	Substrate type and coral composition
1990, 1992, 2002, 2006	Marine research consultants	Substrate type and composition
1992	Marine research consultants	Substrate type and composition
1994-1998	Eric Brown (PhD research)	Coral cover, size frequency distribution and recruitment
1999-2007	CRAMP (1999-2001) DLNR-DAR (2002-07)	Substrate type and composition

Table 17. Summary of reviewed coral reef survey methods.

Investigators	Parameters	Methods Used	Transect details	Quadrats	Points	Analysis
Environmental Consultants Inc.	coral size, growth form, color, depth	visual field estimates, line intercept and quadrat	five 50m transects, perpendicular to shore	1m2 at depths between 2.1m - 3.9m	not applicable	not applicable
Torricer et. al. (UH marine option program)	coral cover, algal cover	modified photo method, visual field ID	sixteen 100m transecs, parrallel to shore at constant depth	10 random photos on each transect, 0.5m x 0.8m size at 1.3m height	not applicable	projected life size images and used 10cm2 grids to assess coral cover
Pacfic Whale Foundation	coral cover	not available	not available	eight 1m2 random	not available	not available
Marine research consultants	coral community cover and structure	photoquadrat transects	eight 50 m transects (4 pairs of parrallel transects) on N & S reef	10 random quadrats (1m x 0.66m)	not applicable	100 equal size segments used to assess coral species cover and substratum
Eric Brown (PhD research)	Coral species richness, % cover and diversity	visual quadrats and digital video transects	three 50m fixed transects parallel to shore along 3m depth contour (at low tide) on N & S reef flat (in CRAMP corridor)	12-48 random quadrats on 3 fixed transects	81 intersections per quadrat	Reeds planar point intercept quadrat method
	Size frequency	visual surveys	as above	not applicable	50 coral colonies on each 10m fixed transect (500 total)	not applicable
	Life history	fixed photoqudrats	10 fixed transects within each transect (see above)	20 random non-overallping video frames on each transect	50 random points in each frame	image analysis point count 99 software
CRAMP	% cover, richness, coral diversity, algal groups, substrate cover	digital video	10 permanent 10m transects at 3m depth on N and S reef flat.	20 random video frames,	50 random points per frame	photogrid software
	% cover, richness, coral diversity, algal groups, substrate cover	digital still image	as above	20 non-overlapping images, 50cm x 69cm size at 1.7m height	50 random points per image (1000 points per transect)	photogrid software
	2D estimates of aerial cover	fixed photoquadrat	within transect area	5 haphazard along depth contour, 0.33m/2 area at 50cm height		images of sessile organizms are traced and digitized.

6.5.1 Environmental Consultants Inc.1974

The first comprehensive study was conducted by Environmental Consultants Inc. in 1974 and provided the first comprehensive coral and fish data for Honolua Bay. ECI surveyed the distribution, abundance, and diversity of corals in January and April 1974. This included measurements of coral size, growth form, color, habitat and depth of each species. They also measured the physical variables including water motion, water transparency, temperature, depth and substratum type. Visual estimates were made in the field using five 50m transects perpendicular to the shoreline (Figure 18). Line intercept and quadrats were used to estimate coral abundance and distribution.

ECI described Honolua's coral reef ecosystem as "outstanding". "The biota of the reef environment is particularly outstanding owing to the diverse nature and luxuriant growth of corals found there. At least one rare species of reef animal (the coral, *Porites convexa*) was observed in Honolua Bay." They estimated the Bay's total mean live coral cover was 48%. The most diverse flora and fauna was on the fringing reef, including the reef flat and boulders at the shoreline behind it.

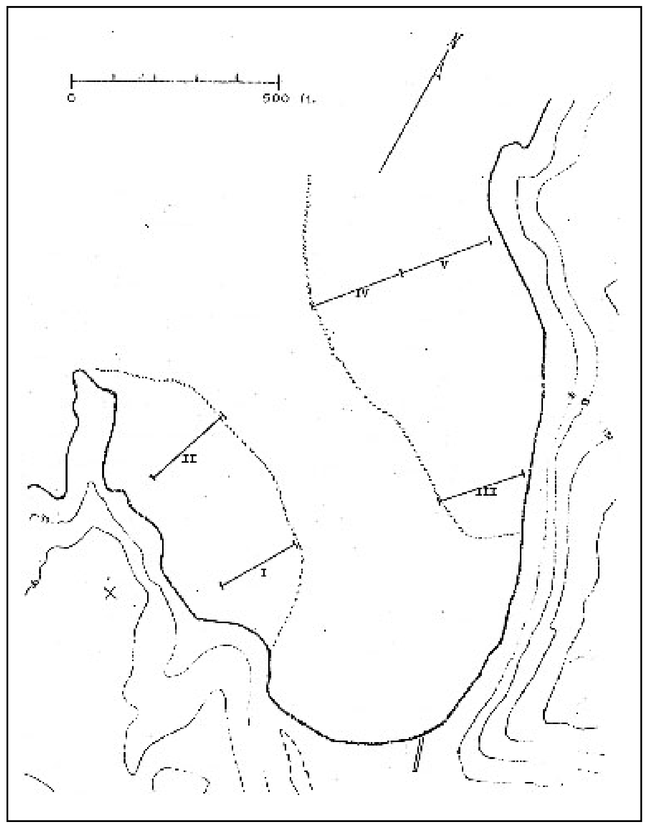

Figure 18. Location of ECI's transects.

ECI divided the bay into three areas: a fringing reef extending into the bay and bordering the north and south shorelines; a deeper sand bottom area between the fringing reefs; and an inner area of silt, sand and boulder bottom offshore from the sand and cobble beach, as described previously in Section 6.4. They provided a detailed description of the coral community structure in each region. This is summarized below and in Figure 19.

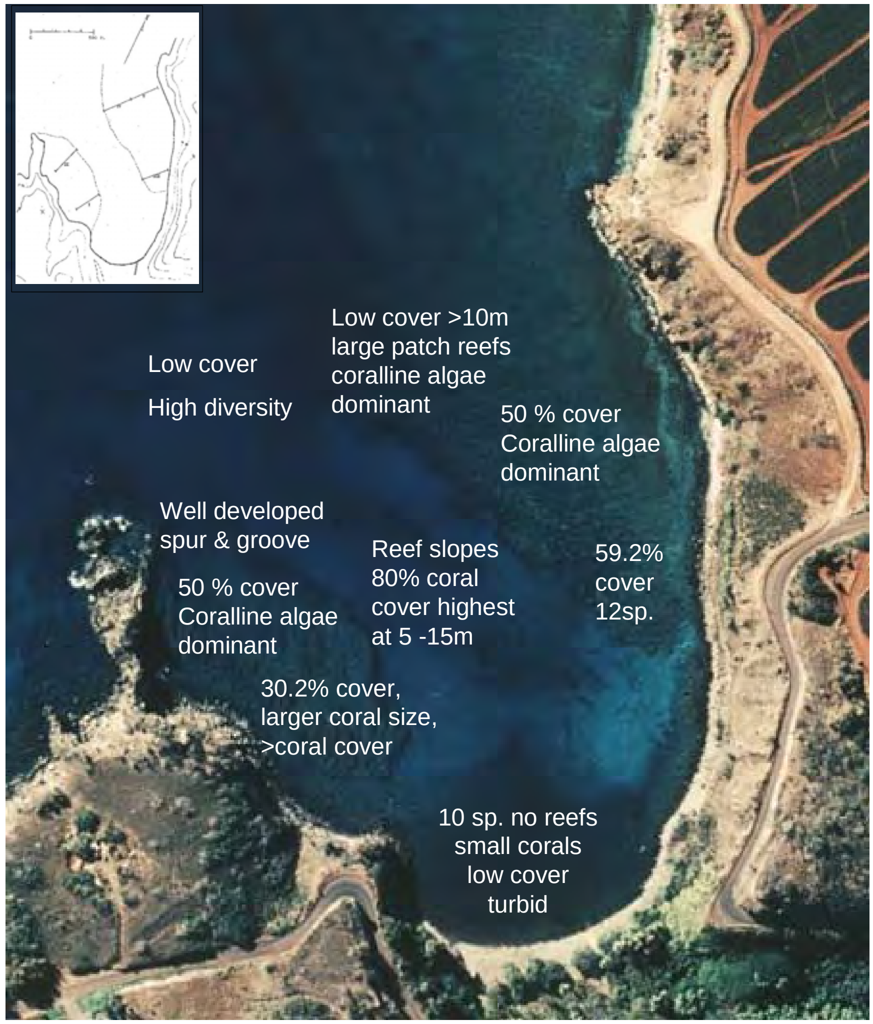

Figure 19. Honolua Bay coral cover described by ECI, 1976. Inset shows transect locations.

The inner bay was characterized as having high turbidity, reduced temperature and salinity, small corals and low coral cover. Ten species of coral were identified although reefs were absent. Water quality was influenced by the nearby intermittent stream and groundwater seepage, and most hard substrata was covered with sediment and not suitable for coral settlement and attachment. Most corals were confined to the tops of boulders or cobbles projecting above the soft bottom. The smaller coral size could be attributed to slower growth rate, or because of periodic environmental disruption from floodwater and sediment entering the bay during heavy rains. Eight coral species were found with 30m of the boat ramp near the black sand beach.

The reef was consolidated approximately 100m from the back margin of the bay, with coral cover averaging 45% (Nth 59.2%, Sth 30.2%). Corals were larger in size with greater coverage. The reef margin was a distinct wall between 1 and 3m high and reef flats were irregular, showing numerous depressions. The reef framework was less developed on the Nth Side, but had higher coral cover, with atleast 12 species of coral on the inner reefs. *Porites lobata* and *Montipora verrucosa* were most abundant and a few of the coral species were only found in the inner part of the bay. Colonies were measured up to 1m diameter.

The middle bay fringing reefs had the greatest development and diversity. Coral cover averaged 50% on the middle reef and 80% on the slopes. The vertical thickness of the middle reef was much greater and the reef slopes were steep 45 - 60 degrees. Most of the Bay's coral species were found on the middle bay reefs, with *Porites* sp. and *Montipora* sp. dominant.

Porites compressa was dominant on the reef slopes with the highest cover found between 5m and 15m. *Monitopora verrucosa* was also common. On the shallow near upper edge of the reef face, massive colonies of *Porites lobata* were common and all 3 species. of *Montipora* were abundant. There were no significant differences in coral fauna reported between the north and south reefs.

The middle bay reef flats, shoreward form the reef slopes, had different biota than the reef slopes. Coralline algae replaced reef corals as the dominant bottom organism. The reef flat became shallow near the shoreline and several coral species, especially *Porites compressa* dropped out, while *Leptastrea*, *Pavona* and *Monitpora* remained common. Only a few corals were found at the shore.

The outer bay had low coral cover at depths greater than 10m, but some large patch reefs existed. Coralline algae such as. *Porolithon* sp. were dominant. The reef front along the southern bay had a well developed groove and spur system oriented towards the NW, in the direction of maximum wave energy. This groove and spur system was well developed compared to most Hawaiian Reefs. The groove and spur system was poorly developed on the north side although ECI did not survey Lipoa point. They suggested that wave action was more severe on the south side. The most common species were *Montipora*, branching *porites* below 10m, and encrusting *porites* and *montipora* and stout-branched *pocillopra* in shallower water.

The deep submarine slope was surveyed at two locations (55 and 43 feet deep) in an earlier study by ECI (ECI ,1971 in ECI, 1974). They found that coral cover was low, although diversity was high. The most common coral species were encrusting *Porites* and *Montipor*a and branching *Pocillopora*. The coral communities deep offshore from Honolua did not differ significantly from along the coast at comparable depths.

Honolua bay had the most diverse coral community of sites surveyed along the NW Maui Coast, including 18 species representing most of the common Hawaiian shallow water species (Appendix B). Refer to ECI (1974) for a detailed description of the location and growth form of coral species occurring in Honolua Bay.

6.5.2 Torricer *et al.* 1979

In 1979 nine students from the University of Hawaii Marine Option Program conducted field surveys of the algae, substrate and fish populations in Honolua Bay (Torricer *et al.* 1979). Sixteen 100m transects were located in the 3 regions of the bay, parallel to the shore at constant depth (Figure 20). Three transects were located outside Honolua Bay (Figure 20). Ten random points were selected on each transect and a modified photographic method was used to estimate coral and algal cover. A Nikonas II 35 mm lens mounted 1.3m above the bottom was used to capture 0.5m x 0.8m sections, covering a total area of 4m along the transect line. Corals and algae were visually identified in the field, and unknown species were collected for later identification. Percent cover was estimated by dividing the substrate into 6 categories: 1. hard basalt bottom, 2. rubble-loose, dead coral, 3. sand, 4. silt and mud 5. algal mat, 6. live coral. In the laboratory percentage cover was estimated by projecting life-size images onto a screen with 10cm² grids. The frequency of occurrence of the substrate types and similarity indices between transects were processed using computer programs.

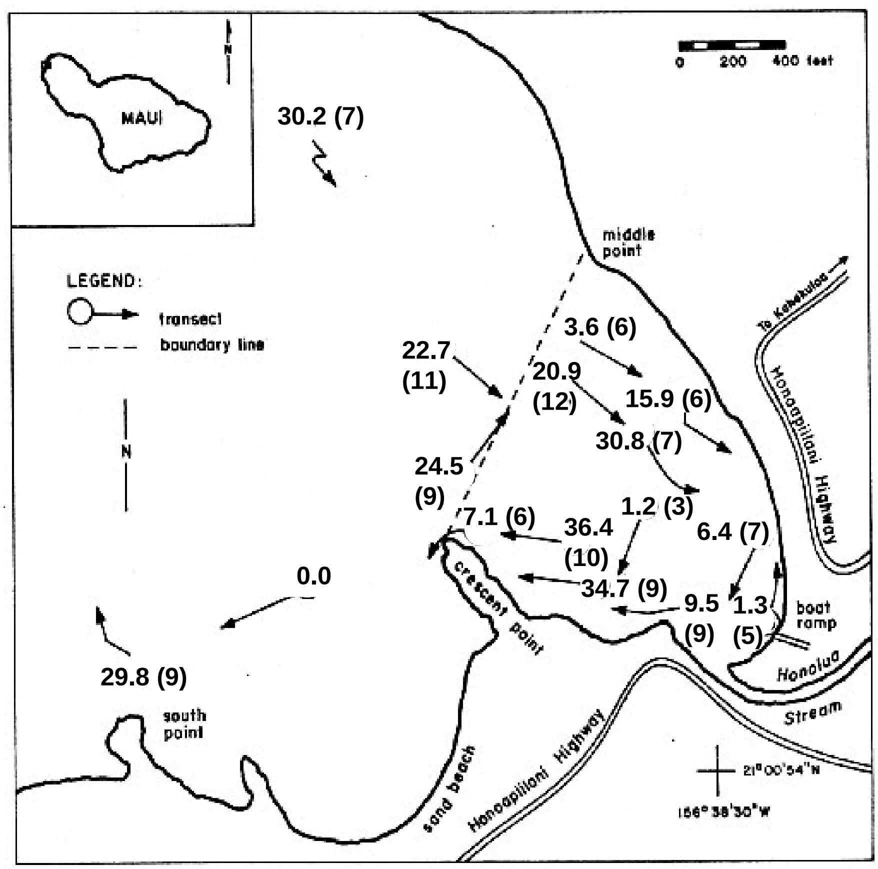

Figure 20. Location of 16 transects (shown by arrow), percent coral cover, number of species (in brackets) measured by Torricer *et al.* 1979. Figure adapted from Torricer et al. 1979

Frequency of occurrence was defined as the number of transects that a substrate type or species appeared divided by the total number of transects. The similarity index, was obtained using the Sorensen quotient, which indicated how similar transects are by comparing the percentage of individual species.

