A Natural and Cultural History of Maunalua Bay and Its Watershed

A research project submitted to the faculty of
San Francisco State University
In partial fulfillment of
The requirements for
The degree

Master of Arts
In
Geography: Resource Management & Environmental Planning

by

Anne Atkinson

San Francisco, California

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CERTIFICATION OF APPROVAL

I certify that I have read *A Natural and Cultural History of Maunalua Bay* by Anne Atkinson, and that in my opinion this work meets the criteria for approving a research project submitted in partial fulfillment of the requirements for the degree: Master of Arts in Geography: Resource Management and Environmental Planning at San Francisco State University.

Barbara Holzman
Professor of Geography

Nancy Wilkinson
Professor of Geography

A NATURAL AND CULTURAL HISTORY OF MAUNALUA BAY

Anne Elizabeth Atkinson
San Francisco State University
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The Hawaiian Islands have a long history of human-induced landscape modification that began on a small scale when the first settlers arrived on the Islands, and increased in scale over time with increases in population. Urbanization in the Maunalua Bay region on the Hawaiian Island of O‘ahu has brought with it many of the problems that typify modern development in Hawaii, including pollution and sedimentation of aquatic and marine environments, and disturbance or destruction of wetland, grassland, shrub and forest habitats. However, despite the vast environmental modifications caused by humans, there are sites is the study area where endangered, endemic birds and remnants of native vegetation persist, and where native aquatic fauna species are more numerous than introduced species. Community concern about the preservation and protection the area's remaining natural and cultural resources are being addressed by a local grassroots organization, Mālama Maunalua, whose efforts are focused on improving ecological conditions in Maunalua Bay, and promoting increased community stewardship.

I certify that the Abstract is a correct representation of the content of this research project.

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Chair, Thesis Committee Date

PREFACE AND/OR ACKNOWLEDGEMENTS

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I. INTRODUCTION

Isolated by 2,300 miles from the nearest continental land mass in the world's largest ocean, the islands of the Hawaiian Archipelago were formed by magma that erupted out of rifts in the ocean floor millions of years ago. The Islands have produced a highly endemic biota, resulting in some of the world's best examples of adaptive radiation (Culliney 2006). A unique cultural heritage also evolved on the Hawaiian Islands, organized by the Polynesian people, whose sophisticated voyaging skills and courageous expeditions of discovery led them to become the first people to settle on these islands. The natural history of the Hawaiian Islands is inexorably intertwined with the cultural heritage of the Polynesians, who adapted to life in Hawaii by organizing systems of government and production suited to the environment. The volcanic origins of the Hawaiian Islands themselves and the story of how their native plants, animals and human culture continue to evolve provide an important contribution to the world's natural and cultural histories.

The Hawaiian Islands have a long history of landscape modification originating from both human and natural forces. Human modification of landscapes probably began on a small scale when the first settlers arrived on the Islands (likely between 200 and 600 AD) from the Marquesas Islands, located nearly 2,500 miles (4,023 kilometers) south of the main Hawaiian Islands (Graves and Addison 1995; Kirch 1998). These people, who may have first landed their canoes on the Hawaiian Island of O‘ahu, likely participated in an "occupying" economy, using found resources and simple systems of cultivation to survive (Buck 1993, 48). Handy, Handy and Pukui (1972) and others note that two-way navigation probably occurred between Hawaii and the founders' islands of origin, making it possible for these voyagers to bring to Hawaii more people, plants, and domesticated animals (Kirch 1985; Buck 1993). As the population of the islands grew, and a second migration occurred from the Society Islands (including Tahiti) around A.D. 1100 and 1200, more organized systems of production were established (Kirch 1985).

The traditional Hawaiian systems of extracting life-sustaining resources from the land developed over time. Hawaiian resource management systems are specific to particular places, involve ritual and spiritual components, and are based on centuries of observation and adaptation to tropical seasons and other environmental patterns (Handy, Handy, and Pukui 1972). While the traditional Hawaiian system of resource management involved activities that likely disturbed ecological systems, the scale and rate of ecological disturbance caused by the Polynesians differs in important ways from the human changes that followed European contact. Modern human alteration of the Hawaiian landscape and coastal areas continues today at an accelerated pace and broader scale, and includes myriad effects of residential development, tourism and urbanization.

The island of O‘ahu, known as "the gathering place", is the most populous island in the Hawaiian Archipelago. As home to over eighty percent of the state's population, it is the Hawaiian Island with most of the state's urban and suburban development.

Between the geologic features of Koko Head and Black Point on the southeastern shore of O‘ahu lies nearly eight-miles of fringing reef coastline in Maunalua Bay. Over the past half century, this region has been transformed from a sparsely

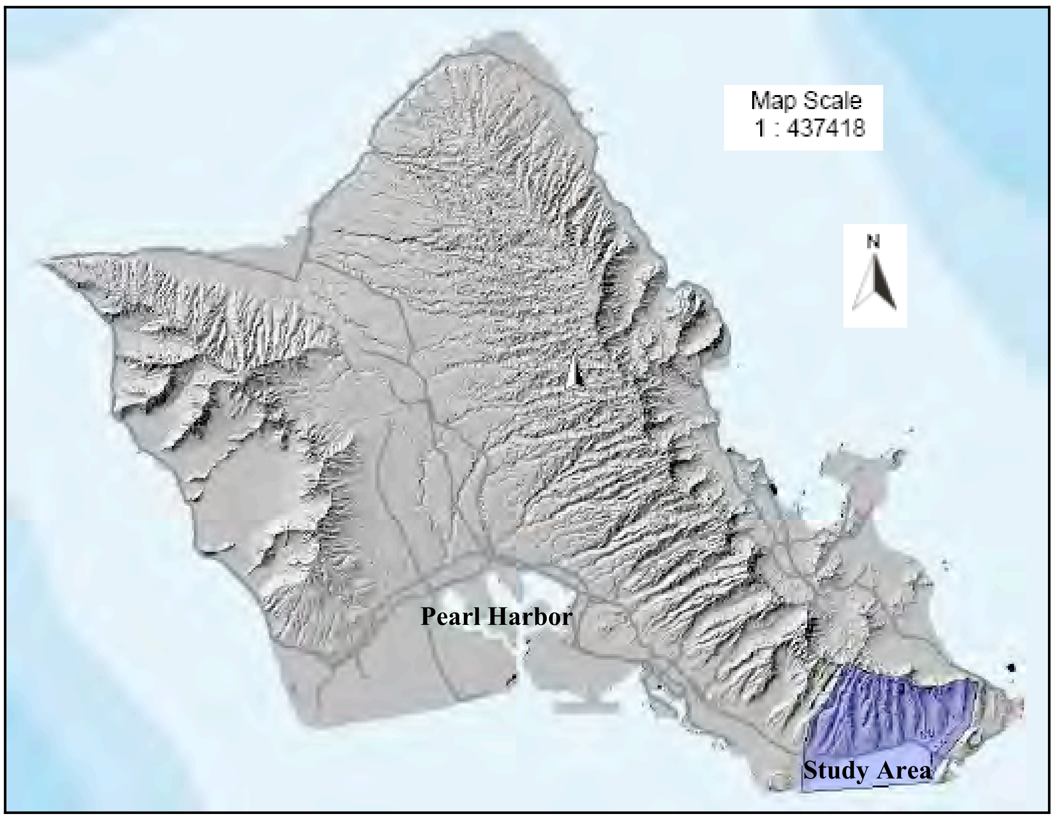

Figure 1. Island of O‘ahu with study are a highlighted (PBIN 200 5).

populated agricultural area with few residents, to a densely populated suburb (Figure 1). Urbanization has brought with it many of the problems that typify development in Hawaii, including pollution and sedimentation of aquatic and marine environments, and disturbance or destruction of wetland, grassland, shrub and forest habitats. Concerned by the deteriorating conditions in Maunalua Bay, particularly a marked decline in the number of fish in the nearshore marine environment, community leaders organized a group called Mālama Maunalua. Formed in October 2005, Mālama Maunalua seeks to promote more abundant marine life in Maunalua Bay, cleaner Bay water, and to inspire responsibility, pride and stewardship in caring for Maunalua Bay (Mālama Maunalua 2006a). This research project seeks to support Mālama Maunalua's efforts, by providing literature on the natural and cultural history of the region which can be used in their outreach and educational efforts.

This project is a study of some of the significant biophysical and cultural changes that have occurred at the study site through time. This narrative, descriptive study is predicated on the assumptions that Mālama Maunalua's stated goals are achievable and ecologically and culturally beneficial, that outreach materials containing information on regional natural and cultural history are effective tools for inspiring and informing community environmental stewardship, and that the information on the region's cultural and natural history assembled here will be useful to producing educational outreach materials to support Mālama Maunalua's efforts.

The Study

The objective of this research project is to compile information on the natural and cultural history of Maunalua Bay in a narrative format that will be useful to furthering the goals of Mālama Maunalua. By integrating cultural, biological and physical components, this study seeks to create a timeline of human and biophysical changes in the region. The results section of this study begins with chapter, entitled "The Land", which is a discussion of the study area's climate and geologic history, and the flora and fauna of its terrestrial and aquatic environments. Chapter three on "The Bay" characterizes some of the significant aspects of changes affecting the marine environment of the study area. Chapter four, entitled "The People" focuses on human land-use and landscape changes in the region, and includes discussions of settlement, land management regimes, and urban development. Finally, chapter five, entitled "The Future Bay" explore current and planned cultural renewal and ecological restoration projects in the region.

Maunalua Bay, O'ahu and its watershed were chosen for study because this region is the focus of a community-based cultural and environmental education project that promotes cultural pride and ecological health at a regional scale. The organization spearheading this effort, Mālama Maunalua, envisions a future when fish populations are plentiful and supported by a clean marine environment, and when local residents, businesses and community groups work together to care for the health of the Bay. This research project provides natural and cultural historical information on the Maunalua region and is intended to be used by Mālama Maunalua to support educational outreach activities through the production of websites, newsletters, informational displays, brochures, fundraising literature, and other outreach materials. In addition to improving ecological conditions that support a robust population of fish, part of Mālama Maunalua's vision is to encourage community responsibility for caring for the Bay. The organziation's stated vision is "A Maunalua Bay where fish are once again plentiful, pollution and sedimentation are mitigated, and where individuals, community groups, businesses and agencies take *kuleana* [responsibility] in caring for and sustainably managing the bay".

Mālama Maunalua's strategy for promoting community *kuleana* (responsibility) is through public outreach and education that seeks to reestablish the connections between the community and the land (*'aina*) (Mālama Maunalua 2006). For the short term, these efforts involve place-based, collaborative community efforts, such as coordinating invasive alien algae removal projects, facilitating an advisory group of fishers, implementing strategies to reduce sediment and pollution, and coordinating cultural and environmental education programs (Maunalua 2006). Mālama Maunalua's long-term vision is for the spirit of *kuleana* to manifest itself through the community implementation of a resource management regime based on traditional Hawaiian values. and thereby foster action to *mālama* (take care of*)* the place. Specifically, "We see the *ahupua'a* system [traditional Hawaiian system of resource management] being revitalized to its full extent, allowing us to understand and appreciate the connections between the land and the water, between people and the *'aina*. We see the wisdom and knowledge of our *kupuna* [ancestors] being rediscovered and integrated into our way of managing resources" (Mālama Maunalua 2006).

There is a dearth of information on the cultural and biophysical history and characteristics of the study site. While environmental and cultural histories of the area exist, no single study offers both a physical and a cultural characterization in one document. This study contributes a narrative history that illuminates some of the interwoven aspects of human and biophysical systems, and provides the background for looking at long-term ecological changes, which are often missed when examining the impacts of management regimes that operate on smaller time scales (Bowman 2001; Foster *et al.* 2003).

Literature Review

This literature review will discuss the environmental history as it applies to conducting natural and cultural history studies, and provide contextual information on how environmental history came into being as a distinct field of academic inquiry, what distinguishes environmental history from other types of history, and a discussion of how environmental histories can be useful.

Origins of Modern Environmental History

Long before the emergence of environmental history as a field of academic inquiry in the 1970s, environmental histories existed as written or oral cultural traditions, that served to pass down important information about how to interpret and survive in the natural world, and to define the role of human societies and individuals in that world. In the mid-19th Century, following Darwin and Wallace's revolutionary scientific work on evolution, interest in the function of natural systems was piqued, and concern over the ecological problems of deforestation and resource exploitation began to concern some scholars.

Much later in 1969, photos of the earth taken from the Apollo II voyage to the moon gave scholars a new perspective on the natural world (Crosby 1995). All at once, the earth could be seen in the context of vast, deep space, which forever changed impressions of the earth as large and indestructible (Crosby 1995). Also in the 1960s, a number of important literary works helped to shape a new impression of the natural world as more susceptible to human influence than previously thought. Carson (1962) exposed the disturbing impacts of pesticide use on bird populations. Nash (1967) analyzed Americans' view of nature and helped to build the foundation for discourses on American human-nature relationships. Nash's work was followed by Ehrlich's (1968) and Hardin's (1968) works, which alerted readers to the consequences of a growing world population's dependency on the resources of a finite planet (Crosby 1995).

Environmental historians were interested in analyzing and discussing some of the ways minorities—or less visible communities—used and viewed their environments and the world-views of Native Americans and other indigenous cultures were studied with interest in new university courses. In 1976, John Opie founded the American Society for Environmental History and the journal *Environmental Review* (now *Environmental History*). To suggest, however, that environmental histories began with the establishment of university courses and an academic journal and society would be misleading.