Mean live coral cover for all transects was low (17.2% mean) although high levels of diversity did occur (max 12 species) (Figure 22). The number of coral species and coral abundance increased in the southern Bay, near Crescent Point (Figure 20). The north reef near middle point, had less coral cover but a higher diversity in some areas. The regional abundance and distribution of reef corals was influenced by 3 key factors: substrate relief, sedimentation, and salinity. Corals were more abundant on the fringing basalt ledges than in the sand/silt channel extending into the Bay. Coral growth in the sand/silt channel was limited to the intermittent patches of suitable hard substrate. Hermatypic (reef building) corals were dominant along the reef slope but cover was reduced near the slope bottom due to sedimentation of sand and silt. The largest area of hard basalt (34.7% cover) occurred in the freshwater mixing zone near the first rock outcrop in the SW section of the Bay. Coral cover was low (9.5%) in this area and may have been limited by the low salinity water.

The inner region of the bay near the boat ramp and stream mouth was covered with fine terrigenous silt extending to the channel. There was low coral cover in this area ranging from 1.3 – 6.4%, with slit/mud covering the remaining area (93.6%-98.8%). The most abundant coral species were *Porites lobata*, *Montipora verrucosa*, and *Porites compressa,* occuring at frequencies of 0.938, 0.875, and 0.563 respectively. One rare species, *Montipora verrilli*, was identified in the field but not validated and could have been the more common species *M. patula* .

6.5.3 Brown, CRAMP and DLNR-DAR (1989 – 2007)

Brown, working with the Pacific Whale Foundation (PWF), surveyed coral cover and fish populations at Honolua Bay and 8 other sites around Maui from 1989 thru 1998. In 1994 PWF started pooling site data for their 9 long-term monitoring sites, and broadened the scope of their monitoring to examine natural and human induced causal factors that might explain patterns in coral cover and fish density. At the same time, Brown began detailed surveys of coral cover, coral size frequency distribution, and coral recruitment for his PhD research. In 1989 PWF's monitoring program was incorporated into Hawaii's Coral Reef and Assessment Monitoring Program (CRAMP). The Hawaii Department of Land and Natural Resources, Division of Aquatic Resources, incorporated Honolua

Bay into its state-wide coral monitoring program in 2002. DAR uses the CRAMP methodology enabling comparison with long-term data. These three monitoring programs are combined in this section to provide one long-term data set.

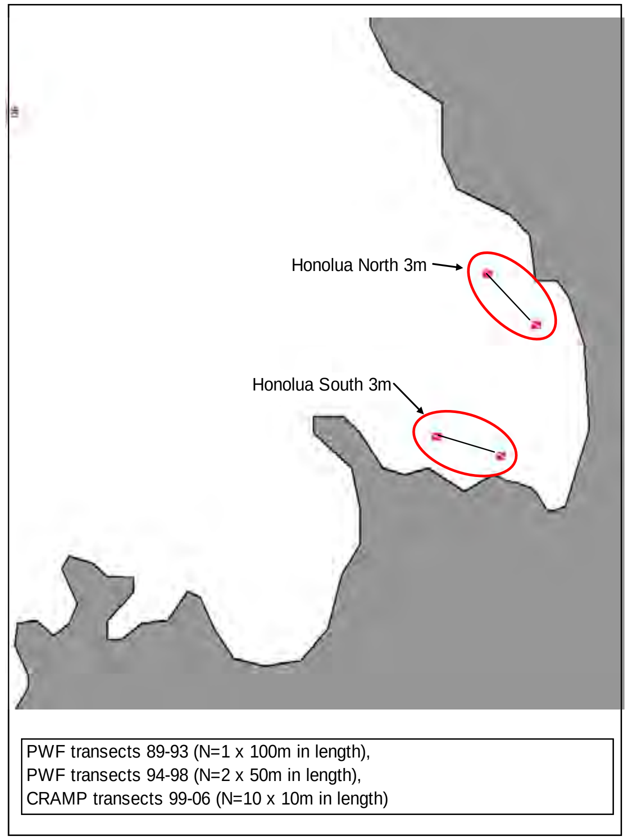

Figure 21. The two regions where PWF and CRAMP transects were located. Source: Brown 07.

Methods

During 1994 – 1998 Brown measured coral cover, coral size frequency distribution, and coral recruitment as part of his PhD research (Brown 2004). He compared 2 long-term monitoring approaches to assess the condition of the coral reef: 1. visual quadrats and digital video transects to assess historical development of each reef over 9 years, and 2. life history parameters such as coral growth, recruitment and mortality, by tracking individual colonies over 4 years with fixed photoquadrats.

Three permanent 50m transects were located on the north and south reef flat parallel to shore along the 3m depth contour. Varying numbers (14-28) of $1m^2$ quadrats were randomly placed on each transect and coral species richness, percent cover and diversity were measured using Reed's planar point intercept quadrat method (Reed 1980 in Brown 2004). Reed's technique utilizes a grid to divide a $1m^2$ quadrat into 81 intersections. Surveys occurred annually from June to August. See Brown (2004) for a detailed description of short-term and long-term monitoring methods.

Brown determined there was an average 5% error in percent cover estimated using digital video. He therefore defined an absolute change of equal or greater than 10% was biologically relevant if the change was statistically significant with high statistical power ($P>0.8$ at $\propto 0.05$).

The Hawaii Coral Reef Assessment Monitoring Program (CRAMP) incorporated PWF's Honolua monitoring sites into its monitoring program in 1999. Transects were randomly selected in the PWF survey area so that data could be compared. Only 2 of 3 PWF transects were included in the CRAMP survey sites. Total area sampled at each station is 35 m^2. CRAMP and PWF survey methods were both used in 2000 to enable comparison of methods. Statistical analyses showed no significant difference in results, enabling comparison of data between studies. CRAMP survey sites were located on the north and south reef-flat at 3m depth (Figure 21). The survey sites are near MRC's shallow transects (T1) in the inner region of the north and south reef (site I and III).

CRAMP utilizes 2 methods to address changes in overall coral cover and growth, recruitment and mortality of benthic organisms. Refer to Brown *et al.* (2004) for a detailed description of CRAMP methodology. The following summary is adapted from the CRAMP web-site (http://cramp.wcc.hawaii.edu/LT_Montoring_files/lt_methods.htm).

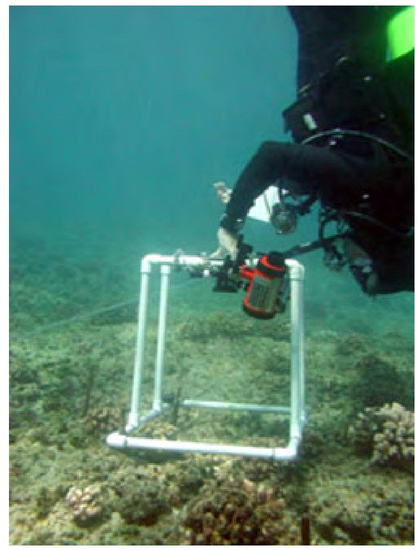

Figure 22. Eric Brown positioning the frame for a photoquadrat. Photo by Paul Jokiel.

The first method initially used digital video to measure changes in coral cover. Ten permanent (fixed) 10m transects were randomly selected at 3m depth. Each transect was analyzed using 20 randomly selected video frames with 50 randomly selected points per frame. Sampling was conduced once a year, which is sufficient to detect a 10% change in coral cover over time with high statistical power (P> 0.8 at a £ .05) across of variety of habitats in Hawai'i (Brown, 2004). This method was updated in 2003 by replacing digital video with digital still images to assess substrate cover (Figure 22). Before switching tools, the compatibility of methods was assessed through inter-calibration. The updated method utilizes non-overlapping digital stills to assess the characteristics of benthic populations. High resolution digital images are taken along a 10 m transect using an Olympus 5050 zoom digital camera with an Olympus PT050 underwater housing. The camera is mounted to an aluminum monopod frame, 1.7 m from the substrate to provide a 50x69 cm image. A 6 cm bar provides a measurement scale. The software program PhotoGrid (Bird 2001) is used to quantify percent cover, richness and diversity of corals, algal functional groups and substrate cover. Images are downloaded and the 20 non-overlapping images from each 10 m transect are imported into PhotoGrid where 50 randomly selected points are projected onto each image for a total of

1,000 points per transect. These data are saved in a comma separated values (CSV) file, proofread in Excel and imported into Microsoft Access XP, a relational database. Access data can then be queried and exported to statistical programs for analyses.

The second method employs fixed photoquadrats to examine trends of individual organisms with regards to growth, recruitment and mortality (Figure 23). Five haphazardly selected photoquadrats at each depth contour are established with 4 pins at each corner to ensure accurate repositioning of the frame. The frame dimension sample 0.33 m^2 of the substrate at a height of 0.5m from the bottom. Images of sessile organisms are traced and digitized to give 2D estimates of aerial coverage.

Figure 23. Fixed photoqudrat at 3m depth on the N reef. Source: CRAMP, 2007

Sediment composition, sediment grain size and rugosity data are also collected during the surveys. This data was not easily accessible and has not been included in this review.

Results

Average coral cover decreased on the north and south reef flat between 1994 and 2006 (Figures 24 and 25). Average coral cover on the north reef flat was 38% in 1994, and 9% in 2006 (Figure 24). The south reef decreased from 43% to 9% average coral cover between 1994 and 2006 (Figure 25). After a decrease in coral cover from 1994-1999 at both sites, coral cover appeared to be stabilizing around 15-20% cover between 2000-

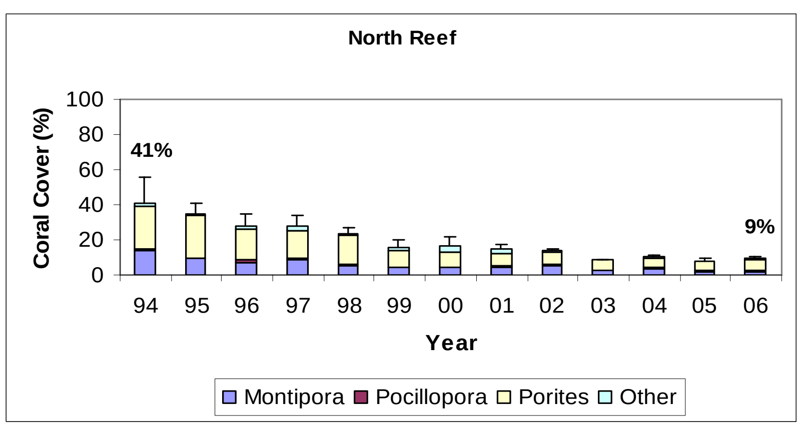

Figure 24. Average coral cover on the north reef flat measured by PWF, CRAMP and DLNR from 1994 – 2006.

2004 (Brown, 2004), but then decreased in 2005. The three dominant corals were *Montipora* sp., *Pocillopora* sp. and *Porites* sp. The community structure differed between the 2 regions, with *Porites* sp. dominating coral cover on north reef and sediment resistant *Montipora* sp. dominating the southern reef.

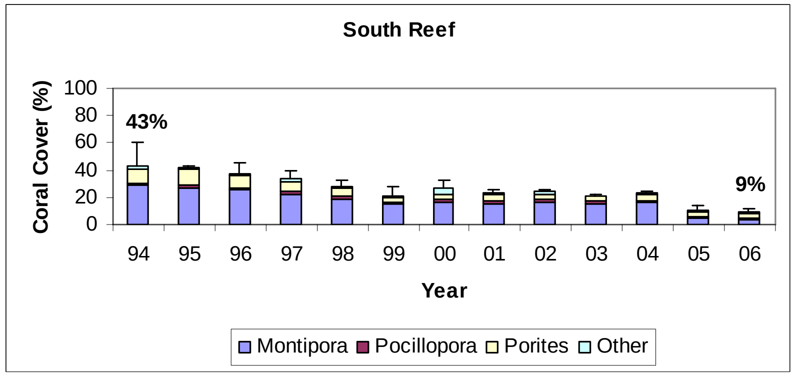

Figure 25. Average coral cover on the south reef flat measured by PWF, CRAMP and DAR from 1994 – 2006.

Brown (2004) showed that the initial decline on the north reef flat from 1994-1999, was primarily due to an 11% decrease (relative 63% decrease) in *Porites lobata* cover. The decline in coral cover from 1994 - 1999 on the south reef flat was primarily due to a 4% decrease (50% relative decline) in *Montipora patula*.

Brown was able to explain long-term trends on Honolua reefs, even though there was no consistent pattern between his various data sets collected using different short-term and long-term methods. He suggested that the low invisible recruitment for coral species on the north reef flat coupled with low growth rate and high mortality suggested that they were experiencing low recruitment success. The low rates of recruitment, low growth and high mortality shown by his short-term studies suggested that future disturbances could further degrade the reef structure.

The south reef flats also appeared to be declining. Contrasting patterns were seen between Brown's long-term data sets, the photoquadrats and size frequency distribution. *Montipora capitata* and *Pocilloproa meandrina* populations appeared to be stable in comparison to *Porites compressa* and *Porites lobata* populations, which were declining. He suggested that the reef communities could be undergoing a shift in community structure from *Porites* spp. to *Montipora* spp. However he thought this was unlikely given that *M. patuala* cover decreased 3.1% from 7% to 3.9% between 1994 - 2002. Instead he predicted there would be a slow steady decline in several abundant coral species. In addition the remaining species showed no evidence of increasing cover.

Brown (2004) showed that there was no significant difference in data collected using PWF and CRAMP survey methods and was able to compare data sets. He found that coral cover on the north reef flat decreased significantly between 1995 and 1996. No other years (from 1994 - 2002) differed significantly. Coral cover on the south reef was significantly different between 1997 - 1998 with almost no difference between 1995 -1996. He proposed that the north reef might be impacted by wave disturbance while the south was impacted by sediment stress.

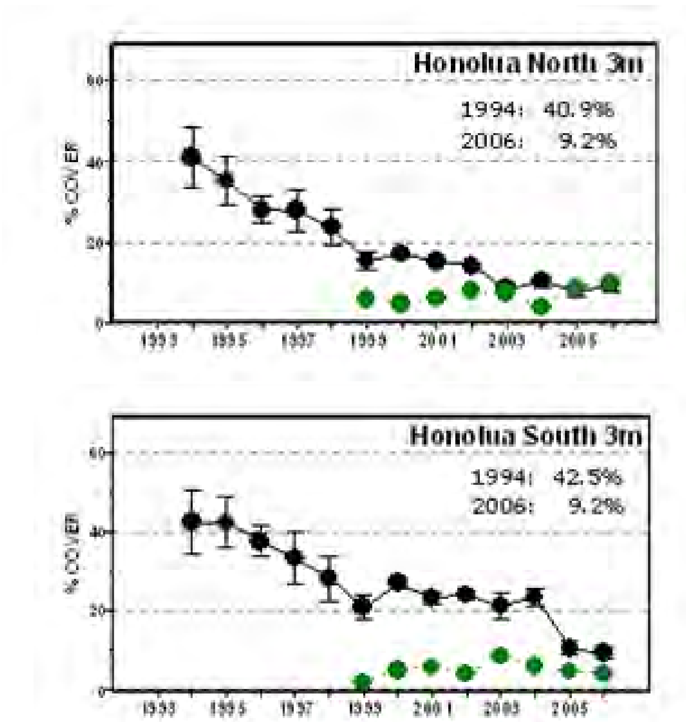

Figure 26. Trends in coral and algal cover on Honolua reef flats. Source: DLNR-DAR (2007).

Although coral cover has decreased on the reef flats in Honolua Bay, fish stocks have remained healthy and abundant grazing fish and invertebrates have controlled macroalgal growth with the bay (DLNR-DAR 2007) (Figure 26).

6.5.4 Marine Research Consultants (1990-2006)

Methods

MRC assessed coral community cover structure using a photoquadrat transect method modified after Kinzie and Snider (1978) (Dollar and Grigg, 2004). Four pairs of 50m transects were located on the North and South Reefs, in similar areas surveyed by ECI in 1974. Ten random quadrats (1m x 0.66m) were selected on each 50m transect. Coral cover for each species and substratum type were assessed in the lab using a grid of 100 equal segments. Results of the photo-quadrat analysis were combined with in-situ cover estimates and community structure parameters (percent cover, species diversity) were calculated.

MRC surveyed the inner and outer regions of the North and South Reefs in 1990, 1992, 2002, and 2006 (Figure 27). Two transects (one on the reef platform and one on the reef slope) were surveyed at each site. The findings from MRC's latest report are summarized below.

Figure 27. Aerial photograph of Honolua showing location of benthic transects used by Dollar to assess coral and fish cover in 1990, 1993, 2002, & 2006. Source: MRC, 2007.

Results

MRC's time-series data indicated a reduction in coral cover between 1992 and 2002, and a slight increase between 2002–2006. As no surveys were conducted between 1992 - 2002, it could not be determined if one large runoff event or several events contributed to the decline.

Mean coral cover ranged from 38 $\pm$ 6% (s.e.) to 89 + 5% in 1990, consisting of 6 to 12 coral species (Table 19). Coral cover was lower on the shallower reef flats and higher on the deeper reef slopes (Table 18, Figure 28). In 1992, mean cover ranged from 69 $\pm$ 4% to 89 $\pm$ 3%.

There were significant increases on two of the eight transects in 1992 compared to 1990 (two-tailed test, P = 0.01) (Table 19). Coral cover did not decrease significantly on any transect between 1990 and 1992. Coral cover diversity (*H'c*) was higher on all transects in 1990 compared to 1992 (Table 18). Overall, these results indicated no detrimental changes to coral community structure between 1990 and 1992.

A winter storm with high rainfall in January 2002 resulted in substantial input of terrigenous sediment to the Bay through stream discharge. The erosion of soil from cultivated pineapple fields and subsequent drainage to Honolua Bay had been previously observed. However the sediment input in 2002 appeared to be one of the most intense episodes in recent years and resulted in a prolonged period of both turbid water in the inner Bay, and deposition of sediment on the reef surface. The third survey of coral community structure was conducted in July 2002, approximately six months after the 2002 storm. Deposits of muddy red sediment up to 10 cm thick covered the sand in the inner central channel, and some of the reef structure, including living and dead coral skeletons at the base of the reef slope at the location of Transect I-2. Some terrigenous sediment remained on the upper reef platform bound to sediment turf at the time of the survey, and recently killed coral skeletons were abundant.

Table 18 Percent cover, number of species, and species cover diversity (H'c) for phototransects conducted in 1990, 1992, 2002 and 2006 in Honolua Bay, Maui, Hawaii. Source: MRC (2007).

TRANSECT	I-1 (2 m)				I-2 (7 m)				II-1 (4 m)				II-2 (8m)			
SPECIES	1990	1992	2002	2006	1990	1992	2002	2006	1990	1992	2002	2006	1990	1992	2002	2006
Porites lobata	7.2	10.4	18.6	16.5	10.6	18.9	8.8	7.4	9.0	15.7	21.8	32.9	22.2	20.4	13.1	9.9
Porites compressa	4.2	3.5	1.9		12.2	8.8	4.6	3.3	2.3	8.9	6.3	2.1	46.3	44.7	29.0	3.1
Porites brighami	0.3								0.1							
Pocillopora meandrina			2.1	1.1		0.8	1.2	1.0	0.2	1.6	4.3	0.8			2.1	0.3
Pocillopora eydouxi	0.7			1.0	0.7				1.7							
Pocillopora damicornis				0.1												
Montipora capitata	5.9	21.1	3.4	4.5	32.9	34.8	6.4	40.5	4.0	12.8	5.0	12.6	11.8	22.4	11.6	31.7
Montipora patula	4.9	18.6	2.2	4.6	12.9	6.9	2.4	3.5	7.5	18.9	5.1	9.1	4.6	1.1	4.0	2.8
Montipora flabellata	13.7	18.5	20.9	1.8	7.8				11.9	14.1	1.3					
Pavona varians	1.2	0.8	0.2	0.6	0.6	1.0		1.8	1.8	3.0	0.3	0.2	3.7	0.1	0.4	2.0
Pavona duerdeni		1.6	0.1						1.0	0.3						
Leptastrea purpurea									0.1		0.1	0.2				
Palythoa tuberculosa				0.1		0.1				0.2			0.1			
Cyphastrea ocellina	0.3					0.1			0.1							
TRANSECT TOTAL	38.4	74.5	49.4	30.3	77.7	71.4	23.4	57.5	39.7	75.5	44.2	57.9	88.7	88.7	60.2	49.8
Std. Err.	6.1	5.0	4.6	3.6	6.5	6.7	4.2	4.9	5.6	4.2	3.7	4.5	5.1	3.5	8.3	3.7
SPECIES NUMBER	9	7	8	9	7	8	5	6	12	9	8	7	6	5	6	6
SPECIES DIVERSITY	1.73	1.60	1.35	1.41	1.53	1.31	1.43	1.02	1.85	1.79	1.50	1.16	1.25	1.08	1.33	1.07

TRANSECT	III-1 (3 m)				III-2 (7 m)				IV-1 (4 m)				IV-2 (7 m)			
SPECIES	1990	1992	2002	2006	1990	1992	2002	2006	1990	1992	2002	2006	1990	1992	2002	2006
Porites lobata	27.6	50.6	8.0	39.1	14.0	0.1	19.3	9.4	35.1	27.7	34.7	28.1	28.8	2.5	0.7	0.6
Porites compressa	11.1	7.2	1.7		24.5	59.9	25.7	2.0	3.2	33.6	0.2	2.2	17.7	49.1	40.8	16.3
Porites rus																6.1
Pocillopora meandrina		3.0	1.5	0.1					0.3	0.4	2.4	3.2	1.3			
Pocillopora eydouxi									7.6				0.0			
Montipora capitata	18.5	4.8	3.8	2.9	37.0	7.3	10.6	19.7	3.8	1.7	0.6	8.9	24.5	17.4	0.8	14.1
Montipora patula	15.7	11.5	2.3	0.4	14.4	6.0	4.8	6.8	5.4	5.7	3.1	2.9	12.1		4.5	14.4
Montipora flabellata		1.8	1.7			0.1			5.2		0.6		0.5			
Pavona varians	2.8	0.2		2.6	0.9	1.7	1.2	1.4	2.0			1.1	1.2	2.4	1.4	3.4
Pavona duerdeni	3.1	0.8							0.4			0.2		1.3		
Leptastrea purpurea		0.1									0.2		0.2			
Psammocora stellata						5.4										
Cyphastrea ocellina		0.1														
Leptastrea bottae										0.1						
TRANSECT TOTAL	78.8	80.1	19.0	45.1	90.8	80.5	61.6	39.3	63.0	69.2	41.8	46.6	86.3	72.7	48.2	54.9
Std. Err.	6.6	4.5	4.1	5.0	2.5	6.2	8.8	4.0	4.2	3.7	4.8	5.0	4.3	3.2	6.5	4.7
SPECIES NUMBER	6	10	6	5	5	7	5	5	9	6	7	7	8	5	5	6
SPECIES DIVERSITY	1.55	1.25	1.57	0.52	1.34	0.91	1.31	1.26	1.48	1.05	0.68	1.12	1.49	0.91	0.59	1.53

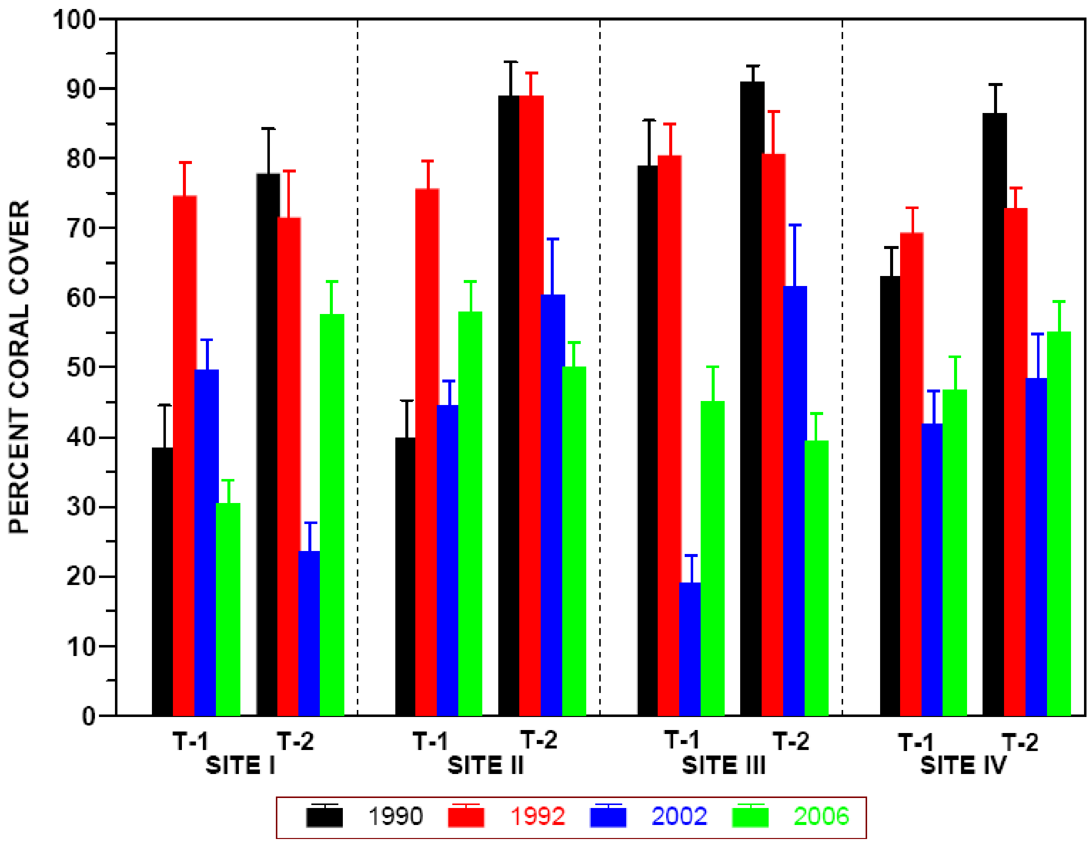

Figure 28 Histograms of coral cover (+ s.e.) from photoquadrat transects conducted in Honolua Bay, West Maui in 1990, 1992, 2002 and 2006. For transect site locations, see Figure 27 Source: MRC, 2007.

Dense growth of the golden algae *Chrysocystis fragilis* (family Chrysophyta) covered much of the outer areas of the reef in the vicinity of Site IV in July 2002. This algae was also abundant during the 1992 survey. Normally, *C. fragilis* is removed from the reef during winter months by surge from long period swells, and does not reestablish until calm periods in the summer. During the 2002 survey, *C. fragilis* occurred in the densest aggregations ever observed by the authors on Hawaiian reefs, covering about 26% of the bottom on Transect IV-2. These dense aggregations could have been overgrowing living colonies of *Porites compressa* smothering the coral. However further detailed observations were necessary to substantiate if it caused coral mortality.

Mean coral cover on the eight transects in 2002 ranged from 19 ± 4% to 62 ± 9%, and decreased on all transects between 1992 and 2002 (Table 19, Figure 29). Pooled total coral cover on all eight transects equaled 69.7% of bottom cover in 1990, 76.6% of bottom cover in 1992 and 43.5% of bottom cover in 2002. Thus, there was a reduction of approximately 33% of coral bottom cover between 1992 and 2002. Wilcoxon sign-rank tests indicated that coral cover decreased significantly on seven of the eight transects between1992 - 2002 (P = 0.02) (Table 19). The greatest decreases in total mean coral cover between 1992 and 2002 occurred at transects I-2 (54%) and III-1 (60%). Both of these transects are located in the inner Bay where sediment deposition was the greatest. Coral cover diversity (*H'c*) showed the same pattern between the two surveys, with decreases on 4 of the 8 transects between 1992 and 2002 (Table 18). Because of the long gap between the 1992 and 2002 surveys, it is not possible to determine if the substantial decrease in coral cover throughout the Bay was a result of the single sediment event, or was a progressive decrease from a variety of other causes. Complete results of the 2002 survey have been published in a peer-reviewed scientific journal (Dollar & Grigg, 2004).

Table 19: Observed test criteria (T) for nonparametric Wilcoxon matched-pairs Signed ranks test for related samples comparing total coral cover on 10 quadrats comprising transects in Honolua Bay, West Maui between samplings in 1990, 1992, 2002 and 2006. "*" indicates significant difference for two-tailed tests (P = 0.05); Yellow shading of T criterion indicates significant decrease in cover; blue shading of T criterion indicates significant increase in coral cover between surveys. Source MRC (2007).

SURVEY	TRANSECT							
YEAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
'90-'92	0*	23	1*	27	25	17	17	8
'92-'02	4*	0*	0*	4*	0*	15	2*	4*
02-'06	6*	0*	15	19	7*	9	25	22

Between 2002 and 2006 there were no reported major incidences of sediment discharge into Honolua Bay. Overall observations of the benthic communities in 2006 indicated that there was little to no terrigenous sediment on the floor of the inner channel as was observed in 2002, and the channel floor consisted of white sand. While there was little mud remaining on living coral colonies much of the non-living coral structure of the reef was brownish red in color. While dead colonies were still abundant on the reef flat and slope, few of these colonies had the appearance of recent mortality. In addition, most living coral colonies did not exhibit evidence of disease or bleaching, and were generally "healthy" in appearance.

Mean coral cover on the eight transects in 2006 ranged from 30 $\pm$ 13% to 58 $\pm$ 20%. Mean total coral cover was lower in 2006 compared to 2002 on three transects, and increased on five transects (Table 18). Pooled coral cover on all transects in

2006 was 47.6% of bottom cover, representing a 4% increase in coral cover over 2002. Wilcoxon sign-rank tests showed significant increases in coral cover in 2006 on two transects (I-2 and III-1) and a significant decrease (P = 0.05) on transect I-1 (Table 19). Hence, overall, there appears to be a slight overall increase in coral cover within the Bay between 2002 and 2006, particularly in the areas that were not affected the most by sediment discharge in 2002. The slight increase in overall coral suggests that the reef communities within the Bay are in the initial stages of recovery from the sediment event of 2002. Grigg and Maragos (1974) estimated that it takes approximately 50 years for reefs to reach full recovery on bare substrata in tradewind-sheltered areas of the Island of Hawaii. In terms of protection from destructive wave forces, these habitats are similar to Honolua Bay. Hence, what can be considered the initial stages of recovery in Honolua Bay four years after the sediment damage fits well within the documented recovery period of similar Hawaiian reef habitats.