The first environmental histories were either written or oral cultural traditions. These prehistoric traditions relayed stories about human creation, and the essence of the human-cultural relationship with nature. They transferred knowledge about localized methods of production that helped succeeding generations to negotiate complex natural systems, and ultimately, to survive in particular places. Over time, many of these histories were richly developed, and often incorporated nuanced scientific knowledge of the natural world that served to perpetuate human survival. These historical traditions were often structured in a manner that accommodated fluctuations and changes in the biophysical landscape that sustained human communities, and included important information about human organizational systems, such as agricultural practices and social structures (Merchant 2002).

Traditional environmental histories often provide societies direction in adjusting to population changes and habitat degradation that threaten continued survival.

Rappaport (1971) has defined the regulatory function of historical traditions. For example, the model of nature in a particular culture illuminates how humans view the natural world, and in the case of the New Guinea tribesmen he studied, can function to provide mechanisms that compensate for resource overexploitation (Rappaport 1971; Worster 1984).

Merchant (2002) has narrowed the focus of her historical inquiry to the level of minorities and women within cultures, who may view and utilize the natural world in ways that differ significantly from the larger society. She has pointed out that clues into the lives of individuals within traditional cultures can be found in studying these historical traditions, through examining religious belief systems, manuscripts, literature, maps and artifacts. These clues can help to uncover how these cultures adjusted to and modified the landscapes they occupied (Merchant 2002).

While environmental histories incorporate a variety of approaches to uncovering the past, they all share one common theme: nature plays a primary role in the stories environmental histories tell about the past. Environmental historians study environmental change over time with the assumptions that (1) human activities often affect the biophysical environment; (2) environmental change—whether anthropogenic or not—affects humans; and (3) far from being the only actors, humans play one role among many with other characters and forces, in creating environmental change (Cronon 1993).

Broadly defined, environmental history approaches history from an ecological perspective, providing a platform for examining the past that values nature and the role it plays in shaping human lives (Worster 1984). Nature, in environmental history narratives, is not a passive backdrop against which human stories play out; it plays an active role in shaping and influencing human existence (Worster 1984). In environmental history, nature is valuable: it limits and influences how humans live. Achieving a fuller understanding of a place and the past is not possible without including the non-human biophysical world in the story (Steinberg 2004).

Many modern historians, geographers, and other scholars looking at human aspects of the past typically examine the past with a fascination for particular places in time, recognizing that past events and lives are particular to their historical moment, and therefore must be considered within their historical context. Further, these scholars generally avoid the generalizations and reductionist approaches of other disciplines in seeking to illuminate patterns or establish causality. Instead, these scholars seek to engage in a "dialogue with the past" that is more welcome to discourse on the many possible causes of environmental changes (Cronon 2004, 4).

Further, environmental historians see their work as an interpretation of the past for the present, mindful that their own viewpoint cannot be taken out of interpreting the past, and in telling its story. Taken out of context, absolute claims of factual knowledge about the past can diminish the clarity with which we see past environments and societies (Cronon 1993a)

On the subject of causality, Liebhardt (1988) writes that environmental historians assign causal links between environmental change and human activity in an attempt to order their narratives and embedded facts, but these causal relationships are not definitive. Rather, Liebhardt (1988) argues, environmental historians can suggest associations between human and biophysical processes, thereby offering a framework for weaving factual information into narratives about the past. In doing so, environmental historians can generate work that encourages dialogue, and illuminates the nuances of human-nature relationships.

Environmental historians believe that one cannot understand the past or the present in a meaningful way without a fuller understanding of the biological world, the weather, climate, soil and water that constitute the non-human natural world that has supported and influenced humans throughout time (Crosby 1995; McNeill 2003). Generally, environmental historians agree that history has traditionally been too human-centered in its inquiries, and that the nation-state focused approach to history leaves out important natural components that help to shape historical events and human lives (Worster 1994). Indeed, environmental historians caution that the natural cannot be separated from the human stories of the past, without losing important lessons (Cronon 1990). In this way, environmental histories differ from traditional historical narratives.

What Defines Environmental History?

Rather than focusing on particular subjects, environmental history is an area of inquiry that distinguishes itself by asking certain kinds of questions, and exploring the context and aspect of historical questions (Radkau 2005). The works of "new western historians," such as Worster (1994) and Cronon (1992) use archival resources to uncover the cultural meaning of landscapes, using the landscape as the primary theme of their inquiry (Myers *et al.* 2003). This approach is predicated on an assumption that landscapes contain and display at various times the symbology and other evidence of the ideas, beliefs and cultural identity of the humans that have occupied them (Myers *et al.* 2003). Sauer (1941) suggested that one of the most difficult, but most effective way of conducting this type of historical research is to "…see the land through the eyes of its former occupants, from the standpoint of their needs and capacities" (10).

Environmental historians understand that the way history is approached can have profound ramifications for its interpretation. Indeed, the tenets of science and the idea of nature are both social constructions, and are represented differently in different eras (Merchant 1993). Because science, nature and history are all social constructions, their interpretations are constantly evolving and represent different things in different eras (Merchant 1993).

Another problem of doing environmental history identified by Merchant (1993) posits that human cognition can be interpreted on two levels: (1) via societal institutions of science, religion and art, and (2) individually, based on interactions with other humans and with nature. While environmental historians are concerned with human concepts of nature and human world-views—both individually and collectively—it is easier when weaving a narrative and arguing a point to generalize about concepts. This is problematic, because in generalizing, views of those outside of established societal institutions are often ignored. By engaging in a new interpretation of past events, documents and histories, environmental historians with their "earth's eye-view" can provide a new perspective on history (Merchant 1993, 1), and ask how the views of various minorities and sub-cultures may have differed from majority views in particular places.

Cronon (1990) identifies the issue of inclusiveness that Merchant describes as a problem of holism, or the idea that the whole is greater than the sum of it parts. Cronon 1990) argues that the force that holism lends to theories put forth by historians is the same force that subverts the perspectives of individuals or groups whose views and attitudes differ from those in power, or in the majority. By extension, one fault of environmental history then, is not probing deeply enough to find out the vastly different ways that individuals from the same place in time and space can experience the non-human natural world (Cronon 1990). Cronon (1993) also points out that not all forces of ecosystem change can be labeled as traditional or natural on the one hand, or as capitalist and modern on the other hand. Cronon (1992) also cautions against the idea of "the balance of nature" and argues that environmental historians should look to the relationships of humans to the non-human natural world, and study rates and types of change, rather than contrasting a climax ecological community (an antiquated idea) with destructive human changes.

Cronon (1992), Bowman (2001) and others have written about the tension between writing a compelling narrative, which is by its nature bounded by the value judgments of the writer and uncertainty about past conditions and events. Even in attempts to be objective, environmental historians recognize the inherent subjectivity of their narratives about the past. In weaving interpretations that follow a story line or theme, some points of view are invariably omitted, and some facts are inevitability overlooked. Also, there is uncertainty about the past, as there is about the future, and interpretation of the past can be value laden and politically volatile (Bowman 2001). Indeed, no environmental history can do equal justice to all the important individuals, events and locations that are relevant to a particular study (Merchant 1993). But, conscious efforts can be made to include the voices of women and minorities in narratives about the past (Merchant 1993). Some histories have been written from the point of view of animals that have played important roles in history—such as beaver, foxes and buffalo (Merchant 1993). These non-human viewpoints can encourage readers to think about the past in new ways (Merchant 1993).

Worster (1984) observes that "…as a matter of tradition and convenience, historians agree to deal with certain matters and to omit others" (16). This bias is unavoidable, because as individuals, historians cannot entirely escape their own assumptions, perspectives and biases. However, writing historical narratives is worthwhile, because while they may not establish causality and factual declarations, they can enlighten us through encouraging deeper and imaginative thought about past human environments. On this topic, Cronon (2004) states that historians recognize the embeddedness of bias in their work, and rather that struggle against it, they "…recognize, critique, and understand its consequences" 5).

Indeed, Cronon (1993a) argues that because the past can only be seen from our current vantage point, interpretations of the past by environmental historians should not be seen as absolute truths, but as non-fictional narratives. Cronon (1993a) cautions environmental historians to abstain from making predictions about the future, and instead take a hypothetical approach and create narratives discussing what may possibly happen.

Having discussed some of the problems with environmental history, it is important to also comment on some of the strengths of the field. Batterbury and Bebbington (1999) support the work of environmental historians by pointing out their usefulness in studying ecological phenomena. Environmental historians studying changes to landscapes are inclined to reach the scope of their studies further back in time than other types of historical studies. Indeed, the processes that modify natural environments do so slowly or sporadically, and the impacts of these changes can be difficult to tease out of short term studies. Short term studies run the risk of reinforcing misassumptions or myths about the cause and extent of landscape changes. Even when the study of past events and activities doesn't directly establish causality for landscape changes, these studies are useful in that they can reveal clues about how humans adapt to the limits that the natural world places on them (Batterbury and Bebbington 1999).

Uses of Environmental History

Potential environmental historical inquiries exist where the natural and the scientific interact with the cultural and humanistic, and where inquiries are made into the role of nature in human life. For example, the landscape surrounding Maunalua Bay has been occupied for thousands of years by various human groups with differing world views and cultures. Polynesians practicing a mix of subsistence fishing and agriculture were the first humans to arrive (Kirch 1985). As time passed and interchanges with the outside world took place in the nineteenth century, trade with whaling ships in sandalwood and other resources began. Thus, an examination of history reveals that natural resources have been commodified at this study site for a very long time, and the natural systems there have been altered as a result. For example, changes in geomorphology, vegetative species assemblages, aquatic and terrestrial animal populations, and the introduction of exotic species, all reflect the human history of this place. By examining these changes and including humans in the historical narration of place, environmental histories help promote a broader understanding of natural changes and how deeply they are connected to human existence (Cronon 1993a).

Cronon (1993a) suggests that in addition to the broader use of promoting historical understanding and appreciation of places and processes, environmental histories are useful in guiding resource management and in the formulation of government policy that considers how environments have changed over time. For example, historical analysis can help to illuminate the way resources were used by subsistence cultures, and how they are depleted, by farming development and overfishing. Also, environmental history can contribute to a deeper appreciation of the complex historical human-environment relationships, which can be useful in creating policy. Without history, the experience of the natural and human past of a place is lost, and is often replaced by a cultural myth that obscures much of what is needed to understand places that have changed drastically through millenniums. The more we understand history, Cronon (1993a) argues, the more impressive environmental changes appear.

Foster *et al.* (2003) agrees with Cronon's argument that environmental history is useful in supporting management and policy decisions. Analyses of the results of Long-Term Ecological Research (LTER) studies sponsored by the National Science Foundation have revealed that the impacts of human land-use activities influence ecosystem function long after those activities have ceased. In fact, imprints of activities such as burning, agriculture, deforestation and grazing can influence ecosystems for centuries. It is widely accepted in the fields of ecology and resource management that the natural and cultural history of a study site provides vital information for developing detailed management policy (Foster *et al.* 2003).

Methods

By constructing a narrative history of biophysical and cultural change through time, this study incorporates information on the physical, biological, and cultural history of Maunalua Bay and its watershed. The constraints on historical data, and general data specific to Maunalua are formidable. Resources are few and diverse, and no comprehensive assessment exists. Much of the existing cultural data, and some of the biophysical data, are not specific to Maunalua Bay. There is a dearth of information on the ecological characterization of the region, which constrained the development of related sections of this project. Further, information on Hawaiian society before European contact is not plentiful. Post-contact Hawaii has better documentation, though other than land claim transaction documents associated with the privatization of Hawaiian land in the mid-19th Century, historical cultural information specific to the study region is scant.

The sources of information for this inquiry include government and privately published studies, archival documents, books, and journal articles. There are several places where these documents are housed, including: the Hawaii State Library; the Hawaii State Archives; the University of Hawaii Library, the Hawaii Historical Society; the Bishop Museum; the Hawaii Department of Land and Natural Resources; the City and County of Honolulu Planning Department, San Francisco State University Library, and online resources. While conducting research, information was evaluated for its applicability to the study using two criteria: (1) its relevance to the site, and (2) its value as a contribution to understanding the natural or cultural history of the Bay and its watershed.

Setting the stage for the patterns of human settlement, land development and modification that are discussed later, the study begins with a discussion of the physical setting of the study area. Geological information was compiled using the *Atlas of Hawaii* (Clague 1998) and a field trip guide to southeast O‘ahu produced for a meeting of American Geophysical Union members (Rowland and Garcia 2004). Climate information specific to the study area was obtained from Giambelluca and Schroeder’s (1998) chapter in *Atlas of Hawaii* and from a report by the U.S. Army Corps of Engineers (1994) on urban flood control.

An inventory of available information on past and current conditions of the Bay and its watershed was conducted by searching documents produced by the Bishop

Museum, and environmental impact statements and environmental impact reports housed at the University of Hawaii's Environmental Center and the Hamilton Library at the University of Hawaii. While there have been some studies of the region, none are comprehensive or long-term.

Information on historic vegetation zones and existing native vegetation in the study area was compiled using the Pacific Basin Information Node's mapping WebGIS service (PBIN 2005). Information from a variety of journal articles and books contributed to the construction of past and present species assemblages in the study area, including Reichard (2006), Culliney (2006) and Pratt and Gon (1998).

The terrestrial fauna section of this study is focused on birds. Olson and James (1991) and James and Olson (1991) describe excavations of prehistoric, extinct birds for examination. Presence of bird species recently inhabiting the study area was gleaned in 2006 from the Pacific Basin Information Node's mapping WebGIS service (PBIN 2005). An analysis of relevant books and journal articles was conducted to construct the narrative on terrestrial fauna, including the U.S. Fish and Wildlife Service's (2006) revised recovery plan for Hawaiian Birds. The freshwater and estuarine section of this study relied extensively on a Bishop Museum study of non-native freshwater and estuarine species detected on the south and west shores of O‘ahu (Englund *et al.* 2000).

The marine section of this study relied extensively on a Bishop Museum study of non-native marine species in O‘ahu at Waikiki and Hawaii Kai (Coles, DeFelice, and Eldredge 2002). The cultural component of this study also has a regional focus, and includes an examination of significant archaeological findings, early human settlement, and land-use in the study area. Kirch’s (1985) work provides background information for this section. Takemoto (*et al.* 1975), Barrera (1979), and Thomas (1995) provide studies of archaeological finds in the study area.

Local Hawaiian mythology information was collected from Stump’s (1981) characterization of the Maunalua region, from Takemoto et al. (1975), and from Malo (1951). Exploring Hawaiian mythology helps to clarify information about the Hawaiian past and present, the Hawaiian social structure, and aspects of Hawaiians’ shared reality (Buck 1993). While the scope of this study does not allow for an examination of chants and hula, mythology related to the region is briefly discussed throughout where myths relate to significant physical or cultural features.

Hawaiian land management and land use information for this study was garnered from previous studies commissioned for the preparation of environmental impact assessments and statements, including Takemoto et al. (1975) and Maly and Smith (1998). Chinen (1958) provides information on land tenure changes, Handy, Handy and Pukui (1972) describe human-nature relationships, and Stump (1981) provides general information specific to the cultural history of the Hawaii Kai region. Information on the future Bay and community efforts was culled from personal communications with Alyssa Miller, the Coordinator for Mālama Maunalua, and from attending planning meetings with Mālama Maunalua, as well as my own observations.

Following the introductory chapter, the results of this research are divided into four chapters: "The Land", "The Bay", "The People", and "The Future Bay". The second chapter, "The Land" discusses the biophysical features Maunalua Bay watershed, and how they have changed over time. The third section, "The Bay", discusses past and present characteristics of the study site's aquatic and marine habitats, and the fourth chapter, entitled "The People", explores ancient Hawaiian society and systems of land management and western contact. Finally, the "The Future Bay" section examines the community efforts to bolster both the ecological health and Hawaiian cultural pride in the region.

II. THE LAND

The Study Site

The island of O‘ahu, known as “the gathering place”, is the most populous island in the Hawaiian Archipelago. Home to almost 900,000 of the state’s 1,200,000 residents, O‘ahu is the Hawaiian island with most of the state’s urban and suburban development. Between the features of Koko Head and Black Point on the southeastern shore of O‘ahu, lies an eight-mile stretch of fringing reef coastline in Maunalua Bay (Figure 2). The two peaks of Koko Crater and Koko Head at the eastern end of the Bay likely inspired the name of Maunalua, which means ‘two mountains’ in Hawaiian (Clark 2005). The north-south boundaries of the study area extend toward the mountains (*mauka*) to the ridgeline of the Ko‘olau Range, and in the seaward (*makai*) direction to shoreline. The east-west boundaries are between *Kūpikipiki‘ō* Point to the west at 21°15.51′N latitude and 157°47.63′ W longitude, and *Kawaihoa* Point to the east at 21°15.74′ N latitude and 157°42.59′ W longitude. The study area covers approximately 28 square miles (PBIN 2005).

The landscape of the study area is characterized by a succession of U-shaped valleys and ridges that include the residential neighborhoods of Kahala, Wai‘alae Nui, Wai‘alae Iki, ‘Aina Haina, Hawai‘iloa Ridge, Niu Valley, Kuli‘ou‘ou‘, Haha‘ione Valley, Mariners Ridge, Hawaii Kai, and Portlock (Figure 3). The following section discusses some of the primary geological features and formative processes that have shaped the landscape of the region.

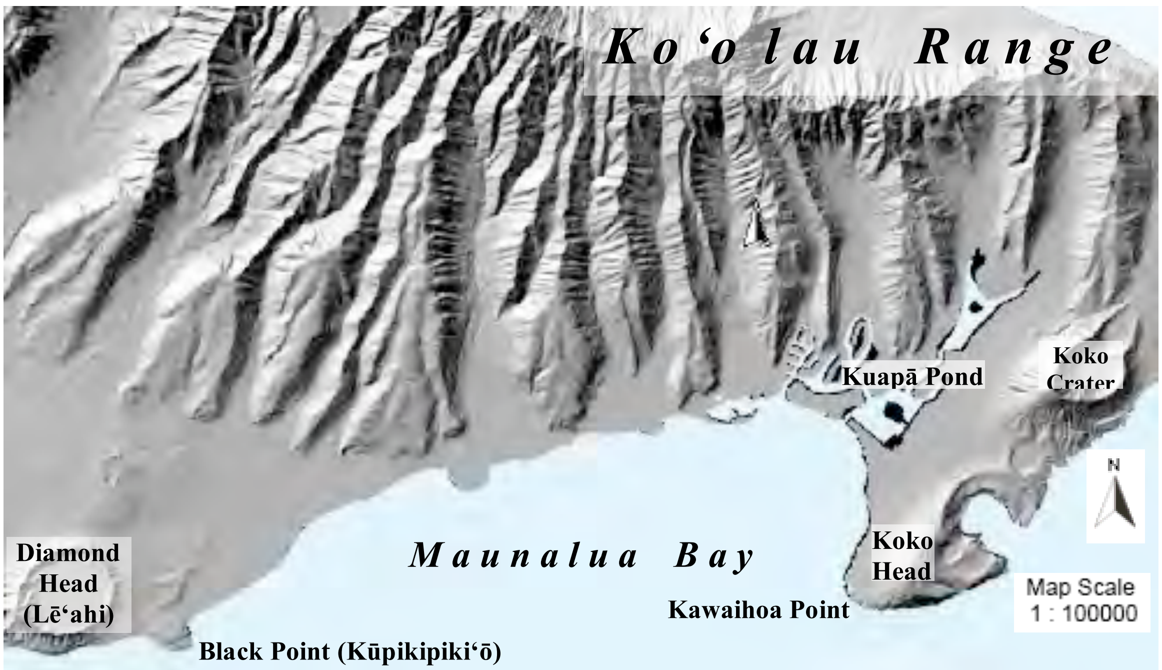

Figure 2. Detail of Maunalua Bay study area (PBIN 2005).

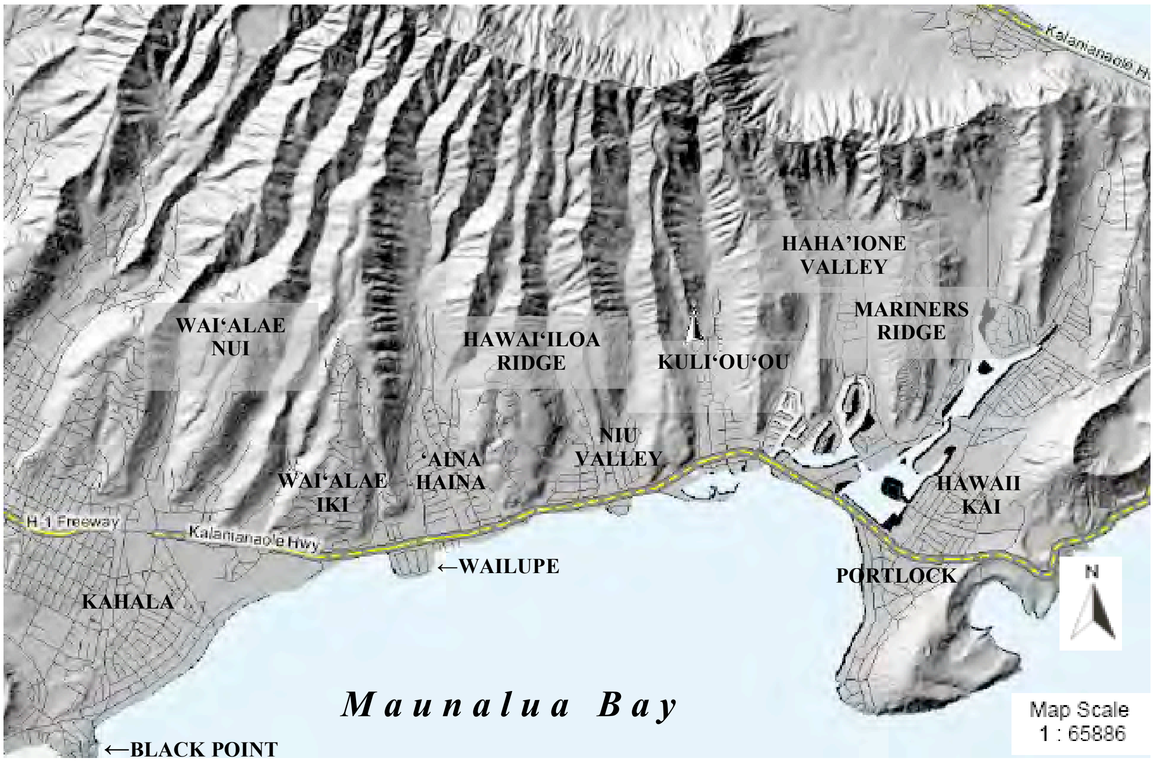

Figure 3. Residential neighborhoods within study area (CCHDPP 1999; PBIN2005).

Geology

One of the most isolated archipelagos in the world, the volcanic islands of the Hawaiian archipelago stretch approximately 3,800 miles across the Pacific Ocean (Clague 1998). The theory of the origin of the Hawaiian Islands involves a source of liquid basalt called the Hawaiian hotspot. According to this theory, volcanoes are created as the oceanic lithosphere of the Pacific Plate moves over an upwelling of liquid magma erupting from a fissure on the ocean floor called the Hawaiian hotspot. For over 30 million years, as the Pacific Plate has moved over this relatively stationary hotspot, a succession of shield volcanoes has been created. Each one builds up and eventually breaks the surface of the ocean and is carried on the Pacific Plate in a northwest direction (Clague 1998; Tarduno *et al.* 2003). The older islands to the west that have moved off the hotspot, are experiencing an erosional stage and tend to be smaller. As a result of erosion and subsidence, the Hawaiian Islands will all eventually become smaller islands, then atolls, and then seamounts as they subside beneath the ocean surface (Rowland and Garcia 2004).

Located at the eastern end of the island chain just west of Kaua‘i, O‘ahu is the third largest in the Hawaiian Islands. O‘ahu’s geologic landscape is dominated by two mountain ranges created by the two shield volcanoes that constructed the Island. The Ko‘olau Volcano, on the eastern side of the island is the younger of the two volcanoes, and surfaced between ~2.9 to 2.1 million years ago, but began building as a seamount ~4 million years ago (Rowland and Garcia 2004). The western Wai‘anae Volcano is ~3.9 to 2.5 million years old (Clague 1998; Rowland and Garcia 2004). The northeast-southeast position of the Ko‘olau mountain range is the result of the location of rift zones that constructed the range, and was reinforced by ancient avalanches on the northeast side of Ko‘olau (Rowland and Garcia 2004) (Figure 4).

Figure 4. O‘ahu mountain ranges (PBIN 2005).

Some of the Island’s most well known and significant geologic features are within the study area. In addition to the Ko‘olau range already discussed, whose southern extent constitutes the northern boundary of this study, *Kūpikipiki‘ō* Point near *Lē‘ahi* marks the southwestern boundary and *Kawaihoa* Point at Koko Head marks the southeastern boundaries of the study area.

Lēʻahi (better known as Diamond Head) and Koko Head are tuff cone structures composed mostly fine-ash rock, which were created as part of a rejuvenation stage of volcanic activity that began during the late Pleistocene, approximately 800,000 years ago (Rowland and Garcia 2004; Ziegler 2002). By the time of rejuvenation stage activity, the Koʻolau Volcano had experienced a long erosional stage and was at that time between ~2 and 2.7 million years old (Ziegler 2002; Culliney 2006). During the rejuvenation stage, magma eruptions from rifts on the flanks Koʻolau Volcano were centered primarily in southeastern Oʻahu, and were aptly named the Honolulu Volcanics (Clague 1998).

The symmetry of the *Lēʻahi* tuff cone indicates that it was created in a relatively short period of time (perhaps less than a month) and the coral found in the cone of *Lēʻahi* reveals that it was partially a hydromagmatic eruption (an eruption generated by interactions of lava and ground or surface water) (Beget 1993; Fletcher 2005). However, in the lowest layers of *Lēʻahi*'s ash, there is evidence that trees were present at the time of eruption, meaning that at least part of the eruption was on land (Rowland and Garcia 2004).

The results of later volcanic eruptions produced *Kūpikipikiʻō* Point and Kaimukī Shield (Figure 5). *Kūpikipikiʻō* Point was created about 410,000 years ago from a lava flow of alkalic basalt that poured out from a vent in the southeastern flank of *Lēʻahi* over Maunalua Bay's waters (USGS 1995; Hazlett and Hyndman 1996). The basalt of *Kūpikipikiʻō* is resistant to erosion, and is now covered by an affluent residential neighborhood called Black Point (Hazlett and Hyndman 1996). To the north of *Lēʻahi*, the gently sloping Kaimukī Shield is composed of smooth, glassy lava (*pāhoehoe*) and stony lava (*ʻaʻā*) resulting from land-based volcanic activity (Gill 1989; Rowland and Garcia 2004). Toward the eastern edge of the study area, the remnants of cinder cones at Koko Head, Koko Crater and Haunama Bay form the Koko Rift triplet—a distinct row of vents of the Honolulu Volcanic Series (Fletcher 2005).