When the coral cover of all transects is pooled, the most abundant species was *Porites lobata* in the 1990 and 2002 surveys, *Porites compressa* in 1992, and *Montipora capitata* in 2006 (Table 18). *Montipora capitata* ranked second in 1990 and 1992 and third in 2002. *Montipora* is known to be an especially sediment resistant genera (Te 1998 in Dollar & Grigg, 2004). *Porites compressa*, which is normally the dominant species in wave-sheltered areas in Hawaii, comprised only about 30% of total coral cover in Honolua Bay in 2002 and 7% in 2006 (Table 18). In addition, coral cover diversity increased on only three of the eight transects between both 1992 - 2006 and 2002-2006. The overall lower diversity in 2006 may be a result of lower mortality and higher growth response by the more sediment tolerant species (e.g. *Montipora* spp.) Hence, it is clear that there is a major change in the species composition in Honolua Bay in terms of individual species capacity to deal with sediment stress.

In summary, MRC's time-series records indicated a reduction in coral cover from 1992 to 2002, and a slight increase in cover between 2002 and 2006. It is important to note that there is a long gap in the data between 1992 and 2002 during which other events may have occurred to contribute to the decline in coral cover documented in 2002. Based on examination of historical records of rainfall and wave height, the meteorological events that resulted in significant decline in coral cover in 2002 were not especially severe or unusual (Dollar & Grigg 2004). "It is surprising that the sediment impacts to the Bay occurred after 1996 when construction was completed of numerous drainage control structures to the watershed that drains to Honolua Bay. Even with such sediment retention structures in place, localized extreme rain events still resulted in detrimental loading of sediment into the inner Bay. As the overall rainfall event in 2002 was not even near the documented peak rainfall, it is possible that the impacts from severe sedimentation in 2002 were not unique in the recent history of the Bay, but represent the latest episode of a cycle of impact and recovery that may occur on something like decadal intervals." (MRC, 2007).

6.6 Coral Diseases

ECI, 1974 observed that portions of some colonies of *P.lobata* "displayed abnormally large calices colored red and showing weakened skeletons in contrast to normal green areas". These abnormal sections resembled *Porites Lichen* and were not a significant component of the population. Although ECI suspected calices were caused by a parasitic infection, it is possible that ECI were observing a coral disease such as a *Porites* growth anomaly (Figure 29).

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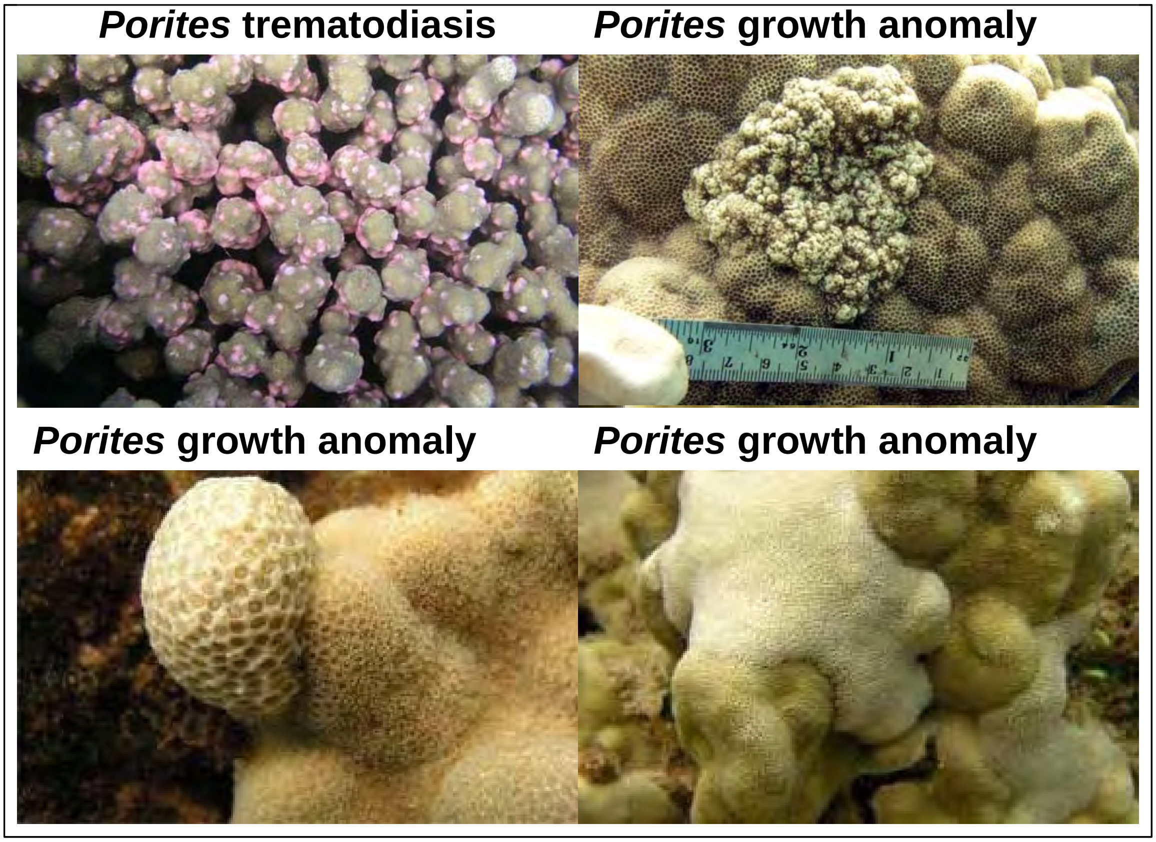
Walsh *et al.* (06) conducted systematic surveys of coral disease in Maui in June 2006. The major groups of corals on Maui (*Porites, Montipora, Pocillopora)* were surveyed using a combination of field surveys and laboratory investigation including pathology and microbiology to document coral lesions and their potential causes. Coral disease was found to be widespread at low levels at all nine sites, including Honolua (north reef). Six disease states were documented at an overall prevalence of 1.3%. The levels of disease differed among sites, with Honolua having the highest prevalence. The composition of the coral community, coral density or overall coral cover at each of the sites did not explain the differences in disease prevalence. *Porites* trematodiasis and *Porites* growth anomalies were the most common diseases and growth anomalies in both *Porite*s and *Montipora* were more common on Maui than had previously been found on Oahu or in the NWHI. Coral genera differed in their levels of disease, with disease prevalence highest in *Porites* and lowest in *Pocillopora,* which is consistent with what has been found elsewhere on the reefs of the Hawaiian archipelago.

Disease surveys were conducted on the north reef of Honolua using two 25m belt transects at 9ft depth (see Appendix D for GPS coordinates). Three disease states were observed: *Porites* trematodiasis (Figure 29), *Porites* growth anomalies (Figure 29), and *Porites* Tissue Loss Syndrome (Figure 30). P. trematodiasis was most prevalent (18.3%), followed by *Porites* growth anomalies (1.63%) and *Porites* tissue loss syndrome (0.81%).

Figure 29. Disease states observed at Honolua, June 2005 (photos courtesy of Greta Aeby)



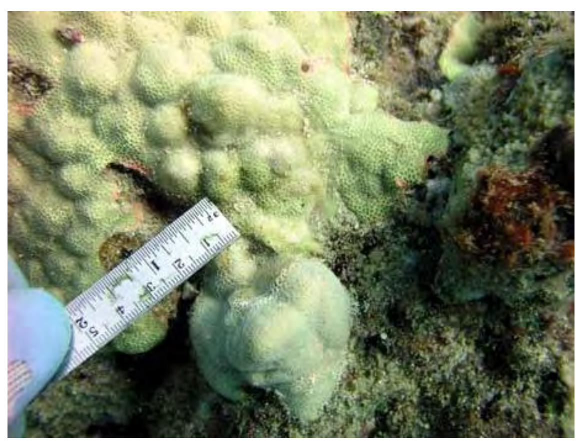


Figure 30. *Porites* tissue loss syndrome. Photo courtesy of Greta Aeby.

No *Monitopora* diseases were observed. The average number of coral colonies per transect was 8.1 per m^2 with *Montipora* comprising the greatest percentage of colonies (71.9%) followed by *Porites* (20.2%) and *Pocillopora* (7.9%).

Total coral cover on the transects were estimated at 27.65%, consisting of Porites lobata (19.96%), *Montipora Patula* (2.81%), *M. capitata* (1.28%), Porites compressa (0.74%), *Pocillopora meandrina* (0.74%), *M. flabellate* (0.58%), *Pavona varians* (0.62%) and and un-identified sp. (0.91%). Macrolagae cover was estimated at 53.23% with turf algae the most dominant (50.18% total cover).

To ensure that coral disease does not become a major problem in Hawaii, the authors recommended that more information is needed about the distribution, ecology, etiology, virulence and transmission of diseases in Hawaiian corals.

6.7 Other marine invertebrates

The only known invertebrate survey of Honolua Bay was conducted by ECI in 1974. ECI (1974) qualitatively surveyed invertebrates in Honolua Bay. Due to time restrictions they were not able to do a thorough survey for cryptic species. ECI found that Echinodermata were the most conspicuous component of the benthic fauna, other than corals. They found nearly every common Hawaiian sea urchin, except *Colobocentrotus atratus*, a species restricted to wave washed rocky shores. They thought this species could possibly occur on Lipoa Point. They thought that one of the species, an unnamed *toxopneustid* could have been a rare species in Hawaii and recommended that a specimen should be collected for identification.

Divers also recorded the numbers of sea urchins they found on their reef transects. They identified the following species, which are listed in order of decreasing abundance. Notes on population abundance are also included:

- *Echinometra mathaei* (Blainville), occurred in dense populations in areas exposed to wave surge.
- *Tripneustes gratilla* (L.), common everywhere, populations are locally aggregated.
- *Echinothrix sp*. (*diadema* (L>) and/or *calamaris* (Pallas), common but not locally abundant.
- *Heterocentrotus mammillatus* (L.), common inside the bay particularly near low salinity seepage, uncommon on the outer part of the bay.
- *Echinometra mathaei oblanga* Blainville (uncommon but not rare).
- *Diadema paucispinum* Agassiz, uncommon found where coral cover is high.
- *Pseudoboletia indiana* (Michelin) rare, inner transects.

ECI did reconnaissance surveys of the reef and sandy bottom for invertebrates starting at the waterline. At the waterline they observed several snails on basalt boulders lining the sides of the bay. Species included: *Littorina pint*ado, M*orula uva*, and *Morula granulate*. The rock snail *Nerita pica*, was abundant subtidally in many places. Below the waterline on larger basalt boulders close to the inner end of the reef, *Hipponyx* sp (possibly *pilosus*) was particularly abundant. A large population of the shell-less nail, *Plakobranchus ocellatus* was observed on the boulders and soft bottom of the highly turbid zone fronting the sand and cobble beach. The bandana shrimp, *Stenopus hispidus*, was also found in this area. The only large mollusks observed on the reef were cones, *Conus lividus*. ECI also observed a few individuals of the crown of thorns starfish *Acanthaster planci*, and the sea cucumber, *Holothuria atra*. Beneath the boulders at the base of the reef face, a species of brittlestar (*Ophiocoma* sp.) was very abundant. An oyster like bivalve, *Isognomon perna*, was also found there.

ECI thought the central bay sand area appeared ideal for sand-dwelling organisms such as snails of the genus *Terebra*. However they located no organisms greater than ¼ inch when sieving the sand. They also did not see any organisms during the reconnaissance surveys. They noted that "the sand bottom was unusually flat, except for ripple marks, with mounds, entrance burrows, and trails conspicuously absent". They thought that a closer inspection of the reef and sand bottom may reveal a greater diversity of mollusks, crustaces, and other invertebrates. The only moderately abundant population of inverts, except sea urchins, occurred in the inner reaches of the bay.

6.8 Marine Plants

The first comprehensive survey of marine flora was conducted by Torricer *et al*. (1979). They used SCUBA and a modified point-quadrat method, utilizing
50cm^2 quadrats placed at 5 points along a 100m transect line. They observed a diverse benthic flora comprising 31 algal species, including 28 known, 2 unidentified red, and 1 unknown on rubble, sand and silt substrates (Table 20). Algal species included a wide variety of encrusting and filamentous red and green algae, and coralline red algae abundant only on basalt shelves. Red algae were dominant throughout the bay, with crustose forms even observed growing under a layer of silt on boulders in the near-shore waters. Negligible amounts of euryhaline algae such as *Enteromorpha* sp. or *Ulva* sp. were observed even though there was fresh water input from Honolua stream. Torricer *et al.* also observed that sea urchin and fish communities grazed on the algal populations and that there was apparent competition between algae and coral for space.

There have been no comprehensive algal surveys of Honolua Bay since the Torricer *et al.* 1979 study. Percent algae cover of algae functional groups has been regularly monitored through the Hawaii Coral Reef Assessment and Monitoring Program (CRAMP) since 1999. However observations are limited to the CRAMP transect sites and algae is generally not identified to species level. Long-term monitoring data has shown that algal cover had not increased over time (Figure 26).

Honolua has also been included in larger monitoring programs for invasive alage. Dr Cindy Hunter from the University of Hawaii, undertook an algal assessment in 2000, as part of a larger state-wide study of alien and invasive algae. Dr Celia Smith and her colleagues from the University of Hawaii Botany Department, have been surveying algae in Honolua Bay annually as part of a larger monitoring program for invasive algae. Monitoring has shown there is low invasive algae in the bay, likely due to grazing by the abundant herbivorous fish population (DLNR-DAR, 2007).

Table 20. Algal species observed by Torrier *et al.* 1979.

Phylum	Species
Cyanophyta	Filamentous genus undeterminded
	Symploca sp.
Chlorophyta	Filamentous genus undeterminded
	Enteromorpha sp.
	Dictyosphaeria cavernsa
	Dictyosphaeria versluysii
	Microdictyon sp.
	Udotea sp.
	Bryopsis sp.
	Codium sp.
	Halimeda sp.
Phaeophyta	Encrusting genus undetermined
	Filamentous genus undeterminded
	Ralfsia sp.
	Dictyota sp.
	Lobophora sp.
	Turbinaira sp.
Rhodophyta	Genus undertermined (from transect 7)
	Encrusting genus undetermined
	Filamentous genus undeterminded
	Family Corallinacea genus undertermined
	Galaxaura sp.
	Pterocladia sp.
	Amphiroa sp.
	Jania sp.
	Haloplegma sp.
	Spyridia sp.
	Amansia sp.
	Tolypiocladia sp.
Undetermined	Unidentified 1
	Unidentified 2

6.9 Fish surveys

6.9.1 Survey Methods

The fish census methods are summarized in Table 21 below and referred to in the following section.

Table 21. Summary of reviewed fish survey methods.