Figure 5. Diagram of eastern Maunalua Bay's geologic features as observed looking west from the Hawaii Kai overlook (Gill 1989 in Rowland and Garcia 2004).

An important Hawaiian legend related to this area involved Pele, the goddess of fire, lightning, dance, volcanoes and violence. Legends of Pele describe a journey from Kauaʻi to Hawaiʻi. Each of the places where Pele stopped on her journey is also a place that modern geologists consider to be a site of modern volcanism (Westervelt 1963 in Rowland and Garcia 2004). According to legend, Kapo, Pele's sister, had a detachable vagina. In an effort to entice Kamapua'a, a pig-god who was trying to rape Pele, away from her sister, Kapo threw her vagina on Koko Head, and Kamapua'a followed it there (Takemoto *et al.* 1975; Gill 1989). The impression of the vagina left is visible on the northeast side of Koko Head. Originally named Kohelepelepe, Koko Crater's name was shortened during missionary times from its original name, which translates to labia minora in Hawaiian (Clark 2005).

Extending in a northeast-southeast position, the Koʻolau Range is perpendicular to the prevailing trade winds (Fletcher 2005). Its windward or northeastern facing slopes benefit from orographic rainfall carried by the trade winds, with the leeward, southeastern facing slope being drier, leading to more erosion of the windward side of the volcanic range than on the leeward side (Rowland and Garcia 2004). During trade wind weather, there is a consistent accumulation of rain bearing clouds near the Koʻolau summit on the windward side of the Koʻolau Range, contributing to the persistently green vegetation and increased erosion on the upper slopes of the Koʻolau. These cloud formations dissipate as they move to the southwest from the Koʻolau summit into the warmer, drier conditions of the study area (Gill 1989) (Figure 6).

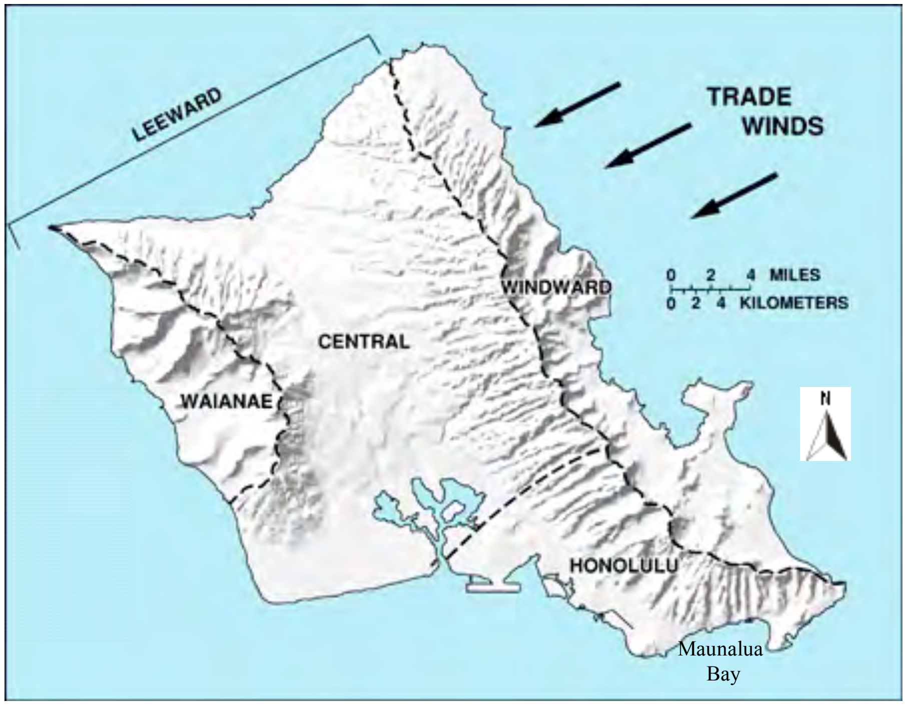

Figure 6. Windward and leeward areas and physiographic provinces of O‘ahu (Gronberg 2004).

The soils of the drier, leeward sides of the islands are less eroded from rainfall than the wetter, windward sides. In fact, the remains of the surface of the Ko‘olau shield is visible at the study site, with none of the surface features remaining on the wetter, windward side of the Ko’olau Range (Rowland and Garcia 2004). These shield remains are visible today as planezes (triangular-shaped, upland slopes of the original shield volcano surface), separated by eroded, amphitheater-headed valleys characteristic of the study site area (MacDonald, Peterson and Abbott 1993; Rowland and Garcia 2004) (Figures 7).

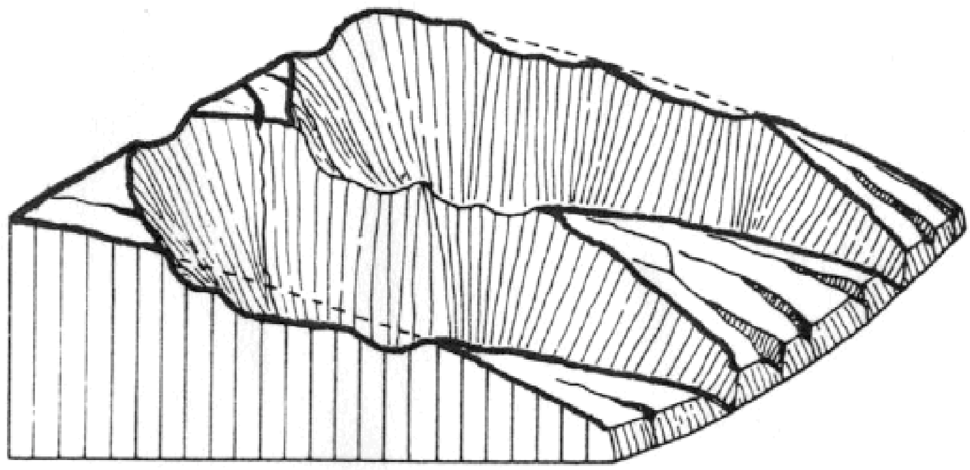

Figure 7. Diagram of triangular shaped plenezes separated by erosional valleys (MacDonald, Peterson and Abbott 1993, 218).

Wai‘alae Iki and Hawai‘iloa Ridge are excellent examples of plenezes (Figure 8). These triangular planezes have their bases towards the coastline with their apex pointed up the ridges. Their surface approximates the original slope of the surface of the Ko‘olau shield volcano, though their slopes have steepened considerably due to erosion (Gill 1989). While most of the sediment produced from erosion of this landscape has been deposited along the south coast of O‘ahu, the valley floors separating these plenezes are gradually filling with sediment (Rowland and Garcia 2004).

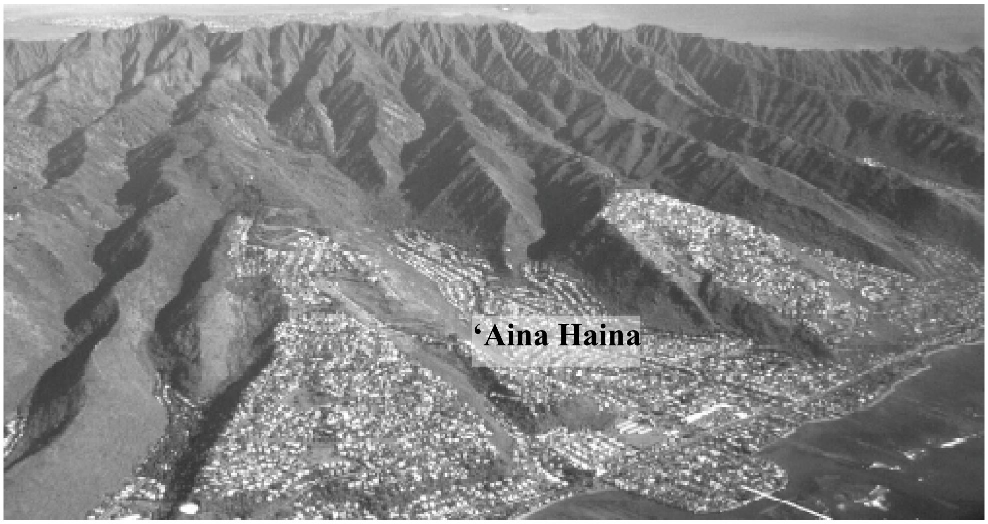

Figure 8. Separated by the valley community of ‘Aina Haina, Wai‘alae Iki (left) and Hawai‘iloa Ridge (right) are examples of residential neighborhoods built on plenezes (Rowland and Garcia 2004, 19).

Climate

Located in the middle of the earth’s largest ocean, the Hawaiian Archipelago has a climate influenced strongly by the Pacific Ocean. The Pacific is responsible for regulating the wind, temperature and precipitation on the Islands. The main Hawaiian Islands are between 19° and 22° north latitude in a belt of persistent trade winds originating from the North Pacific anticyclone, which brings warm moist air to the islands on currents of wind (Giambelluca and Schroeder 1998). A circulation pattern known as the Hadley cell is characterized by warm, rising air at the Equator, which moves polewards, and then sinks at or near 30° latitude. The inversion layer created by the sinking warm, moist air of the northern hemisphere Hadley cell is responsible for a phenomenon in Hawaii called the trade wind inversion, which occurs most frequently in the summer (Giambelluca and Schroeder 1998). The inversion layer prevents warm air from rising, and a cap under which clouds are less effective at producing rain (Giambelluca and Schroeder 1998).

The climate of the Hawaiian Islands is characterized by its persistent sunshine, moderate humidity and pleasant temperatures (Giambelluca and Schroeder 1998). There is some seasonal variability, and the early Hawaiians recognized a warm season (*kau*) from May through September, when the sun is located directly overhead during the day, and trade winds blow 80 to 95 percent of the time from the northeast (Giambelluca and Schroeder 1998). A cooler, wetter season known as *ho'oilo* occurs from October through April, when trade winds decrease 50 to 80 percent (U.S. Army Corps of Engineers 1994; Giambelluca and Schroeder 1998). The *ho'oilo* (winter) season is characterized by a lower sun, increased rainfall, and cooler temperatures (U.S. Army Corps of Engineers 1994; Giambelluca and Schroeder 1998).

Occasionally, *Kona* (leeward) weather visits the islands. The term "*Kona* weather" is used to describe an episode of light winds caused by a belt of high atmospheric pressure over the Islands, typically resulting in upslope winds during the day caused by solar heating, and downslope winds at night (Schroeder 1993). During some winter seasons, *Kona* storms are generated from low pressure systems (Giambelluca and Schroeder 1998). Winter *Kona* storms are variable, occurring as many as five times in one year, and absent other years (Giambelluca and Schroeder 1998). They can be fierce, bringing days of heavy rain and high winds, and are responsible for most of the flooding in the region (U.S. Army Corps of Engineers 1994; KCCAPDL 2004).

There is also great variability in climate over short distances in Hawaii. Rainfall in the study area ranges from as little as 20 inches per year at the most southern coastal areas such as *Kūpikipiki'ō* and Portlock, to as much as 160 inches per year at the higher elevations of the Ko'olau Range to the north (Figure 9) (U.S. Army Corps of Engineers 1994; Giambelluca and Schroeder 1998).

Temperatures are fairly stable in the study area. At a station in the 'Aina Haina Valley, nearly central in the study area, temperatures range from a maximum of 93° F (34°C) to a minimum of 56° F (13°C), with the February average of 72° F (22°C) and an August average of 79° F (26°C) (U.S. Army Corps of Engineers 1994; PBIN 2005).

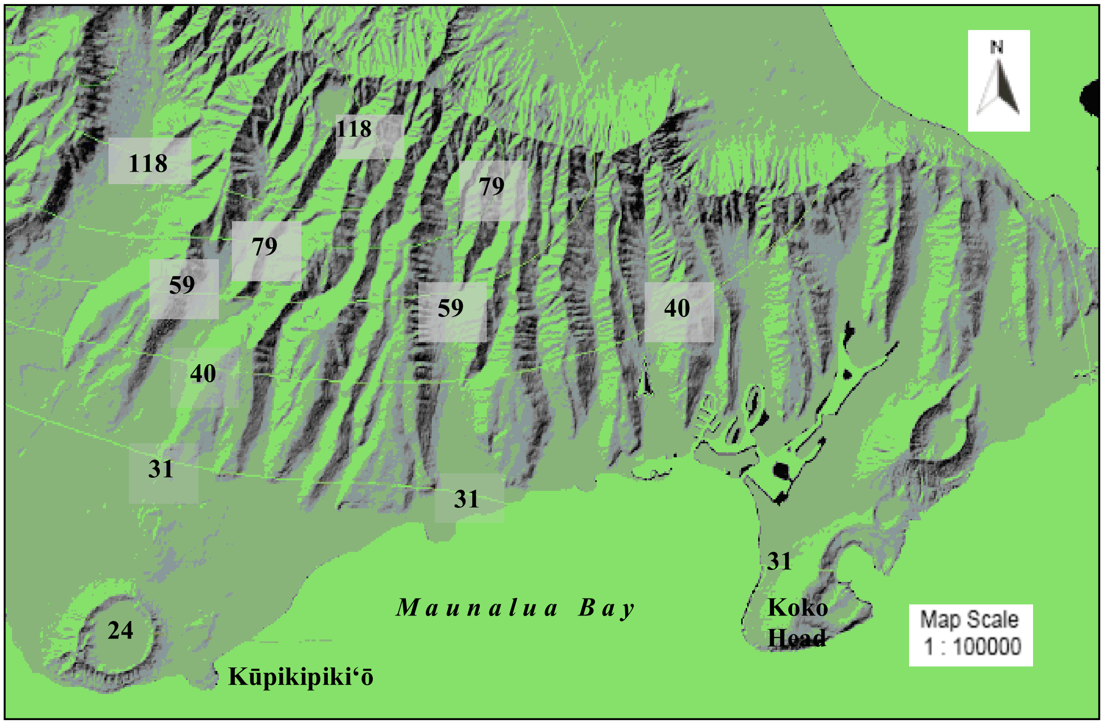

Figure 9. Annual median rainfall in inches (PBIN 2005).

Flora

The story of Hawaii's biota is common to both its plants and animals. Relatively few founder species arriving on the islands by chance via wind, avian or marine dispersal underwent considerable evolution, changing so much as to create new species recognized as endemic to Hawaii. Over the millions of years prior to human discovery, Hawaii's plants and animals were evolving into thousands of endemic species, frequently specialized to very specific habitat niches and not adapted to predation from continental organisms. The isolation of the Hawaiian Islands, their varied topography and climate extremes over short distances, all contribute to creating a degree of plant endemism greater than any place else in the world (Reichard 2006). For example, over 89 percent of Hawaii's total native plant species are endemic (Slikas 2003). This high level of endemism has also made Hawaii's vegetation vulnerable to disturbance from habitat loss and introduced species that have contributed to Hawaii's position as the U.S state with the most threatened plants (Reichard 2006). The species assemblage of Hawaii's vegetation from pre-discovery to the present has been a nearly complete transformation to non-native species in most areas (Culliney 2006).

Historic Flora

While little is known about the vegetation of primeval Hawaii, before Polynesian settlement, it is generally accepted that only fragments of vegetation associated with formerly widespread lowland forests, wetlands and estuaries still exist (Culliney 2006). Plant fossils are rare in Hawaii, and only a few have been discovered in pollen core samples, or preserved in the sediment layers found in caves, bogs or marshes (Culliney 2006). Palynology studies on Oʻahu have revealed that sometime between 36,000 years ago to 800 A.D., endemic fan palm trees called *loulu* (*Coniogramme pilosa*) comprised a high percentage of the vegetation in the leeward Ewa Plain in southwest Oʻahu (Culliney 2006; Starr and Starr 2007) (Figure 10). The plant with the second highest pollen abundance found in these core samples was unknown to researchers, until field collectors with the National Tropical Botanical Society (Ken Wood and Steve Perlman) discovered two surviving individuals on a small rock pinnacle offshore from Kahoʻolawe island in 1992 (Lorence and Wood 1994). The legume, a match with the pollen found in the core sample, was named *kanaloa* (*Kanaloa kahoolawensis*) (Hawaiian Ecosystems at Risk 2005). *Kanaloa* reaches to about three feet high and up to 6-7 feet in diameter and was likely the most common understory plant in Oʻahu's pre-discovery native lowland forest (Culliney 2006).

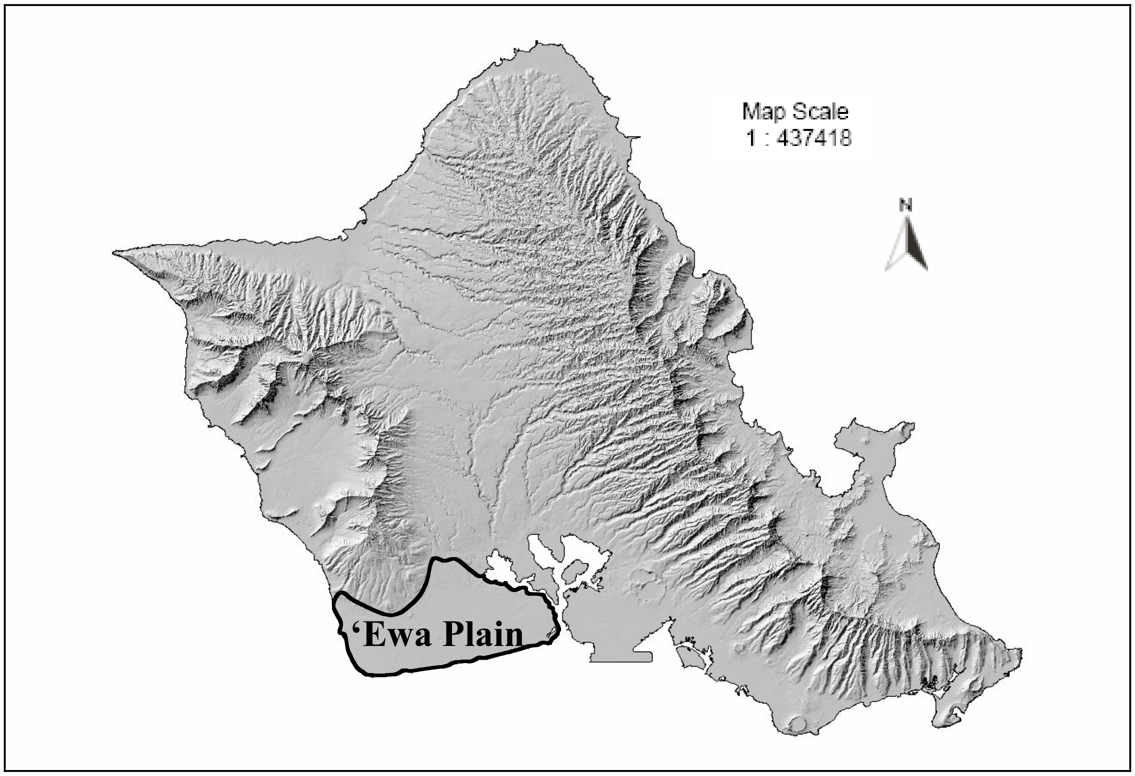

Figure 10. ‘Ewa Plain on O‘ahu (Starr and Starr 2007a).

In addition to loulu palm trees and kanaloa, the lowland coastal plains and forests of O‘ahu were vegetated with wiliwili (*Erythrina sandwicensis*),‘a‘ali‘i (*Dodonaea viscosa*), kōlea (*Myrsine lanaiensis*), hame (*Antidesma platyphyllum*), ōhi‘a (*Metrosideros polymorpha*), koa (*Acacia koa*), mēhamehame (*Flueggea neowawraea*) and other forest species found in the core samples taken from the Ewa Plains (Hawaiian Ecosystems at Risk 2005; Culliney 2006). Coring samples indicate that this assemblage of plant species persisted for thousands of years, until most species numbers declined precipitously, concomitantly with the first appearance of airborne charcoal particles around A.D. 800, perhaps associated with the activity of humans (Culliney 2006).

Flora Today

As mentioned, very little of the study area's landscape is dominated by the region's historic native vegetation (Figure 11). Where these areas do exist, they are located above about 1000 feet elevation up the slopes of the Koʻolau Range.

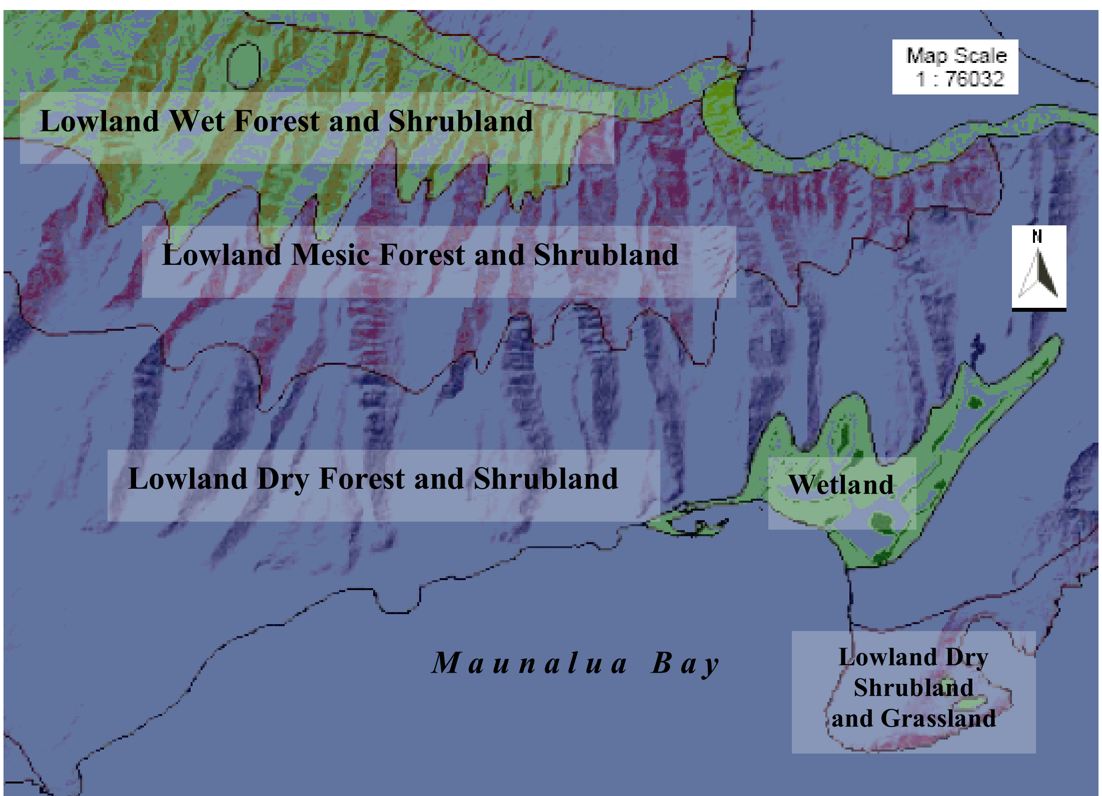

Figure 11. Native historic vegetation zones (PBIN 2005).

One of these zones is located where the housing development of Hawai'iloa Ridge ends near the center of the study area (Figure 12). Here, a 25-acre remnant of native lowland dry forest and shrubland, typically found on the lower leeward slopes of Hawaiian Islands, is a reminder that this type of ecosystem was once the most extensive zone on O'ahu (Pratt and Gon 1998).

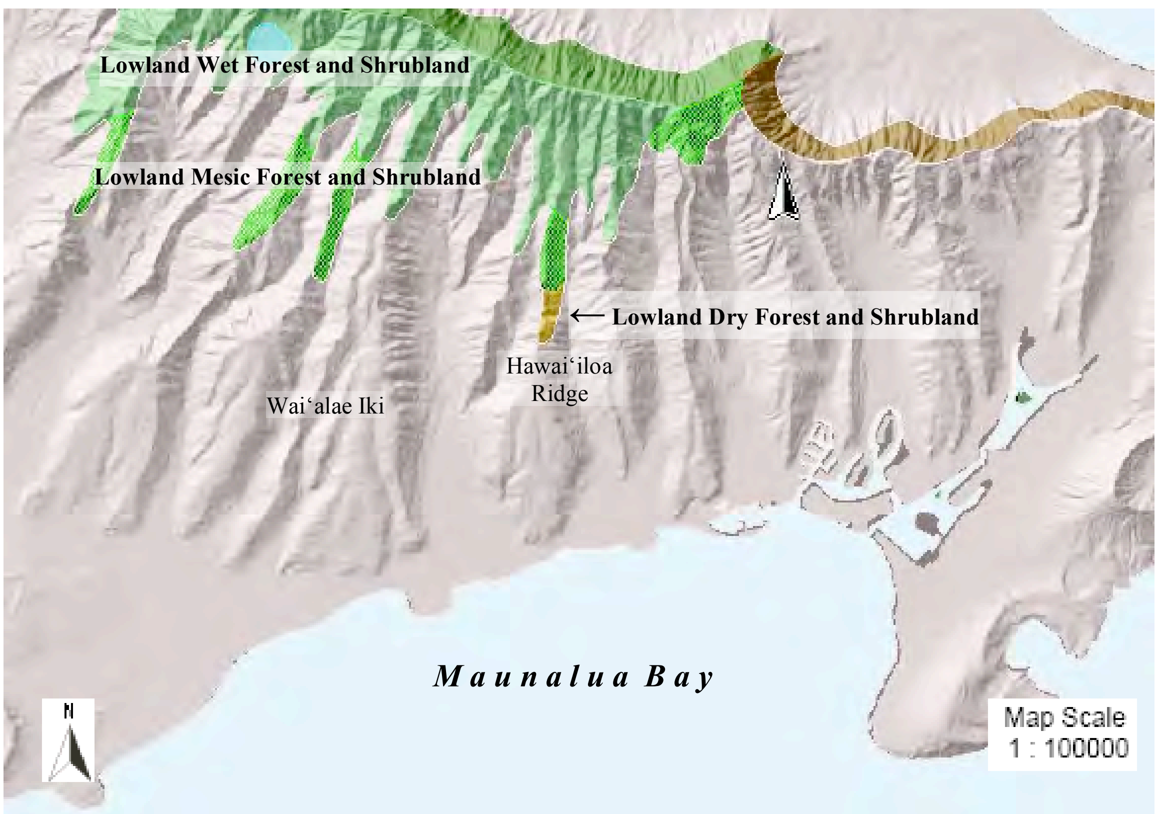

Figure 12. Remaining native historic vegetation (PBIN 2005).