Investigators	Parameters	Census Methods	Transect details
Environmental Consultants Inc.	Identified common reef fish that were diurnal, large and mobile species. Species identification and count.	SCUBA surveys using modification of Brock (1954), also see Key (1973). 1 diver survey team.	21 transects (20m x 6m), at 20m intervals along and perpendicular to 5 main traverse lines
Torricer et. al. (UH marine option program)	Species identification, number of individuals per species, estimated standard length (tip of snaut to caudal peduncle).	SCUBA or snorkel surveys using modification of methds used by Brock (1954), Odum & Odum (1955), Bardach (1959), McVey (1970). 4 diver survey team (one transect roller, 2 counters, 1 safety diver), surveyed 2m from bottom.	16 x 110m transects, ranging from 1.2m to 13.7m, parallel to shore at constant depth, first 10m not surveyed, stations on each transect were isolated temporally not spatially, surveyed twice (20 minutes apart).
Friedlander/ CRAMP / DLNR-DAR	Identified all visible fishes to lowest possible taxon, estimated total length (cm), calculated weight from length, total length (cm) converted to standard legnth by total length fitting parameters from FishBase (www.fishbase.org).	SCUBA surveys conducted 3 times a year using standard underwater visual belt transect methods (Brock, 1954; Brock, 1982).	4 transects (25m x 5m) at 5m gaps located along center line of CRAMP benthic survey grids (permanent transects on north and south reef at 3m depth)
DLNR-DAR	Abundance and size of resource fish species (total length cm). Total length (TL) was converted to standard length(SL) using length-fitting parameters obtained from fishbase. Biomass estimated from total length using a length weigh conversion: $W=aSl^{b.}$ Biomass converted to grams m^{-2}.	SCUBA surveys of 'resource' fish. Pair of divers swimming in parrallel, 10m apart, following a depth contour, for 5 minute perid, with each diver recording all main fishery target sp. greater or equal to 15cm within a 5 m belt transect)	5 sites surveyed (3 at 3-5m depth) and 2 at 10m depth, surveys start at a fixed site coordinate
Marine Research Consultants Inc.	Readily visible fish surveyed, species identified.	SCUBA surveys using modification of belt transect methods used by Hobson (1974).	4 paired transects 50 m length, on N and S inner and outer reef, same as coral survey sites

6.9.2 Environmental Consultants, Inc. 1974

Environmental Consultants 1974 used a modification of the method used by Brock (1954; see also Key 1973) to survey 21 transects (20m x 6m), each covering approximately $120m^2$ (Table 21). They observed a total of 38 fish species from 14 families. The fish population appeared to be a mixture of species typical of open and protected coast environments. They found that the number of species and number of individual fish per transect were roughly comparable to other areas along the West Maui coast, which had higher diversity along the points compared to bays (ECI, 1971).

The distribution and abundance of fish within the bay were strongly correlated with the distribution and composition of hard substratum reef areas. Fish abundance decreased rapidly over the sand bottom, typical of most coral reef environments in Hawaii. The authors suggested that this reflected the strong dependence of most fish species on the reef for shelter, food, nesting sites etc. Because of this strong dependence, they suggested that any alterations that affected the benthic communities would be reflected, to a great or lesser degree, by changes in the fish fauna.

6.9.3 Torricer *et al* 1979

Torricer *et al*. undertook a census of fish populations in 1979 using the methods outlined in Table 21. They counted a total 6,123 individual fish, with a mean of 236 fish per station, on the 2 fringing reefs, boulders and reef flats. The fish population included 76 species, representing 44 genera from 18 families, with a mean of 22 species per transect. They stated the total ichthyofauna included 95 species, including the fish species identified in previous studies by Gaffney, 1975 and Taylor, 1975 (in Torricer *et al.* 1979)., Similarly to ECI (1974), they found the greatest number and diversity of fish over the reef flats and fringing reef that had high coral cover. They also observed a large number of juveniles in the boulder habitat, as did ECI (1974). Their findings supported ECI's assumption that the inshore waters

Table 22. 10 most common species observed by Torricer *et al* 1979.

Species	Frequency of Occurrence	No. of Fish
Thalasooma duperreyi	1	821
Stegastes fasciolatus	0.846	774
Acanthurus nigrofuscus	0.846	547
Stethojulis balteata	0.731	138
Parupeneus multifasciatus	0.731	78
Pervagor spilosoma	0.731	76
Gomphosus varius	0.654	59
Chaetodon unimaculatus	0.654	52
Acanthurus triostegus	0.615	178
Canthigaster janthinopterus	0.615	47
Total		2,770

functioned as a nursery ground for some of the reef fish. The fish population was dominated by carnivores (62.9%) over herbivores (37.1%), and *Thalassoma duperreyi* was the most abundant and frequently observed. The 10 most common species are listed in Table 22. They attributed the large and diverse fish population to ecological conditions within the bay. The 2 fringing reefs, reef flats and boulders provided an assortment of shelter and substrate for benthic-oriented reef fishes, while few fish inhabited the open mid channel sand/silt area. They concluded that the reef fish population was characteristic of a typical, isolated, outer reef assemblage.

6.9.4 Friedlander/CRAMP/DLNR-DAR

Friedlander started monitoring fish populations on CRAMP's benthic habitat monitoring sites in 1998. Fish monitoring has also been conducted by the CRAMP survey team and is currently conducted by DLNR-DAR biologists.

Friedlander *et al.* (2003) examined the relationships between fish assemblages, their associated habitat, and degree of protection from fishing over a broad spatial scale throughout the MHI, including Honolua Bay. Fish assemblages were assessed using standard underwater visual belt transect method listed in Table 21. See Friedlander *et al.* (2003) for a more detailed explanation of survey methods, accuracy assessment and statistical analysis. The authors found that most fish assemblage characteristics showed positive responses to either physical or biological or human-induced protection. "Fish biomass was lowest in areas of direct wave exposure and highest in areas partially sheltered from swells. Higher values of fish species richness, number of individuals, biomass, and diversity were observed in areas with higher substrate complexity. Areas completely protected from fishing had distinct fish assemblages with higher standing stock and diversity that areas where fishing was permitted or areas that were partially protected from fishing." "Marine protected areas in the MHI with high habitat complexity, moderate wave disturbance, a high percentage of branching and/or lobate coral coupled with legal protection from fishing pressure had higher values for most fish assemblage characteristics". Thus the fish population in Honolua Bay had among the highest values for most fish assemblage characteristics (species diversity, species richness, number of individual and biomass) (Friedlander et al. 2003). The top ten species observed in Honolua-Mokuleia MLCD are listed in Table 23. A complete species list is provided in Appendix C.

Table 23. Top ten species in the Honolua-Mokuleia MLCD, ordered by Index of Relative Dominance (IRD = % freq. x % biomass). No. = numerical density in number of individuals per hectare x 1000. Biomass = biomass density in t ha-1. % freq. = percent frequency of occurrence on all transects within the management regime. % no. = percentage of total number of individuals within management regime. % biomass = percentage of total biomass within the management regime. Copied with permission from Friedlander *et al*. 2006.

Taxon name	Common name	Hawaiian name	No. (no. ha^{-1} x 1000)	Biomass (t ha^{-1})	% freq.	% no.	% biomass	IRD
Naso unicornis	Bluespine Unicornfish	*kala*	0.14	0.115	37.84	1.61	17.05	645.20
Acanthurus nigrofuscus	Brown Surgeonfish	*maiii*	1.04	0.047	67.57	11.70	6.94	468.78
Acanthurus triostegus	Convict Tang	*manini*	0.54	0.071	29.73	6.13	10.48	311.58
Naso lituratus	Orangespine Unicornfish	*umaumalei*	0.12	0.044	40.54	1.31	6.55	265.42
Acanthurus leucopareius	Whitebar Surgeonfish	*maikoiko*	0.17	0.042	35.14	1.95	6.23	218.94
Acanthurus blochii	Ringtail Surgeonfish	*pualu*	0.13	0.053	24.32	1.41	7.79	189.55
Scarus rubroviolaceus	Redlip Parrotfish	*palukaluka*	0.16	0.019	40.54	1.85	2.86	116.09
Parupeneus multifasciatus	Manybar Goatfish	*moano*	0.16	0.013	56.76	1.78	1.95	110.83
Acanthurus olivaceus	Orangeband Surgeonfish	*naenae*	0.06	0.017	29.73	0.63	2.48	73.82
Caranx melampygus	Blue Trevally	*omilu*	0.03	0.016	29.73	0.34	2.34	69.68

Fish survey data collected by the CRAMP from 1998 showed that among 60 reefs, their survey site on the north reef at Honolua North ranked 3 in species richness, 49 in density, 30 in biomass, and 3 in diversity. The survey locations on the south reef ranked 1 in species richness, 34 in density, 21 in biomass, and 7 in diversity. The most abundant species were the Saddle wrasse (*Thalassoma duperrey*) and the Brown surgeonfish (*Acanthurus nigrofuscus*) at the North and South reefs respectively. The species with the highest biomass were the Yellowfin goatfish (*Mulloidichthys vanicolensis*) and the Chubs (*Kyphosus spp.*) at the North and South reefs respectively. *Gymnothorax eurostus* presence was listed as notable because this species is not common to sites surveyed. Fish data collected from the north and south reef survey sites is displayed in Table 24. CRAMP fish data from 1991 -2001 is also available on-line at NOAA's coral reef information system (coris) (NODC#0000969).

Table 24. Fish Data from Honolua North 3m and Honolua South 3m. Copied directly from CRAMP (http://cramp.wcc.hawaii.edu/).

Species	Density (#/125m²) North 3 m Mean	SD	South 3 m Mean	SD	Biomass (g/125m²) North 3 m Mean	SD	South 3 m Mean	SD
Abudefduf abdominalis			1.3	2.5			44.7	89.4
Abudefduf sordidus			0.3	0.5			30	60.1
Acanthurus blochii	1.0	2.0	7.3	13.8	355.3	710.7	1780.4	3307.4
Acanthurus dussumieri			0.3	0.5			80.8	161.6
Acanthurus leucopareius	1.0	1.2			156.8	182.8		
Acanthurus nigrofuscus	18.0	5.0	40.8	15.9	1034.5	289.1	2055.0	825.9
Acanthurus olivaceus	1.8	1.3	0.5	1.0	599.3	406.0	104.4	208.8
Acanthurus triostegus	1.3	1.5	3.8	6.8	102.6	118.5	374.5	706.6
Arothron hispidus			0.3	0.5			111.8	223.6
Aulostomus chinensis	0.3	0.5	0.5	0.6	10.3	20.6	23.2	27.1
Calotomus carolinus	0.8	1.0	0.5	0.6	142.5	164.5	188.1	230.3
Cantherhines dumerilii	0.3	0.5	1.5	3.0	98.8	197.7	818.5	1637.1
Cantherhines sandwichiensis			0.3	0.5			7.2	14.4
Canthigaster jactator	2.5	1.3	2.5	2.4	18.2	9.4	10.3	9.6
Cephalopholis argus			0.3	0.5			17.7	35.4
Chaetodon lunula	0.8	1.0			61.9	79.0		
Chaetodon multicinctus	0.5	1.0	0.3	0.5	14.6	29.3	7.3	14.6
Chaetodon ornatissimus	1.3	1.3	0.3	0.5	204.2	263.1	38.1	76.3
Chaetodon quadrimaculatus	0.8	1.0	1.3	1.5	54.3	63.3	82.8	98.5
Chaetodon trifascialis	1.0	1.2	2.3	0.5	71.2	93.1	99.7	22.2
Chaetodon unimaculatus	1.0	0.8	1.5	1.0	66.6	50.4	86.4	57.6
Chlorurus perspicillatus	0.8	1.0			1478.8	2257.8		
Chlorurus sordidus	1.5	1.0			632.9	346.5		
Chromis ovalis	1.3	2.5	3.0	6.0	1.2	2.4	3.7	7.4
Chromis vanderbilti	7.0	5.0	15.3	5.1	27.1	19.0	58.8	22.9
Cirrhitops fasciatus	0.3	0.5	0.3	0.5	0.9	1.8	2.5	5.0
Cirrhitus pinnulatus			0.3	0.5			40.4	80.7
Cirripectes vanderbilti	0.3	0.5	1.0	1.4	1.1	2.1	6.5	11.9
Coris venusta	0.8	1.0			11.3	14.9		
Ctenochaetus strigosus	1.5	3.0	1.3	2.5	151.9	303.8	125.9	251.8
Fistularia commersonii	0.3	0.5			25.1	50.2		
Gomphosus varius	4.8	2.2	3.5	1.9	72.3	30.9	79.1	54.3
Gymnothorax eurostus			0.3	0.5			17.1	34.2
Kyphosus species			19.8	21.2			4686.4	5556.7
Labroides phthirophagus			0.5	0.6			0.9	1.5
Lutjanus kasmira	0.3	0.5	0.3	0.5	27.2	54.4	27.2	54.4
Melichthys vidua	0.5	0.6	0.5	1.0	129.7	152.4	262.6	525.1
Mulloidichthys vanicolensis	17.0	34.0			3196.7	6393.4		
Naso lituratus	3.3	2.1	3.8	1.0	1162.6	446.8	1337.2	275.4

Table 24. continued

Honolua, Maui Fish Data: 3 m	Density (#/125m²)				Biomass (g/125m²)			
	North		South		North		South	
	3 m		3 m		3 m		3 m	
Species	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Naso unicornis	0.8	1.0	2.3	3.3	274.6	317.4	1292.2	1990.4
Oxycheilinus unifasciatus			0.3	0.5			13.5	27.0
Paracirrhites arcatus	1.3	1.5	3.3	3.2	34.0	40.8	102.2	78.0
Paracirrhites forsteri	0.3	0.5	0.3	0.5	13.8	27.7	20.9	41.8
Parupeneus bifasciatus			0.3	0.5			13.1	26.3
Parupeneus cyclostomus			1.5	1.7			155.0	179.0
Parupeneus multifasciatus	1.5	0.6	3.3	3.3	182.5	102.1	240.3	173.8
Plagiotremus goslinei			0.3	0.5			0.6	1.1
Plectroglyphidodon imparipennis	1.0	0.8	2.3	1.7	2.2	1.7	5.7	6.0
Plectroglyphidodon johnstonianus	2.0	0.8	2.5	1.7	12.4	5.1	14.4	10.5
Rhinecanthus rectangulus	2.5	1.9	1.0	0.8	344.1	186.2	134.6	111.5
Scarus psittacus	3.8	3.2	7.5	6.6	327.7	314.1	197.0	200.1
Scarus rubroviolaceus	0.5	0.6	1.8	1.0	2707.1	3869.2	2659.6	3498.1
Scomberoides lysan	0.3	0.5	0.3	0.5	31.4	62.9	38.2	76.3
Stegastes fasciolatus	5.0	4.1	11.3	4.2	69.6	72.8	167.8	52.6
Stethojulis balteata	1.0	0	2.5	2.5	10.1	6.2	27.5	31.5
Thalassoma ballieui	1.0	0.8	0.3	0.5	94.8	77.4	23.7	47.4
Thalassoma duperrey	19.8	3.0	30.5	4.1	409.1	123.4	815.2	236.6
Zebrasoma flavescens	0.8	1.5			70.7	141.4		
Total/Depth Avg ± SD:	**112.5**	2.2	**185.8**	2.7	**14493.9**	**411.4**	**18530.5**	429.5
Species Richness	**44**		**50**					
Species Diversity	**2.61**		**2.50**					

6.9.5 Marine Research Consultants, 2007

Marine Research Consultants surveyed visible fish species in 1990, 1992, 2002 and 2006 using a belt transect survey method (Table 21). There was some variability in the survey locations between surveys because transects were not permanently marked. However MRC believe that the variability would be small because of the distinct composition of the reef zones where transects were located. MRC observed a rich and diverse fish community that was typical of Hawaiian reefs during all surveys. They found that "the number of species, total number of individuals, and abundance of food fishes and their tendency not to avoid divers reflects the refuge status of the Bay, and the lack of fishing pressure. The prohibition of fishing within Honolua Bay has resulted in an attractive showcase, and illustrates the value of Marine Life Conservation Districts as refuges for fish".

MRC recorded a total of 60 species from 19 families in 2006. The number of species ranged from 20 (north inner reef) to 34 (north outer reef). They did not observe any major differences in patterns of abundance or diversity on the reef flats compared to the deeper reef slopes. The most abundant fish groups were algal feeding acanthruids. "The brown surgeon fish (ma'i'i'i, *Acanthurus* *nigrofuscus*) and convict tang (manini, *A. triostegus*)were abundant at most sites. The goldring surgeonfish (kole, *Ctenochaetus strigosus*) and the orange spine unicornfish (umaumalei, *Naso lituratus*) were also common. The saddle wrasse (hinalea, *Thalassoma duperrey*) was abundant at all site. Plantivorous damselfishes of the genus Chromis were also common. The reef triggerfish (Humuhumu-nukunuku-a-pua'a, *Rhinecanthus rectangulus*) was common in shallow water. Other common fishes included the mnaybar goatfish (moano, *Parupeneus multifasciatus*) and rich varity of butterflyfish (*Chatetodon* spp.)" MRC, 2007.