The lowland dry forest and shrubland vegetation zone is characterized by warm to hot temperatures, with seasonal droughts and less weathered soils than wet forests. This zone once supported sandalwood (*Santalum*) species, which were depleted from these areas in the early 1800s for sale and trade. This zone supports native grasses such *pili* (*Heteropogon contortus*) and *kawelu* (*Eragrostis variabilis*). Native shrubs such as *aalii* (Dodonaea viscosa), *akia* (*Wikstroemia* species), *kooko'olau* (*Bidens* species), are often present in this zone, providing habitat to largely depleted or endangered populations of native insects and bird species. Forests of *ohi'a lehua* (*Metrosideros polymorpha*), *koa* (*Koa acacia*), *lama* (*Diopyros sandwicensis*), and *wiliwili* (*Erythrina sandwicensis*) occur here. Forested zones such as this one are considered a 'realm of the gods' by Hawaiians, and were harvested for their medicinal plants and hardwoods in Hawaiian times (Pratt and Gon 1998).

Approximately 250 acres of native lowland mesic forest and shrubland remain in the study area between 1,000 and 1,400 feet elevation. These zones are located in patches near the Ko'olau summit above the Kuli'ou'ou Valley, on the ridge directly upslope from the dry forest patch described above near Hawai'iloa Ridge, and on the ridges north of Wai'alae Iki and Wai'alae Nui. Vegetation is similar to the lowland dry forest and shrubland described above, with additional infrequent occurances of rare trees of such as *olopua* (*Nestegis sandwicensis*) or *halapepe* (*Pleomele* species), which appear in less disturbed sites such as gulches.

Above the mesic zone at about 1400 to 2500 feet elevation, wet forest occupies about 1000 acres of ridges and valleys near the Koʻolau summit from the head of Niu Valley westward through the study area (PBIN 2005). Closed canopy forests of *ohi'a lehua* (*Metrosideros polymorpha*) are sometimes found with codominant koa or olapa trees. Shrublands of plants such as *uluhe* (*Dicranopteris linearis*) and *akala* (*Rubus hawaiensis*) and various ferns have also been recorded in this zone. Rarely, bogs of mosses, sedges and grasses are found in this zone, providing habitat for Hawaii's native forest birds and more than 50 endangered plant species, including: *ha'iwale* (*Cyrtandra species*), endemic mints (*Phyllostegi species*), and ferns such as *kihi* (*Adenphorus periens*) (Pratt and Gon 1998).

As one drives along Kalanianaʻole Highway fronting the coastline of Manualua Bay and looks toward the island's interior, one can observe the steep heads of the valleys cut into the slopes of the Koʻolau Range. These slopes are vegetated by patches of closed-canopy forests of the native *ohi'a lehua* (*Metrosideros polymorpha*), occasionally codmoninated by *koa* (*Acacia koa*) or *olapa* (*Cheirodendron trigynum*) (Fosburg 1972; Pratt and Gon 1998). On the sides of the valleys, the lower slopes are covered with non-native *Kiawe* or algarroba (*Prosopis pallida*) forest.

Vegetation midway up the slopes of the valleys is characterized by non-native *koa haole* (*Leucaena leucocephala*) and Brazilian pepper tree or Chirstmasberry (*Schinus terebinthifolius*) (Fosberg 1972). Higher up the slopes and ridges non-native lantana

(*Lantana camara*) is present, with some grasses (Fosberg 1972). The slopes and spurs at the end of ridge are vegetated with grasses such as native pili along with other non-native grasses and weeds, non-native cactus (*Opuntia cochenillifera*), patches of lantana (*Lantana camara*) and various other shrubs (Fosberg 1972).

Non-Native Introductions

Archeological evidence indicates that an area a few miles north of the study site on the windward side of the Ko‘olau Range—the Bellows Dune site—was permanently settled by about A.D. 600 (Kirch 1998). It is believed that these settlers and the settlers that followed them, introduced approximately 27 plant species brought for cultivation; including taro, sweet potato, yam, banana, coconut, bamboo, and tumeric (Sohmer and Gustafson 1987). Domesticated animals, including swine, dogs and chickens were also introduced as early as A.D. 600 (Handy, Handy and Pukui 1972). In addition, Hawaiian residents used fire to purposefully alter vegetation cover (Kirch 1998).

Barrera’s (1979) archaeological research on charcoal and ash deposits in Kuli‘ou‘ou Valley led him to posit that swiddening is a likely explanation for the presence of charcoal in the valley floor. Dryland swidden agriculture involves burning large areas of virgin forest to accommodate the cultivation of plants (Barrera 1979). Barrera (1979) suggests that around the thirteenth century, rainfall supported dryland swidden farming activities in the Kuli‘ou‘ou Valley lowlands. Supporting this theory, a fourteenth century *heiau* (temple or shrine) is located just to the north of Kuapā Pond, and was likely associated with agricultural production, fishing and animal husbandry (James 1991). In the fifteenth century, evidence indicates that swidden agricultural activities expanded to the upland slopes, where agricultural terraces were irrigated by streams during months of low rainfall (Barrera 1979). This type of agriculture probably peaked on the main Hawaiian Islands around 1650, when Hawaiian population was at its highest point prior to European contact in 1778 (Kirch 1982 in Stone 1988). The Polynesians use of fire to alter lowland vegetation could be responsible for the extinction of one-third to one-half of the freshwater mollusks and bird species becoming extinct since humans arrived on the islands (Kirch 1982).

Thus the beginning of changes to Hawaiian vegetation was linked to the arrival of Polynesians. Followed later by free-roaming livestock and a vast array of introduced species associated with European contact, Hawaii's native vegetation has suffered many disturbances, from which most species never recovered (Culliney 2006).

While there have been many significant floral introductions to Hawaii since the first Polynesian settlers arrived, only a few that are particularly relevant to the study site are discussed in this section. In many areas of the study site, and particularly at the heads of Niu and Kuliʻouʻou Valleys, the *kukui* tree (*Aleurites moluccana*) can be observed**.** *Kukui* was brought to Hawaii by Polynesian settlers for its nut oil. Today, this species can be used as an indicator of how high in elevation exotic vegetation has encroached on native vegetation (Gill 1989). Areas at or below the elevation where *kukui* are seen are likely areas populated with exotic forest species, including ironwood trees (*Casuarina equisetifolia*) (Gill 1989).

One of the most prolific terrestrial floral introductions of the nineteenth century was algarroba (*Prosopis pallida*), or *kiawe* in Hawaiian. Wherever there are not residences, ornamental gardens or other development in the study area, *kiawe* dominates the lower parts and the flat lands in the region (Fosberg 1972). *Kiawe* was introduced to Hawaii when a single tree was planted in 1828 by Farther Bachelot—the first Catholic priest in Hawaii—at the corner of a church in Honolulu from a seed he brought with him from Paris (Skolmen 1990). By 1840, the progeny of that single tree were spreading to dry, leeward plains on all of the islands (Skolmen 1990). As of 1990, it is estimated that 150,000 acres of dry *kiawe* forests on the Hawaii Islands are descended from that single tree (Skolmen 1990).

Another major, intentional floral introduction to Hawaii is the mangrove. In an effort to control erosion on slopes, the American Sugar Company introduced the red mangrove (*Rhizophora mangle*) from Florida to Molokai in 1902. Seedlings of these mangroves were transported to O‘ahu, where they were planted and developed into extensive stands in canals deltas such as Pearl Harbor, which had a 40-acre stand between 1951 and 1975 (Sauer 1988). In 1922, four additional mangrove species were introduced to O‘ahu by Hawaiian Sugar Planers Association (Sauer 1988). Presumably, this was done for the purpose of sediment retention. These Philippine species of mangrove seedlings, numbering 14,000, included: *Rhizophora mucronata*, *Bruguiera gymnorrhiza*, *Burguiera parvilflora*, and *Ceriops tagal* and were planted in O‘ahu's marshes, including salt marshes in Kuapā Pond and along Maunalua Bay (Englund *et al.* 2000a). While none of these Phillipine species thrived to the degree that red mangrove has, black mangrove (*Bruguiera gymnorrhiza*) has become naturalized on several sites on O‘ahu's coast including the study area, and produces flowers that are popular in lei-making (Sauer 1988). *Rhizophora mucronata* and *Burguiera parvilflora* survived for only a few years, and *Ceriops tagal* died soon after planting (Sauer 1988).

While introduced mangroves provide sediment retention and flowers for lei-making, there are many negative ecological effects attributed to mangrove species in Hawaii. For example, mangroves contribute to the degradation of habitats occupied by endangered bird species such as the Hawaiian stilt (*Himantopus mexicanus knudseni*), and the native fish species that live in anchialine pools. They have also covered over some native Hawaiian archaeological sites (Allen 1998).

Fauna

Terrestrial Fauna

Insects provide a remarkable example of adaptive radiation in Hawaii. Adaptive radiation is an evolutionary process where individuals from a single species evolve to occupy a variety of habitats and to utilize differing resources. A population undergoing adaptive radiation ultimately distinguishes itself as a different species from the founder (MacDonald 2003).

Having evolved from an estimated 400 to 500 founders, Hawaii's approximately 10,000 species of insects are 95 percent endemic (Howarth, Montgomery and Mull 1998). Founder insects have been arriving at the Hawaiian Islands for over 30 million years from all directions. These founders were dispersed to Hawaii by storms, jet streams, on birds, rafts of floating debris, or under the power by their own flight. Some of the most impressive examples of this adaptive evolution are provided by the Drosphilidae family (fruit flies). Approximately 1,000 species are believed to be related to one or two founding Drosophilidae females (Culliney 2006).

In addition to insects, another example of the adaptive radiation of Hawaiian species are O‘ahu's endemic tree snails. These achatinellids evolved to feed only on fungi growing on tree leaves, and in more abundant historical numbers, likely played an important ecological role in Hawaii's forest ecosystem. Originally, 35 to 40 species lived on the mountain ranges of O'ahu. Today, only one species, *Achatinella fuscobasis* is known to reside near the study area, near the peak of the southern Ko'olau Range (Hadfield 1998).

While the evolutionary histories of Hawaii's invertebrate populations are impressive indeed, a discussion of the natural history of these species is beyond the scope of this study, which will focus primarily on Hawaii's birds. The choice to include birds in this study was based largely on their visibility within the inhabited regions of the study area. Additionally, the presence or absence of certain birds, such as the Hawaiian stilt, are a concern to the community because of their endangered status The presence of these birds can bolster the conservation actions of an informed community, as exemplified by the community of Hawaii Kai mobilizing to protect Hawaiian stilt nesting habitat in the region, which has been described as a "community issue" by a local resident (Roig 2005).

Few terrestrial vertebrates have succeeded in colonizing the Hawaiian Islands. Thus, few examples of pre-discovery Hawaiian terrestrial fauna exist. These include two bat species (one now extinct), 80 land bird species, 24 pelagic bird species, and 34 species of waterbirds (Conant 1998; Slikas 2003). Fossil and other historical records indicate that bird species have produced an abundant variety of species through the process of adaptive radiation. For example, the Hawaiian finch *Drepanidini* tribe, estimated at 27 species at the time of European contact, also has fossil records indicating the existence of another 15 species extant prior to that time (Slikas 2003). Evidence indicates that all of these finch species are descendents from common ancestors, that probably colonized the Hawaiian Island from North America between seven and eight million years ago (Johnson, Marten and Ralph 1989).

Before human arrival in Hawaii, it is estimated that over 140 species of native birds inhabited the islands, many of them endemic (Conant 1998). Today, over half of Hawaii's original avifauna is extinct, and while less than three of Hawaii's 24 species of seabirds species have become extinct, their colonies are small remnants of the once large populations that were found on the main Hawaiian Islands historically (Conant 1998).

Descended from about 20 founders, 66 of Hawaii's original 113 endemic birds species are still present (Conant 1998). Over 30 of these extant birds are endangered, with twelve perilously close to extinction, and six that have not been seen in the wild in many years (Conant 1998).

Many species of birds that have become extinct since humans colonized the Islands have been discovered in recent paleontologic excavations near the Maunalua Bay region in southern O‘ahu (Conant 1998). Excavations revealing the fossilized remains of extinct birds were conducted at three sites: Barbers Point on the Ewa Plain in leeward, southwest O‘ahu; Uluhau Head on Makupu, in southcentral windward O‘ahu; and a cave in the valley of Kuli‘ou‘ou, within the study area (Figure 13). At Barbers Point, excavations from sinkholes in an elevated limestone reef plain revealed evidence of

Polynesian occupation with the fossilized remains of 23 recently uncovered, extinct land birds (Olson and James 1982; James and Olson 1991; Olson and James 1991).

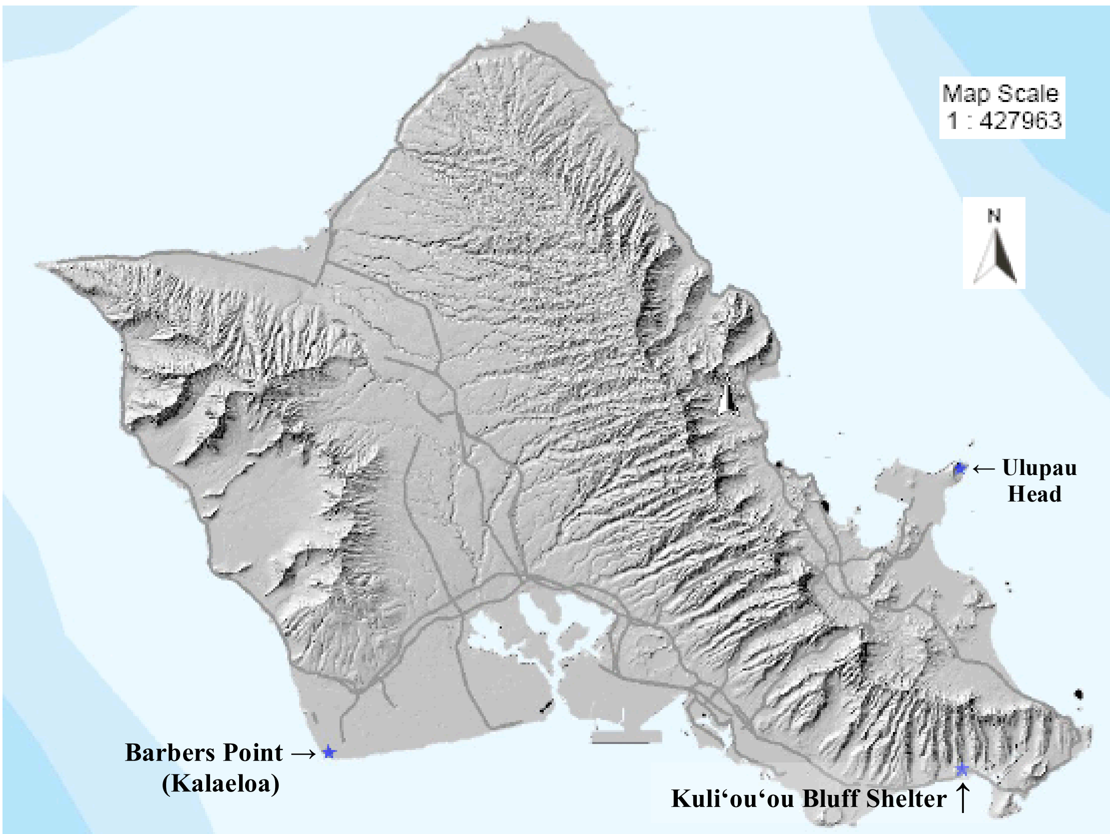

Figure 13. Excavation Sites (Sterling and Summers 1978; PBIN 2005).

Archaeological evidence indicates that the bones and skeletons of extinct birds found at the Barbers Point excavation site were deposited after the first Polynesian migration between ~300 and 600 A.D., and have been radiocarbon dated to sometime in the latter half of the Holocene (Olson and James 1982). This finding could indicate that native birds were a source of food for the first migration of Polynesians. Bird fossils were found in greatest concentration in sediment containing remains associated with human presence, such as charcoal in a hearth, chicken bones, and the remains of two species introduced by Polynesian colonizers: Pacific rats (*Rattus exulans*) and land snails (*Lamellaxis*) (Olson and James 1982). Bird fossils excavated from sinkholes at Barbers Point include birds that are now extirpated from O‘ahu: the palila (*Loxioides bailleui*), the dark-rumped petrel (*Pterodroma phaeopygia sanwichensis*), and the Bonin petrel (*Pterodroma hypoleuca*) (Olson and James 1982; Hawaii Audubon Society 1989). Extinct species of harrier (*Circus dossenus*), and goose (*Branta spp.*, *aff. B. hylobadistes*) were also found at the site with an extinct species of eagle (*Haliaeetus sp.*) (James and Olson 1991; Olson and James 1991).

Sediment within an enclosed cavern filled with freshwater was also discovered and excavated at Barbers Point. The bird fossils found there are likely between 120,000 and 800,000 years old, and include an extinct species of honeyeater, likely endemic to O‘ahu (*Chaetoptila aff. angustipluma*), two species of extinct, large crows (*Corvus impluviatis* and *Corvus viriosi*) and an extinct seabird descended from petrels (*Pterodroma jugabilis*) (Olson and James 1982; James and Olson 1991; Olson and James 1991).

Three extinct bird species were uncovered during excavations from the limestone sinkholes at Barbers Point and from the Uluau crater: a species from the moa-nalo group of herbivorous ducks (*Thambetochen xanion*); a small, flightless rail (*Porzana ziegleri*); and a strigid owl species (*Grallistrix orion*) (James and Olson 1991; Olson and James 1991).

At all three O'ahu sites, Barbers Point, Kuli'ou'ou Shelter, and in the crater of Ulupau Head, fossil remains of an extinct large, flightless rail (*Porzana ralphorum*) were found (James 1982; James 1987; Olson and James 1991). Four extinct Hawaiian finches (from the *Drepanidini* tribe, previously called "Hawaiian Honeycreepers") were also uncovered (*Telespiza persecutrix, Xestospiza fastigaialis, Chloridops wahi,* and *Chloridops regiskongi*) (James and Olson 1991).

While it is clear that many of the extinct birds found in these archaeological digs were alive when Polynesians settled the islands, but not at the time of European contact, identifying precise causes of extinction is difficult (Conant 1998). Conversion of habitat for human use, predation by rats and other predators probably took a toll, but evidence linking bird extinction caused by human predation is not conclusive, and could be attributed to a combination of causes including predation by introduced animals, or habitat destruction by humans or introduced animals (Olson and James 1982; Conant 1998). Ground-nesting land bird species, burrowing seabirds and flightless bird species could have succumbed to predation by humans, and human introduced rats, dogs and pigs

(Olson and James 1982). Birds may also have succumbed to prehistoric disease (Olson and James 1991). Rather than falling victim to predation, passerine birds (the order of perching birds) are more likely to have succumbed due to the effects of human-induced habitat destruction, particularly the clearing of lowland forests for agriculture (Olson and James 1982). While most of the extant endemic Hawaiian forest birds are now only found above 2,000 feet in elevation in the remaining native wet montane forests, fossil records indicate that they were also once present in drier, sea-level regions (Olson and James 1982). Species of birds adapted to the distinct mix of endemic plants that characterized the lowland regions, and unable to survive in the wet montane forest, are likely to have become extinct (Olson and James 1982).

Archaeological studies indicate that by A.D. 600, about 80 percent of vegetation below 1,500 feet elevation had been transformed or destroyed (Kirch 1982 in Athens *et al.* 2002). Athens *et al.* (2002) suggest that this transformation may have taken place after an initial period of human settlement, but before widespread human dispersal and clearing of land for agriculture, and thus could be attributed to the activities of rats brought by the first Polynesian colonists. Without predators, other than potentially the Hawaiian hawk (*Buteo solitarius*) (now extirpated from the Island of O‘ahu), or an extinct eagle, the Polynesian rat, (*Rattus exulan*s) could have hindered forest regeneration by eating seeds, fruit, and invertebrates important to plant pollination and nutrient cycling, and destroying existing plants by consuming new leaf production (Athens *et al.*

2002). The persistence of native vegetation today above 4,921 feet, beyond the elevational range of rats, supports this hypothesis (Athens *et al.* 2002).

Many species of birds succumbed due to the changes brought about after European contact in 1778 (Conant 1998). Between 1778 and 1995, at least 24 endemic Hawaiian bird species became extinct (Conant 1998). More recently, the introduction of alien species has added to predation and habitat destruction as a cause of extinction for native Hawaiian birds (Conant 1998). Since European contact, bird habitat has been lost to invasive species of plants, plantation agriculture, cattle grazing and residential and commercial development. Competition for food with rats, yellowjackets and introduced birds such as cattle egrets and barn owls, have all take a toll on native Hawaiian bird populations (Conant 1998).

About 60 of the 170 birds introduced to Hawaii have become naturalized (Conant 1998). These introduced species now comprise the vast majority of bird life in the lowlands of Hawaii and the study area (Conant 1998). Some of the most commonly seen alien birds include the myna (brought to Hawaii in 1865 to control insect pests), and a number of songbirds (brought in the 1920s and 1930s) imported to replace the native species that had moved up to higher elevations to escape mosquitoes. Introduced alien birds species include: white-rumped shama, northern cardinal, red-crested cardinal, Japanese white-eye, Java sparrow and others (Conant 1998). Game birds such as turkeys, doves, pheasants, quail and francolins were introduced purposefully, while accidentally escaped captive parrots, African weaver finches, cardueline finches and bulbuls have established unintentional populations in Hawaii (Conant 1998).

Finally, introduced diseases such as avian malaria and avian pox have taken a toll on populations of O‘ahu’s extant native forest birds with documented presence in the study area (Conant 1998). These native birds include: O‘ahu *`amakihi* (*Hemignathus virens*), the less common O‘ahu *`apapane* (*Himatione sanguinea*), subpopulations of the endangered O‘ahu ` *elepaio* (*Chasiempis sandwichensis ibidis*), and *`i`iwi* (*Vestiaria coccinea*). Reliable observations by scientists have not been recorded for the *`o`o* (*Psittirostra psittacea*) and the O‘ahu creeper or *`alauahio* (*Paroreomyza maculata*) in at least ten years on O‘ahu. These species may already be extinct (Shallenberger 1977; Jacobi and Atkinson 1995; Woodworth *et al.* 2005; USFWS 2006).

The revised federal Hawaiian Forest Bird Recovery Plan includes two federally listed endangered endemic species with habitat in the study area: the *`elepaio* and the O‘ahu *`alauahio* (*Paroreomyza maculata*) (USFWS 2006). *`Elepaio* is the only species on O`ahu for which recovery efforts beyond continued surveying are planned. Nevertheless, the efforts to investigate disease control, and programs to actively control rodents who prey on *`elepaio* eggs, particularly black rats, will potentially help the *`alauahio* population recover also, if indeed *`alauahio* are in the study area (they have not been observed there in over 20 years) (USFWS 2006). The boundaries of the recovery areas include forested areas in upper elevations, with the exception of the lower Wailupe

Valley (Figure 14). Wailupe Valley is zoned for urban use, has not been fully developed yet, and thus contains suitable forest currently occupied by O`ahu *`elepaio* (NMFS 2001).

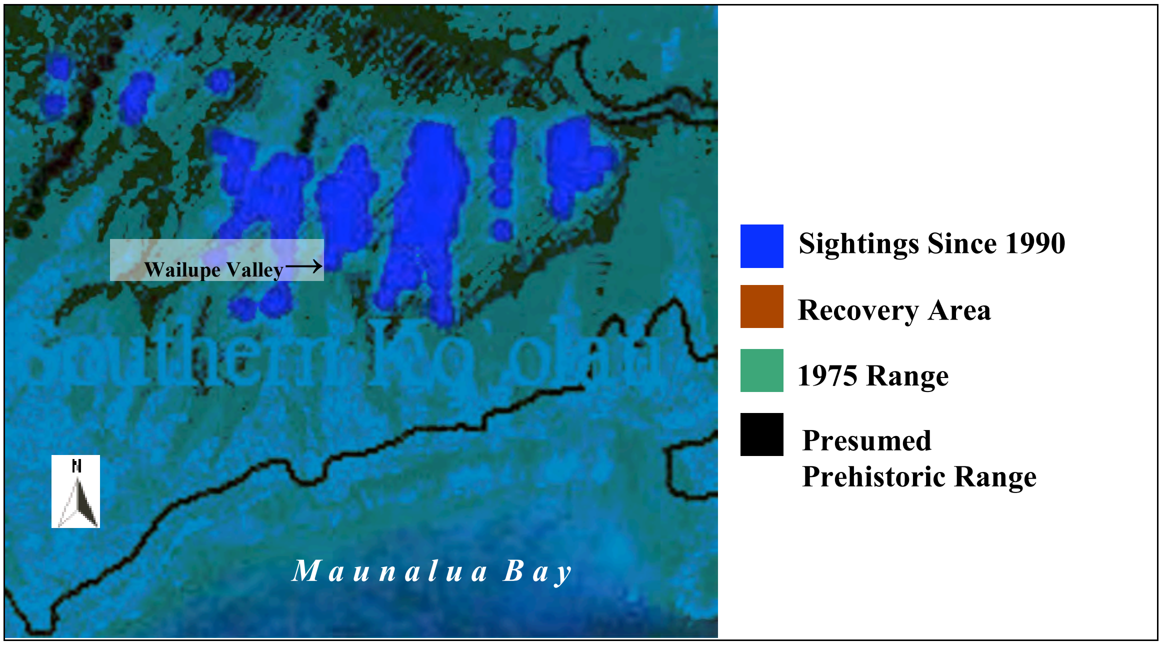

Figure 14. `Elepaio sightings, recovery areas and historic distribution (USFWS 2006).

The current distribution of *`elepaio* in the southern Ko‘olau Mountains represents a remnant of what was once a single, large, continuous population (EPA 2001). Currently, *`elepaio* occupy only four percent of their presumed prehistoric range, with 75 percent of this loss of range occurring in the past 25 years (EPA 2001). *`Elepaio* are found in areas vegetated by mixed-species wet, mesic, dry forest, shrubland and wet cliff plant communities (EPA 2001). While no *`elepaio* have been observed in developed areas, `*elepaio* are adaptable and are frequently observed in riparian areas in valleys dominated by alien forest plants (EPA 2001). `*Elepaio* have not recently been observed in several areas on O`ahu that contain suitable forest habitat, indicating that habitat loss is not the only threat to `*elepaio* populations (EPA 2001). Mosquito-borne diseases and predation by rats may be important contributing factors responsible for the decline of O‘ahu `*elepaio* populations (EPA 2001).

Due to its endangered and endemic status, recovery of endangered `*elepaio* populations is a stated goal of state wildlife managers in O‘ahu. In addition to their biological importance as an endemic species, `*elepaio* are also culturally significant (DLNR 2007). Canoe makers in Hawaiian times considered `*elepaio* their guardian spirits, partly because observing the birds' frequent use of a koa tree would indicate likely insect infestation, thereby identifying trees that would not provide good canoe timber (DLNR 2007).