They observed that juvenile reef fish were most abundant in areas of thick *Porites compressa* growth. Juveniles were mostly from the family Acanthuridae (surgeonfishes), with some from Labridae (wrasses), Mullidae (goatfishes) and Chaetodontidae (butterflyfishes). They also observed several food fishes including jacks (*Caranx melamphygus*), parrotfishes *(Scarus* spp.), goatfishes (*Parupaneus* spp. and *Mulloidichthys* spp.) emperorfish (Mu, *Monotaxis grandoculis*) and the introduced grouper (*Cephalophilis argus*). Some very large milkfish (awa, *Chanos chanos*) were also observed in the central channel area.

MRC noted large number of rudderfish (nenue, *Kyphosus bigibbus*) on the north side of the bay and schools of the introduced bluestripe snapper (taape, *Lutijanus kasmira*) commonly throughout the bay. They noted that many of these fishes, and turtles, were "quite tame and not disturbed by the presence of divers. Many of the smaller reef fishes were also quite familiar with divers and their tendency to approach divers suggested that they had been fed by humans in the past".

6.9.6 Fish Diseases

Walsh *et al*. also surveyed fish disease on Maui's reef in June 2005. Previous research on Oahu found that the introduced bluestripe snapper (ta'ape) and several species of native goatfish had a high prevalence of infection with protozoa in the spleen and kidney and somewhat lower prevalence of bacterial infections in the same organs (Walsh *et al* 06). "Because protozoa can cause severe mortalities in fish, the question arose as to whether these and other parasites were found on Maui in similar species of fish". Walsh et al (06) did necropsies on 45 ta'ape and 7 goatfish comprising 3 species including yellowstripe (*Mulloides flavolineatus*), yellowtail (*Mulloides vanicolensis*), and Pfluger's (*Mulloides pflugeri*). They found: "Prevalence of protozoal infections in ta'ape was 62%, and 80% in yellowtail; one each Pfluger's and yellowstripe goatfish were also examined with infection seen only in the former. The parasites in all species of fish were similar in morphology and in location. Prevalence of bacterial infection in ta'ape was 17% while only 1 yellowtail goatfish was found to be infected. The red nematode, *Spirocamallanus istiblenni*, was found in the gastrointestinal tract of 100% of ta'ape and not in goatfish. In a separate study, tumors in milletseed butterflyfish (*Chaetodon miliaris)* and multiband butterflyfish (*C. multicinctus)* were assessed on Maui as a follow up to studies of this disease done in the early 1980's. Prevalence of tumors in milletseed butterflyfish was 10% and somewhat lower for multibands. Tumors in milletseed butterflyfish had a predominantly dorsal to lateral distribution whereas those of multibands were more lateral and ventral. On histology, tumors were characterized as melanophoromas or iridophoromas, and in some cases, tumors were ulcerated and invasive. Molecular pathology failed to reveal evidence of tumor-inducing viruses including herpes or retroviruses. During coral surveys, tumors were also seen in goldring surgeonfish (*Ctenochaetus strigosus*), and blacklip butterflyfish (*Chaetodon kleinii*) on Molokini. Future efforts to elucidate these tumors should focus on transmission studies and determining whether these may have an impact on fitness. "Walsh *et al.* (2006).

6.10 Marine Mammals

The only known mammal survey was conducted Baird *et al.* (2000). They released a preliminary summary of a 1999 odontocete (toothed whale) population survey of the main Hawai'ian islands. The researchers observed odontocetes in the waters from Lana'i, Maui to Kaho'olawe (including Honolua Bay) for 80 days and had a total of 124 encounters including: 47 spinner dolphin groups; 35 bottlenose dolphins groups, 34 pantropical spotted dolphins groups, 6 false killer whale groups, and 1 pygmy killer whale group. No other literature focusing on marine mammals was found during the literature search.

7.0 Geospatial Information

There are numerous sources for GIS information relating to Honolua. Unfortunately this information is not accessible through one central location. Some data are controlled by the state, located on federal servers, or privately compiled.

In 2005, the Hawai`i Natural Heritage Program published a report that includes a "collection, review, and integration of available information relating to natural resources of marine near-shore waters into a natural diversity database and

Geographic Information System(GIS)". The project included "collecting information on the status and distribution of near-shore flora, fauna, and habitats. The program also developed a decision support system (DSS) to "enable the development, review, and refinement of a comprehensive network of Marine Protected Areas" in the state of Hawaii (Puniwai & Gibson, 2005). The authors concluded that the program had been successful at integrating and providing biogeographic knowledge to a broad community, including researchers and agencies (Puniwai & Gibson, 2005). They were also contracted by DLNR-DAR to maintain a web site of publicly available GIS information (Node, 2006; Pacific Basin Information Node, 2006). This site aggregates federal and state data and allows for users to interact with GIS information without specialized software (Pacific Basin Information Node, 2006).

A list of available GIS coordinates for survey sites are listed in Appendix D. The USDA-NRCS provided GIS information regarding terrestrial land-use structures, such as position of BMP's (Figure 3). They also provided RUSLE data and documentation relating to changing land-use practices (Ino, 2006).

8.0 Analysis of available literature

8.1 Land-Use Trends

Until recently land-use within the Honolua Watershed had not changed considerably for 30 years. The main changes since 1976 have been a decrease in agricultural land with the end of pineapple cultivation (27% to 7% of total area), a 16% increase in the total area covered by forest, and a 5% increase in the area used for residential development.

The lower watershed (below the Pu'u Kukui Watershed Preserve) was mainly utilized for pineapple cultivation thru the late 1990's and phased out from 2004 - 2006. Approximately 401 acres of pineapple was cultivated in the early 1970's and did not change significantly thru the 1990's (Nohara, personal communication). During this time there was only a 1.6% increase in net pineapple production due to improvements in efficient farming practices (Nohara, personal communication). A timeline covering the major trends was presented in Section 2.1, Table 1.

The NRCS Maui field office provided RUSLE data relating to theoretical amounts of runoff in pre and post conservation practice scenarios. The conservation practices were implemented in the late 1970's and continued to be in use through the last planting cycle in the late 1990's. The RUSLE data indicated an average decrease in runoff of 50% in the Honolua watershed with the appropriate implementation of conservation techniques (Nohara, personal communication). The soil conservation practices used on the pineapple fields in the 1990's (the final crop cycle for the fields in Honolua) included: crop residue use; contour farming; cross slope block farming (predetermined width blocks that designate areas for plowing, land preparation (such as access roads), and plantings); chiseling and subsoiling (loosening without inverting the soil); diversions; terraces; conservation crop sequencing (sequence crops so organic residue is maintained); and cross ditching (drainage swales) (Munekiyo, 1992). It would be helpful if ML&P could review BMP maintenance records to develop better estimates of the volumes of sediment that BMP's have captured.

Although there is no soil loss data to substantiate the reduction in soil loss with implementation of BMP's, the effectiveness of USDA-NRCS soil conservation measures are well established. Thus it is likely that soil loss from pineapple fields decreased dramatically in the 1970's with the introduction of BMP's, and continued to decrease with the improvement of pineapple farming practices and installation of 22 BMP's between 1994 – 1996. Another reduction likely occurred in 2003 with the decrease in pineapple, and in 2006 when pineapple cultivation ended. However development activities also began on Honolua Ridge in 2004 and were a potential source of eroding soil.

Most of the watershed is forested (~83% or 2,509 acres) and approximately 74% (2,248.5 acres) of the entire watershed is protected through inclusion in the Pu'u Kukui Watershed Preserve (1,197 acres) and Makai Conservation Area (1,052 acres). Residential development comprises 7.9% (240 acres) of the watershed and 2.5% (76 acres) is golf course. 203 acres (6.7%) are zoned for agriculture. Thus any future land-use changes will occur in the land zoned for agriculture. There are no current plans to expand residential developments or golf courses however this could be proposed in the future. New agricultural uses, such as organic farming or grazing, are not currently planned but could also be proposed. It is likely a portion will be designated for parkland.

Now that pineapple cultivation has ended, efforts should focus on restoring the lower watershed. Priority should be given to revegetating denuded/exposed areas that are eroding such as old pineapple roads, unpaved roads and trails, and badlands. ML&P with assistance from the community has already started revegetating an old pineapple field. Similar collaborative projects should be encouraged.

A watershed plan, that incorporates a unified vision for the Honolua Watershed, is urgently needed to better manage the area. Urgent action is needed to ensure the sustainable use of Honolua Bay for future generations.

8.2 Trends in Water Quality

MRC reported that water quality in Honolua Bay was relatively consistent since their monitoring began in 1990 (MRC, 2007). They observed that the Bay was consistently stratified both vertically and horizontally during that 16 year period. An upper layer of low salinity, high nutrient water was consistently present. This surface layer was influenced by groundwater, stream flow and inputs from land. In contrast the un-mixed lower layer of saltwater was not affected by freshwater input. Three zones were consistent within the bay: an inner zone with low salinity and high nutrients (Si, NO_{3-}, PO_4^{3-}), a central zone with elevated nutrients (Si, NO_{3-}, PO_4^{3-}) and an outer well mixed zone with oceanic conditions (low nutrients).

The geometric means of samples collected at all stations during the nineteen surveys showed that water quality parameters were generally in compliance with State water quality standards for wet embayments. The only exceptions were NO_{3-}, turbidity and Chl *a* in near-shore waters. MRC suggested that the influx of groundwater could result in samples exceeding the DOH geometric mean of NO_3^-, due to naturally elevated levels of in the groundwater. However they did not consider anthropogenic NO_3^-.inputs from fertilizers in the watershed, which were probably contributing to the groundwater.

It is important to emphasize that sampling was conducted once a year and presents a very brief snapshot of water quality conditions. Water samples were collected when freshwater was generally not flowing from Honolua Stream, at low-tide during periods of mild trade-winds and when there was little swell. Thus sampling conditions may not be representative of the average conditions in the Bay. In addition the small number of samples (19 total over 16 years) makes it difficult to establish compliance with water quality standards.

MRC (2007) reported a decrease in NO_3^- in the northern region of the Bay between 2002 and 2006. However because of the limitations in sampling it is difficult to interpret changes in nutrient input. It is likely that NO_3^- inputs have decreased since the end of pineapple cultivation and fertilizer application. Inputs should continue to decrease as remaining soil NO_{3-} leaches from the soil. PO_4^{3-} concentrations in soil and runoff should also decrease without the application of fertilizers. Soil erosion should also decrease as vegetation establishes on the old pineapple fields.

Although new nutrient inputs from agriculture have ended, input from urban runoff is increasing within the watershed. The composition of runoff will likely change in the next few years as construction activities end and residences become established within Honolua Ridge.

The amount of freshwater input (and associated nutrients) from Honolua Stream is likely to increase as drought conditions subside on Maui. Stream flow was interrupted by stream diversion from 1904 – 2004 and has continued to be intermittent since water was returned to the stream. This may be attributable to the drought conditions that Maui has been experiencing since the diversion ended. SWCA (2006) found that stream flow in the upper reaches may be zero during drought conditions. Maui County has been experiencing droughts regularly since 1998 (severe droughts occurred during 1998-99, 2000-02, 2003, 2006-07).

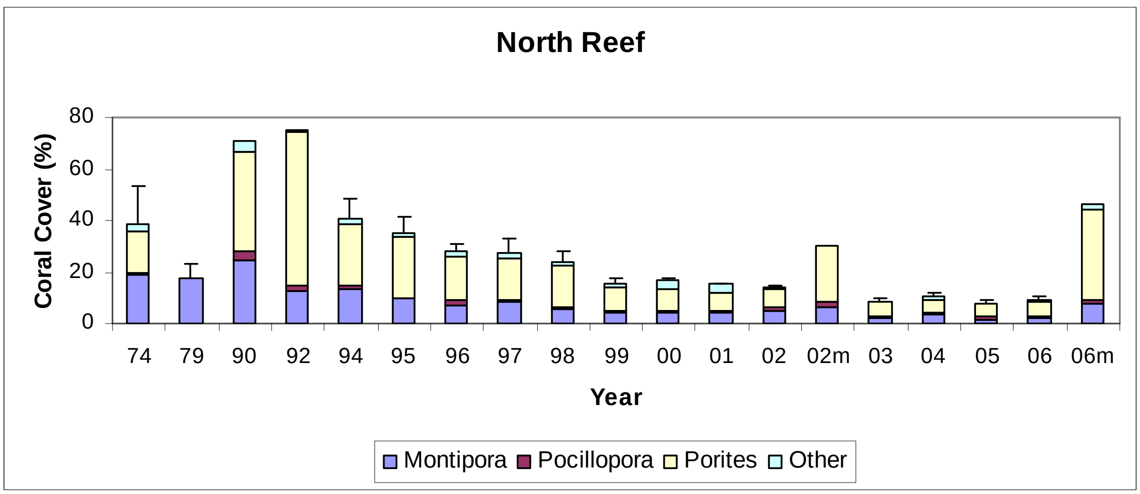
Although water quality parameters have shown little change over the last 16 years, it is likely that there were changes in nutrient and sediment delivery with the implementation of BMP's and improvement of pineapple farming practices in the watershed. Because monitoring was undertaken only once a year and at irregular intervals it is difficult to detect subtle changes in water quality parameters. More frequent monitoring is needed to establish a better idea of water quality condition and also assess changes in water quality within Honolua Bay.

Because of the vertical and horizontal stratification in the Bay, monitoring could be limited to surface waters of the inner bay and Honolua Stream. At a minimum monitoring should occur during the summer and winter months, to capture dry and post-flood conditions. Replicate samples should also be analyzed to account for variability in water quality. Because the area is heavily used by snokelers it is recommended that bacteria levels are routinely monitored to ensure human health and safety. In-situ turbidity sensors and a stream-flow gage should also be installed to assess the variability in sediment runoff. This would enable a better understanding of how sediments are impacting the Bay's coral reefs.

8.3 Trends in Coral Reef Condition

8.3.1 Coral Cover

Coral cover in Honolua Bay has generally decreased since the first surveys were conducted in 1974. It is difficult to compare coral cover data between studies because of differences in survey methods and survey sites (Table 18). In addition to temporal variability, there are also differences between studies conducted during the same year. For example, reef flat coral cover data reported by MRC is consistently higher than CRAMP data (Figure 32). Because of this discrepancy only general trends will be compared between different studies. Coral cover data will only be compared within monitoring programs (eg. within CRAMP or MRC).



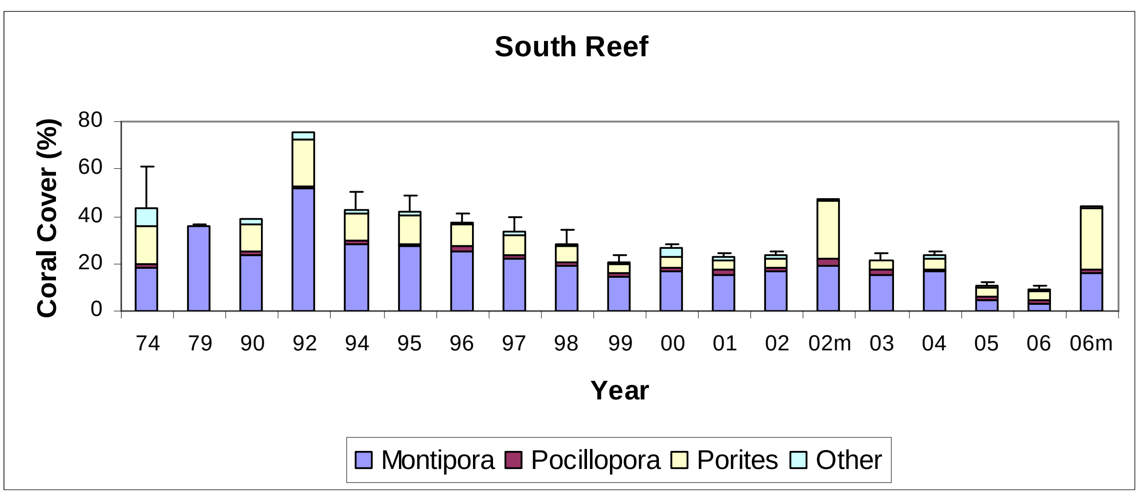


Figure 32. Comparison of average total coral cover on the north and south reef flats of Honolua Bay. Data was collected by ECI (74), Torricer et al. (79) MRC (90, 92, 02, 02m, 06m) and the remainder by Brown/CRAMP/DLNR. NB: only reef flat data was used in the comparison.

All studies concur that there are differences in species composition between the north and south reef. The north reef is dominated by *Porites* sp. while sediment resistant *Montipora* sp. are dominant on the southern reef. There is also agreement that sediments and wave action influence coral cover. High turbidity and sediment deposits in the inner bay have been observed consistently since 1974.

MRC did not observe any significant difference in coral cover between 1990 and 1992. They found that coral cover significantly decreased from 1992 – 2002 and increased slightly between 2002 - 2006. Because monitoring was infrequent MRC could not determine if there had been a gradual decrease in coral cover from 1992 – 2002 or if a single runoff event in 2002 caused the mortality.

It is interesting to compare MRC's data to CRAMP's yearly monitoring from 1994 - 2002. Brown (2004) reported a significant decrease in coral cover on the north reef flat between 1995 -1996, with no other significant differences from 1994 – 2002. There was little difference in coral cover on the southern reef between 1995 -1996 but there was a significant difference from 1997 - 1998. Brown theorized that decreases in coral cover were caused by environmental stressors that differed between the reefs. The northern reef was most influenced by wave action and the southern reef was influenced by sediments.

The CRAMP data from 1994 – 2007 shows a steady decrease in coral cover during 1994 – 1999, stabilization occurring from 2000 – 2004, and then a decrease again in 2005 - 2007. This differs to MRC's observed increase in total coral cover from 2002 – 2006. This slight increase was caused by a significant increase in coral cover on only 2 transects that were not impacted by sediment runoff in 2002. Conversely coral cover decreased significantly on the shallow transect located nearest the shore on the southern inner reef. Cover did not change significantly on the other 5 transects.

Although there are differences between CRAMP and MRC data, the general trend is the same: coral cover has decreased since their monitoring programs started in 1994 and 1990 respectively. It appears that the large decrease in coral cover observed by MRC in 2002 was cumulative rather than caused by a single runoff event. This emphasizes the importance and strength of regular coral reef monitoring.

While there is no turbidity or soil erosion data to compare with trends in coral cover, comparison can be made with rainfall data and incidental reports of runoff events. Apart from the 2002 event, a runoff event was reported on January 2, 2005 in the Maui Times (Hart, 2005). Sediment laden runoff was observed from construction activities on Honolua Ridge. "Heavy showers and isolated thunderstorms produced ponding of roadways, and small stream and drainage ditch flooding across the isles of Molokai, Lanai, and Maui" was also reported on January 2, 2005 (NOAA, 2007) It is likely that these sediment runoff events have impacted coral cover although this can not be confirmed without quantitative data.

Even though there is a lack of quantitative data about the impacts of sediments on Honolua's coral reefs, there is much published information on the effects of sediment runoff on coral reefs (see ICRS, 2004, Fabricius, 2005). Terrestrial runoff is known to effect coral recruitment, decrease coral calcification rates, reduce coral depth distribution limits, alter species composition and decrease biodiversity (ICRS, 2004).

Smothering by sediments or sediment-trapping macroalgae is known to be the main factor affecting recruitment and the survival of early life stages in corals; settlement rates are near-zero on sediment- covered surfaces; and sedimentation tolerance in coral recruits is lower than adult corals (Fabricius, 2005). "Because terrestrial runoff directly affects coral recruitment, runoff-exposed coastal and inshore coral reefs will take longer to recover from disturbances by storms, coral bleaching and outbreaks of coral predators than reefs in cleaner water. Coral reefs in well-flushed locations are at lower risk of being degraded by terrestrial runoff than regions where the retention of pollutants is high" (ICRS, 2004).

It is likely that sediments are contributing to the low coral recruitment success on Honolua's reefs. Brown (2004) showed low coral recruitment success on the northern reef flat. He suggested that the low rates of recruitment, low growth and high mortality shown by his short-term studies indicated that future disturbances could further degrade the reef structure. He also predicted the southern reef flat was undergoing a "slow steady decrease in several abundant coral species" and that the remaining species showed no evidence of increasing cover. Unfortunately his predictions may be occurring on the reef flats in Honolua Bay.

It is apparent that erosion of soil and subsequent sedimentation has caused declines in coral cover and is affecting the condition of Honolua's reefs. In addition other anthropogenic variables, such as chemical pollutants, and increasing human use, are likely exacerbating the stress caused by sediments. Honolua's coral reefs are adapted to the Bay's wave action, water circulation patterns and influx of stream and ground-water. However human activities may have altered the reefs resilience to both natural and anthropogenic stressors. In order to stop this long-term decline in coral cover, management efforts must focus on reducing anthropogenic sources of stress.

Future monitoring should utilize standard survey methods, such as the CRAMP protocol, to reduce discrepancies between long-term studies. There are strengths and limitations in both the CRAMP and MRC monitoring programs.

The CRAMP protocol has been validated and is utilized State-wide. However the goal of the program is to monitor State-wide trends in coral reefs and not individual sites specifically. Thus the number of survey sites per area is usually limited. CRAMP surveys usually include shallow and deep sites around 3m and 10m deep. Because coral cover was low on the outer reef and protocol had not been tested on reef slopes, only shallow survey sites on the reef flat were established in Honolua Bay. Now that protocol has been developed, it would be useful if monitoring could be expanded to include additional sites on the reef slope. Especially as ECI (1974) recorded the highest coral cover on the reef-slopes (Figure 21) and MRC recently observed increases in coral cover there.

MRC's monitoring program focuses specifically on Honolua Bay. Their data provides a more comprehensive picture of coral cover trends throughout the Bay. However the infrequency in monitoring and variability in coral cover data makes it difficult to interpret. The composition of coral species varies considerably between years, with fluctuations in coral habitat between *Montipora* sp. and *Porites* sp (Table 18). This fluctuation could be caused by environmental conditions and/or or survey methods. Because random quadrats were used to assess coral cover, the variation in species cover may be due to differences in survey sites rather than actual change in species composition over time. The use of permanent quadrats, which are randomly selected, would reduce this uncertainty and are recommended for future surveys.

As well as long-term benthic monitoring, long-term in-situ turbidity monitoring is urgently needed to help quantify the impacts of sediments on Honolua's coral reefs. The installation of in-situ turbidity monitors and a stream-gage are strongly recommended. It is also critical that coral recruitment rates continue to be monitored regularly to verify if recruitment success is still low.

8.3.2 Fish Populations

Honolua Bay and has some of the highest fish assemblage characteristics (species diversity, species richness, number of individual and biomass) of reefs in the MHI (Friedlander et al. 2003). Based on the data reviewed in this report it is difficult to determine how the fish population has changed over time. None of the available reports assessed changes in the fish population and it is difficult to compare between studies because of differences in survey methodologies and changes in fish taxonomy. For example there are differences in the top 10 species reported by Friedlander, CRAMP and MRC. Comparison should me made within long-term data-sets. Long-term data has been collected by Friedlander/ CRAMP/DLNR-DAR (from 1998) and MRC (from 1990). This analysis was beyond the scope of this project and is recommended for future work.

9.0 Information Gaps

Information gaps for the marine and terrestrial ecosystem in the Honolua ahupua'a were identified during this review. Certain components of the ahupua'a have either not been studied or data was not accessible for review. Perceived information gaps are listed in groups below. There is a large amount of privately held reports and data that has not been published or made available for general review. This data is housed in ML&P archives, by research organizations, and at various State and Federal agencies and private organizations. In addition early studies are difficult to acquire, due to archival destruction at the UH-Manoa library. ML&P has a private archive of information relating to the plantation dating from its conception, but access is limited.

Watershed Gaps:

- Comprehensive flora and fauna data for the entire watershed
- Assessment of the feral pig population in the watershed
- Effectiveness of the pig fencing program
- Identification of key sediment sources in the watershed
- Hydrological information for the entire watershed
- Review of the status and effectiveness of watershed planning initiatives

Stream Hydrology and Biology Gaps:

- Comprehensive survey of stream flora and fauna
- Quantity and quality of stream flow
- Watershed scale hydrological studies and modeling

- Stream monitoring program
- Effects of stream diversion on stream and marine biota

Marine Ecology Gaps:
- Comprehensive list of marine invertebrates (last surveyed in 1979)
- Marine vertebrate surveys
- Comprehensive list of marine macroalgae
- Comprehensive data on prevalence and occurrence of coral and fish disease
- Analyses of long-term fish data sets
- Causes of coral decline
- Biological impacts of sediments and turbidity
- In-water monitoring of recreational impacts on coral reefs

Water Quality Gaps:
- Location, quantity and quality (nutrients and contaminants) of groundwater input
- Long-term in-situ turbidity data at coral reef
- Quantity and quality of stream flow

Geospatial Information Gaps:
- GPS locations of early coral reef and fish surveys (many sites were identified by landmarks in the field)
- Detailed land-use maps

10.0 Conclusions and Recommendations

This study highlights the multitude and diversity of studies conducted in the Honolua Ahupuaʻa over the last 37 years and identifies gaps in knowledge for both the marine and terrestrial environment. The following recommendations are aimed at improving management of marine and terrestrial resources within the ahupua'a to ensure their sustainable use for future generations.

Develop an integrated coastal area management plan

Until recently land-use within the Honolua Watershed had not changed considerably for 30 years. The main changes since 1976 have been a decrease in agricultural land with the end of pineapple cultivation (27% to 7% of total area), a 16% increase in the total area covered by forest, and a 5% increase in the area used for residential development.

The majority of Honolua watershed (74%) is protected and effectively managed by ML&P and the West Maui Watershed Partnership through inclusion in the Pu'u Kukui Watershed Preserve and ML&P's Makai Conservation Area. Residential development comprises only 7.9% (240 acres) of the watershed, 2.5% (76 acres) is golf course, and 6.7% (203 acres) is zoned for agriculture. Thus any future land-use changes will occur in land zoned for agriculture. There are no current plans to expand residential developments or golf courses however this could be proposed in the future. New agricultural uses, such as organic farming or grazing, are not currently planned but could also be proposed.

It is recommended that management efforts focus on restoring the lower watershed now that pineapple cultivation has ended. Priority should be given to re-vegetating denuded/exposed areas that are eroding such as old pineapple roads, unpaved roads and trails, and badlands. Collaborative projects that actively involve the community and other stakeholders should be encouraged and supported.

Urgent action is needed to manage the large number of visitors accessing Honolua Bay via land and sea. An integrated coastal area management plan, as recommended in the recent visitor use study by Tetratch EM (2006), must be developed to effectively manage and protect the area's marine and terrestrial natural resources. The plan should incorporate holistic watershed management principles and emphasize the mauka makai connection. It is critical that the management planning process includes all stakeholders, as well as the land-owners, and includes a unified vision for the ahupua'a.

It is recommended that ML&P, Maui County and the State work together to immediately adopt management scenario 1 of the visitor use study while they work with the community and other stakeholders to select a more detailed scenario. Scenario 1 includes: maintaining recreational use at 2006 levels through land- and sea-based access controls, providing on-site management, improving education and outreach activities, and establishing a long-term ecosystem monitoring effort.

Implement regular water quality monitoring

It is likely that there were changes in nutrient and sediment delivery to Honolua Bay even though water quality parameters have shown little change over the last 16 years. Changes in water quality parameters were difficult to detect because monitoring was undertaken only once a year and at irregular intervals, presenting a brief snapshot of water quality condition. Water samples were collected when freshwater was generally not flowing from Honolua Stream, at low-tide during periods of mild trade-winds and when there was little swell. Thus sampling conditions may not have been representative of the average conditions in the Bay. In addition the small number of samples (19 total over 16 years) makes it difficult to establish compliance with water quality standards. Routine monitoring is needed to assess compliance with water quality standards and changes in water quality conditions.

Because of the vertical and horizontal stratification within the bay monitoring could be limited to near-shore surface waters of the inner bay and Honolua Stream. At a minimum monitoring must occur during the summer and winter months, to capture dry and post-flood conditions. Replicate samples should also be analyzed to account for variability in water quality. It is recommended that bacteria levels are routinely monitored to ensure water quality meets human health and safety standards, and total suspended solids are analyzed.

Groundwater needs to be sampled periodically to determine background nutrient and contaminant concentrations. Long-term in-situ turbidity monitoring should also be implemented to assess the variability in sediment runoff and help quantify the impacts of sediment runoff on coral reef condition. This monitoring should be integrated with coral reef monitoring programs.

Near-shore water quality and bacteria monitoring should be incorporated into DOH's existing beach water quality monitoring program. Additional monitoring and research should continue to be supported by ML&P and other agencies. The use of volunteer monitoring programs must also be considered as both an outreach and data collection tool. There are several community groups and NGO's that are focusing on Honolua Bay and could potentially organize these efforts. Any future water quality monitoring must be subject to critical review to ensure that sampling and data collection support the water quality status/improvement claims.

In summary the key water quality recommendations are:

- Incorporate near-shore water quality monitoring, including total suspended solids, of Honolua Bay into the State's water quality monitoring program,
- Incorporate bacterial indicator monitoring into DOH's beach monitoring program
- Monitor the quantity and quality of groundwater
- Implement in-situ long-term turbidity monitoring, and
- Monitor stream flow

Continue long-term coral reef monitoring

Coral cover in Honolua Bay has generally decreased since the first surveys were conducted in 1974. It is difficult to compare coral cover data between studies because of differences in survey methods and survey sites. Although there are differences between CRAMP and MRC data, the general trend is the same: coral cover has decreased since their monitoring programs started in 1994 and 1990 respectively. In addition to the long-term decline in coral cover, coral recruitment success is also low (Brown, 2004).

All studies concur that there are differences in species composition between the north and south reef. The north reef is dominated by *Porites* sp. while sediment resistant *Montipora* sp. are dominant on the southern reef. There is also agreement that sediments and wave action influence coral cover. High turbidity and sediment deposits in the inner bay have been observed consistently since 1974.

It is apparent that erosion of soil and subsequent sedimentation events have caused declines in coral cover, impacted coral recruitment success, and are affecting the long-term condition of Honolua's reefs. In addition other anthropogenic variables, such as chemical pollutants and increasing human use, are likely contributing to the long-term decline in coral cover. Honolua's coral reefs have adapted to the bay's wave action, water circulation patterns and influx of stream and ground-water. However human activities are altering the reefs resilience to both natural and anthropogenic stressors. In order to stop this long-term decline in coral cover, management efforts must focus on reducing anthropogenic sources of stress.

The lack of quantitative data makes it difficult to determine the specific cause(s) of the long-term decline in coral cover. The continuation of long-term coral reef monitoring is critical. Future monitoring should utilize standard survey methods, such as the CRAMP protocol, to reduce discrepancies between long-term studies. The CRAMP protocol has been validated and is utilized State-wide and should be continued in Honolua Bay. If possible monitoring should be expanded to include at least one deep site on the reef slope (similar to other CRAMP sites). This would provide a better understanding of Bay-wide trends in coral condition. Alternatively MRC's monitoring program could be used to supplement CRAMP's limited survey sites. However this would require the use of comparable methods, including permanent quadrats by MRC.

As well as long-term benthic monitoring, in-situ long-term turbidity monitoring is urgently needed to help quantify the impacts of sediments on Honolua's coral reefs. The installation of in-situ turbidity monitors and a stream-gage are strongly recommended. It is also critical that coral recruitment rates continue to be monitored regularly.

Support studies that address identified gaps in knowledge
Information gaps for the marine and terrestrial ecosystem in the Honolua ahupua'a were identified during this review. Certain components of the ahupua'a have either not been studied or data was not accessible for review. Perceived information gaps are listed in groups below:

Watershed Gaps:
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- Comprehensive list of marine invertebrates (last surveyed in 1979)
- Comprehensive data on prevalence and occurrence of coral and fish disease
- Marine vertebrate surveys
- Comprehensive list of marine macroalgae
- Analyses of long-term fish data sets
- Cause(s) of coral cover decline
- Biological impacts of sedimentation and turbidity
- In-water monitoring of recreational impacts on coral reefs

Water Quality Gaps:
- Comprehensive long-term water quality data
- Long-term in-situ turbidity data at coral reef

- Location, quantity and quality (nutrients and contaminants) of groundwater input
- Fluxes of freshwater and nutrients from groundwater vs stream flow
- Quantity and quality of stream flow
- Integration of water quality and coral reef monitoring

Geospatial Information Gaps:

- GPS locations of early coral reef and fish surveys (many sites were identified by landmarks in the field)
- Detailed land-use maps

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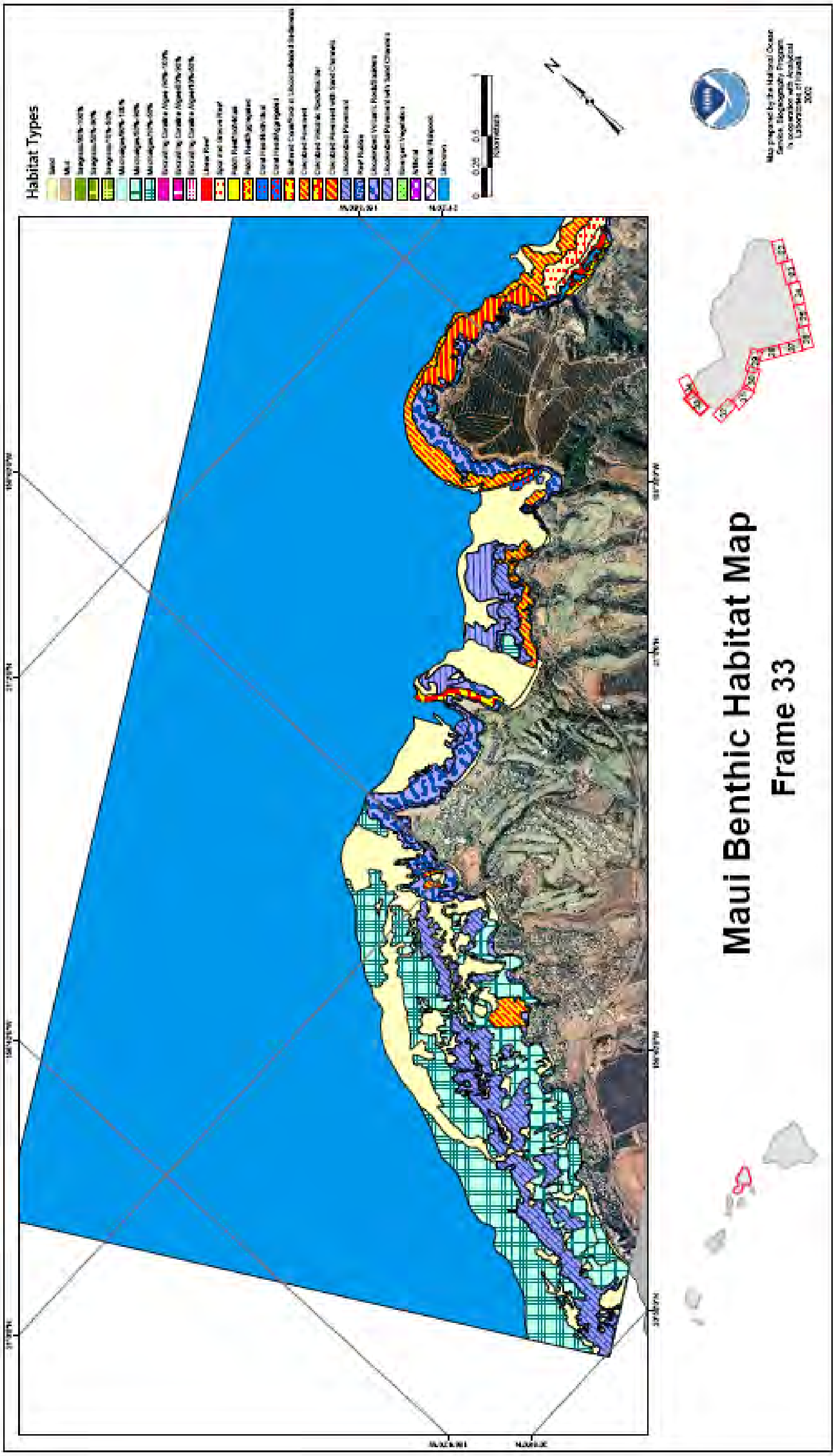
Appendix A: Maui Benthic Habitat Map

Source: NOAA Center for Coastal Monitoring & Assessment (CCMA)
(www.ccmaserver.nos.noaa.gov)



Appendix B: Coral Species Lists

List of coral species identified by ECI (1974) and presence/absence in other surveys.

Species List	1974 ECI	1979 Torricer *et al.*	CRAMP	MRC 07
Cyphastrea ocellina (Dana)	yes	yes	no	yes
Fungia (Pleuractis) scutaria Lamarck	yes	no	no	no
Leptastrea bottae	yes	yes	no	yes
Leptastrea purpurea (Dan)	yes	no	yes	yes
Pavona duerdeni (Vaughan)	yes	yes	yes	yes
Pavona varians	no	no	yes	yes
Montipora flabellata (Struder)	yes	yes	yes	yes
Montipora patula (Verrill)	yes	yes	yes	yes
Montipora verrucosa (Lam.)	yes	yes	yes	no
Montiopora capitata	no	no	no	yes
Pocilloproa damicornis (Linnaeus)	yes	yes	no	yes
Pocillopora liqulata (Dana)	yes	no	no	no
Pocillopora eydouxi M.Ed. & H	yes	no	no	yes
Pocillopora meandrina Dana	yes	yes	yes	yes
Porites compressa Dana	yes	yes	yes	yes
Porites lobata Dana	yes	yes	yes	yes
Porites (Synararea) convexa Dana	yes	no	no	no
Porites brighami	no	no	yes	yes
Porites evermanni	no	no	yes	no
Porities lichen	no	no	yes	no
Porites rus	no	no	no	yes
*Psammocora (Stephanaria) stellat*a Verrill	yes	no	no	yes
Palythoa sp. (a zoanthid, soft coral)	yes	no	no	yes, (*tuberculosa*)
Montirpora verrilli (could be *patula)*	no	yes	no	no
Montipora studei	no	no	yes	no
Number of species	18	12	13	17

Appendix C: List of fish species and mean biomass in Honolua Bay

Source: Friedlander (unpublished data). Mean biomass is given is estimated as tonnes per hectare.

Family	TaxonName	mean_bio
Acanthuridae	*Naso unicornis*	0.115134
Acanthuridae	*Acanthurus triostegus*	0.070763
Acanthuridae	*Acanthurus blochii*	0.052615
Acanthuridae	*Acanthurus nigrofuscus*	0.046845
Acanthuridae	*Naso lituratus*	0.044205
Acanthuridae	*Acanthurus leucopareius*	0.042074
Kyphosidae	*Kyphosus species*	0.023014
Scaridae	*Scarus rubroviolaceus*	0.019335
Mullidae	*Mulloidichthys vanicolensis*	0.018863
Labridae	*Thalassoma duperrey*	0.016771
Acanthuridae	*Acanthurus olivaceus*	0.016765
Carangidae	*Caranx melampygus*	0.015825
Holocentridae	*Myripristis kuntee*	0.015570
Mullidae	*Parupeneus multifasciatus*	0.013185
Monacanthidae	*Cantherhines dumerilii*	0.012514
Mullidae	*Mulloidichthys flavolineatus*	0.011117
Serranidae	*Cephalopholis argus*	0.008812
Lutjanidae	*Lutjanus kasmira*	0.008308
Balistidae	*Rhinecanthus rectangulus*	0.007720
Acanthuridae	*Ctenochaetus strigosus*	0.007207
Acanthuridae	*Acanthurus dussumieri*	0.007003
Balistidae	*Melichthys vidua*	0.006840
Mullidae	*Parupeneus cyclostomus*	0.005378
Diodontidae	*Diodon hystrix*	0.005209
Pomacentridae	*Stegastes fasciolatus*	0.004947
Scaridae	*Chlorurus sordidus*	0.004867
Labridae	*Stethojulis balteata*	0.004605
Pomacentridae	*Chromis vanderbilti*	0.004298
Pomacentridae	*Abudefduf sordidus*	0.004292
Scaridae	*Scarus psittacus*	0.004060
Pomacentridae	*Abudefduf abdominalis*	0.003827
Tetraodontidae	*Arothron hispidus*	0.003775
Scaridae	*Calotomus carolinus*	0.003772
Balistidae	*Sufflamen bursa*	0.003635
Balistidae	*Sufflamen fraenatus*	0.002333

Family	TaxonName	mean_bio
Chaetodontidae	*Chaetodon ornatissimus*	0.002078
Chaetodontidae	*Chaetodon auriga*	0.001793
Labridae	*Gomphosus varius*	0.001654
Carangidae	*Scomberoides lysan*	0.001649
Holocentridae	*Myripristis berndti*	0.001617
Acanthuridae	*Naso hexacanthus*	0.001507
Labridae	*Thalassoma purpureum*	0.001425
Kuhliidae	*Kuhlia sandvicensis*	0.001327
Scaridae	*Chlorurus perspicillatus*	0.001129
Fistulariidae	*Fistularia commersonii*	0.001108
Pomacanthidae	*Centropyge potteri*	0.001061
Mullidae	*Parupeneus bifasciatus*	0.001043
Labridae	*Thalassoma ballieui*	0.001027
Chaetodontidae	*Chaetodon lunula*	0.001012
Pomacentridae	*Plectroglyphidodon johnstonianus*	0.000999
Labridae	*Thalassoma trilobatum*	0.000978
Pomacentridae	*Chromis ovalis*	0.000973
Cirrhitidae	*Cirrhitus pinnulatus*	0.000938
Diodontidae	*Diodon holocanthus*	0.000915
Mullidae	*Parupeneus porphyreus*	0.000822
Balistidae	*Melichthys niger*	0.000793
Carangidae	*Decapterus species*	0.000754
Priacanthidae	*Priacanthus meeki*	0.000666
Labridae	*Anampses cuvier*	0.000662
Chaetodontidae	*Chaetodon unimaculatus*	0.000645
Lutjanidae	*Lutjanus fulvus*	0.000640
Cirrhitidae	*Paracirrhites forsteri*	0.000629
Acanthuridae	*Zebrasoma flavescens*	0.000583
Chaetodontidae	*Chaetodon lunulatus*	0.000567
Cirrhitidae	*Paracirrhites arcatus*	0.000496
Labridae	*Oxycheilinus unifasciatus*	0.000492
Cirrhitidae	*Cirrhitops fasciatus*	0.000477
Pomacentridae	*Chromis hanui*	0.000456
Labridae	*Macropharyngodon geoffroy*	0.000421
Mullidae	*Upeneus arge*	0.000396
Tetraodontidae	*Canthigaster jactator*	0.000372
Labridae	*Pseudocheilinus octotaenia*	0.000354
Chaetodontidae	*Chaetodon quadrimaculatus*	0.000333
Pomacentridae	*Chromis agilis*	0.000330
Acanthuridae	*Naso brevirostris*	0.000317

Family	TaxonName	mean_bio
Belonidae	*Tylosurus crocodilus*	0.000315
Labridae	*Xyrichtys umbrilatus*	0.000304
Chaetodontidae	*Chaetodon multicinctus*	0.000303
Pomacentridae	*Abudefduf vaigiensis*	0.000293
Zanclidae	*Zanclus cornutus*	0.000273
Labridae	*Coris venusta*	0.000267
Labridae	*Bodianus bilunulatus*	0.000249
Labridae	*Halichoeres ornatissimus*	0.000241
Mullidae	*Parupeneus pleurostigma*	0.000229
Pomacentridae	*Plectroglyphidodon imparipennis*	0.000223
Labridae	*Anampses chrysocephalus*	0.000201
Muraenidae	*Gymnothorax meleagris*	0.000161
Monacanthidae	*Cantherhines sandwichiensis*	0.000149
Bothidae	*Bothus mancus*	0.000144
Tetraodontidae	*Canthigaster amboinensis*	0.000144
Labridae	*Coris gaimard*	0.000141
Ostraciidae	*Ostracion meleagris*	0.000115
Labridae	*Xyrichtys pavo*	0.000073
Labridae	*Oxycheilinus bimaculatus*	0.000070
Blenniidae	*Cirripectes vanderbilti*	0.000066
Labridae	*Labroides phthirophagus*	0.000059
Acanthuridae	*Acanthurus nigroris*	0.000044
Synodontidae	*Synodus binotatus*	0.000041
Labridae	*Pseudocheilinus evanidus*	0.000040
Gobiidae	*Hazeus nephodes*	0.000037
Blenniidae	*Plagiotremus goslinei*	0.000018
Chaetodontidae	*Chaetodon miliaris*	0.000014
Aulostomidae	*Aulostomus chinensis*	0.000013
Gobiidae	*Psilogobius mainlandi*	0.000011
Blenniidae	*Exallias brevis*	0.000010
Blenniidae	*Plagiotremus ewaensis*	0.000009
Labridae	*Pseudojuloides cerasinus*	0.000009
Labridae	*Pseudocheilinus tetrataenia*	0.000008
Acanthuridae	*Acanthurus achilles*	0.000006
Gobiidae	*Gnatholepis anjerensis*	0.000004
Blenniidae	*Blenniella gibbifrons*	0.000002
Gobiidae	*Coryphopterus sp.*	0.000001

Appendix D: Available GPS coordinates:

Coral disease transects (Walsh *et al* 06).
Honolua Disease Start:
Map symbol CD2S
Latitude N: 1.01564282
Longitude W: 156.6399155
UTM Northing: 2325691.439
UTM Easting: 745307.0989

Honolua Disease End
Map Symbol: CD2E
Latitude N: 21.01550401
Longitude W: 156.6403497
UTM Northing: 2325691.439
UTM Easting: 745262.1784

DLNR-DAR permanent transect coordinates and CRAMP coordinates
The Geographic coordinates of watershed boundary are:

- Horizontal Coordinate 1: 744719.60
- Vertical Coordinate 1: 2325211.102
- Horizontal Coordinate 2: 745171.18

Vertical Coordinate 2: 2326622.02