Today, a number of bird species occupy the lowlands at the study site. In 2000, near the Wailupe Peninsula, individuals of migratory shorebirds observed included: Pacific golden plover (*Pluvialis fulva*), wandering tattler (*Heteroscelus incanum*), ruddy turnstone (*Arenaria interpres*), long billed dowitcher (*Limnodromus scolopaceus*), and sanderling (*Calidris alba*) (PBIN 2005). That same year, the species described above were also observed near the Paikō Lagoon Wildlife Sanctuary (Figure 15), in addition to the endangered, endemic native Hawaiian stilt (*Himantopus mexicanus knudeseni*), native black-crowned night heron (*Nycticorax nycticorax hoactli*), and migratory birds such as the green winged teal (*Anas crecca*) and the native northern pintail (*Anas acuta*), northern shoveler (*Anas clypeata*), and lesser scaup (*Aythya affinus*) were observed there. Present on O‘ahu but notably absent from these surveys are two endangered, wetland bird species: the endemic, wetland dwelling Hawaiian duck, or *koloa* (*Anas wyvilliana*), and the native Hawaiian moorhen or *‘alae ‘ula* (*Gallinula chlorpus sandwicensis*) (CWCS 2005; PBIN 2005).

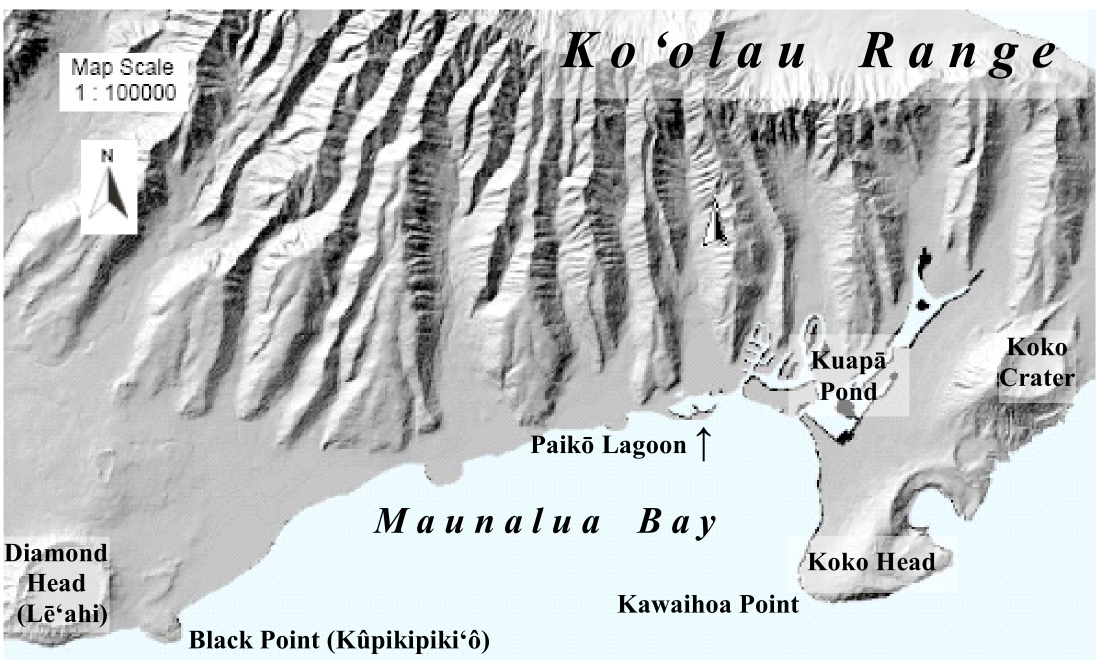

Figure 15. Paikō Lagoon and the study area (PBIN 2005).

While modifications to Paikō Lagoon may have reduced the number of Hawaiian stilts and other waterbirds frequenting the region, a few species have been spotted on an island within the Hawaii Kai Marina (formerly known as Kuapā Pond). In 2006, the Hawaii Kai Marina Association request for a 10-year permit from the U.S. Army Corps of Engineers to dump dredged material from the marina on Rim Island 2 in the former Kuapā Pond, and other places, was met with protest by community members who have observed nesting pairs of endangered Hawaiian stilts on the 3.2 acre Rim Island 2 (Roig 2005) (Figure 16).

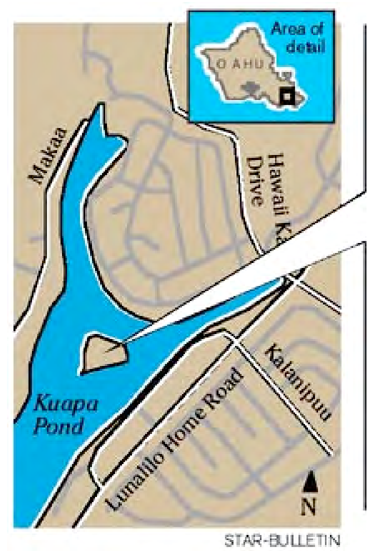

Figure 15. Rim Island 2 (Leone 2006).

Formerly, known as Kuapā Pond, the Hawaii Kai Marina was once one of the largest wetlands on O‘ahu and home to the largest stilt colony on O‘ahu (Leone 2006). Before conversion to a marine embayment, the vegetation of the pond was dominated by saltwort (*Batis maritime*) and provided an important habitat for water and shore birds (Fosberg 1972). The wetlands were lost when the Marina was dredged 40 years ago to create a private boat harbor (Leone 2006). Dredged material deposited over the years in the pond has created two artificial islands: Rim Island 1 and Rim Island 2 (Leone 2006). In addition to the foraging and nesting Hawaiian stilts, individuals of the native and endangered species of Hawaiian coot (*Fulica Americana alai*) have also been observed foraging on Rim Island 2 (Roig 2005).

Once common to all the main Hawaiian Islands, two of Hawaii's three native seabirds no longer breed on O'ahu: the endangered, endemic Hawaiian petrel (*Pterodroma sandwichensis*) and the native, more abundant Hawaiian black noddy (*Anous minutus*). The third seabird, Newell's shearwater (*Puffins auricularis newelli*) potentially breeds on O'ahu in remote, densely vegetated areas above 500 feet elevation, or on cliffs. Finally, the endemic, endangered Hawaiian owl (*Asio flammeus sandwichensis*) is thought to be extant on O'ahu and declining in numbers, although the location of the population is unknown (CWCS 2005; PBIN 2005).

Freshwater Fauna

Due to its geographic isolation, few freshwater species were able to colonize Hawaii's freshwater and estuarine environments (Englund *et al.* 2000). Without direct introduction by humans, the only way for freshwater species to arrive in Hawaii was to survive a long planktonic life during their transport to the Islands by ocean currents (Englund *et al.* 2000). This has resulted in relatively low natural diversity of native freshwater fish species in Hawaii. Hawaii's five native fish species include three species of endemic gobies: *o'opu hi'ukole* or *'o'opu alamo'o* (*Lentipes concolor*), *'o'opu nopili* (*Sicyopterus stimpsoni*) and *'o'opu naniha* (*Stenogobius hawaiiensis*); the native goby *'o'opu nakea* (*Awaous guamensis*); and one endemic species of eleotrid; *'o'opu akupa* or *'o'opu okuhe* (*Eleotris sandwicensis*) (Higashi 1999). These native fishes all achieve large enough size to be considered sport fish, and all but *S. hawaiiensis* have historically been considered prime food fish by many Hawaiians (Titcomb 1972 in Enlglund *et al.* 2000).

At one time, the fauna supported in Hawaii's streams were highly productive, and provided an important food source for early Polynesian inhabitants (Titcomb 1972 in Englund *et al.* 2000). Estuarine habitats in Hawaii are important at various life stages for several species of culturally significant food fish, such as striped mullet or *'ama'ama* (*Mugil cephalus*), *aholehole* (*Kuhlia sandvicensis*), some species of freshwater gobies (particularly *Awaous guamensis*), and crustaceans such as *opae 'oeha'a* (*Macrobrachium grandimanus*) '*opae kala'ole or 'opae kuahiwi* (*Atyoida bisulcata*) (Englund *et al.* 2000). While fishing for these food fish occurs on some Hawaiian Islands in freshwater and estuarine environments, this type of fishing is virtually non-existent on O'ahu (Englund *et al.* 2000). Near the study area and throughout O'ahu, urbanization has greatly impacted estuarine environments with modifications such as dredging, channelization, non-point source pollution runoff and non-native species introductions (Englund *et al.* 2000). Over the past 100 years, these influences have negatively impacted the ecology of lower extents of streams, wetlands, and estuaries more than they have impacted adjacent marine habitats (Englund *et al.* 2000).

The first comprehensive survey of freshwater and estuarine fauna in the study area was conducted by the Bishop Museum in 1998 and 1999 (Enlglund *et al.* 2000).

This study described the study area as containing ecologically degraded freshwater and estuarine environments that have been negatively impacted by a combination of habitat alteration and the presence of non-native species (Englund *et al.* 2000). The lack of freshwater mollusks, damselflies and native fish in the region support the contention that the region has been biologically degraded, though no comparisons can be made to other regions in Hawaii due to the non-existence of other comparable studies of estuarine systems (Englund *et al.* 2000).

Four perennial streams in the study area originate in the upper elevations of the Ko′olau, and flow down valleys to Maunalua Bay. These streams include: Kuliʻouʻou, Wailupe, Niu and Waiʻalae Nui (Hawaii Stream Assessment 1990) (Figure 17). Kuliʻouʻou, Niu and Wailupe streams are all partially lined with retaining walls, and Wailupe stream is partially channelized at its mouth (Hawaii Stream Assessment 1990). Of these four streams, only Kuliʻouʻou drains into what has been categorized as an estuary, which is Paikō Lagoon (Hawaii Stream Assessment 1990).

Englund *et al.*'s (2000) study revealed that Waiʻalae Nui and Wailupe streams had more native aquatic fauna species than introduced, unknown, or new species. Kuliʻouʻou had more introduced, new, or unknown aquatic fauna than native fauna, and Waiʻalae Nui had nearly equal amounts of native fauna and introduced and unknown species combined. For the marine embayments of Paikō and Kuapā, native species were more numerous than introduced, new or unknown species (Englund *et al.* 2000).

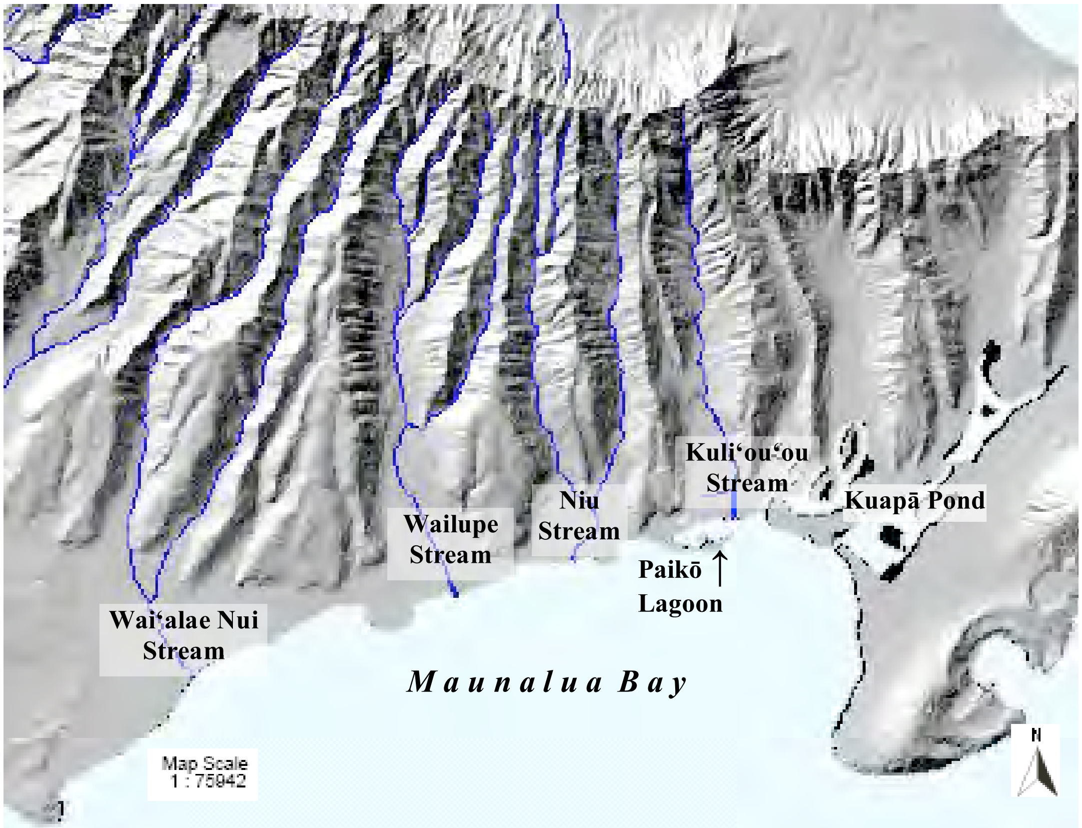

Figure 17. Perennial streams and their tributaries (PBIN 2006).

Generally, more native species were sampled at stations characterized as marine environments (Englund *et al*. 2000).

While present in other areas on O‘ahu, native gobies were not observed at any sampling stations in the study area in Englund *et al.*'s (2000) study. Individuals of *E. sandwicensis*, however, were recorded at the sampling station at Wailupe Stream (Englund *et al.* 2000). Striped mullet and *aholehole* were observed at Paikō Lagoon, Wai‘alae Nui, and Wailupe Stream, with *aholehole* also present at Niu Stream.

The endemic shrimp *öpae kala'ole* or *'opae kuahiwi* (*Atyoida bisulcata*), once a favorite food of native Hawaiians, was not sampled at any of the sites in Englund *et al.*'s (2000) study. The indigenous Hawaiian ghost crab (*Ocypode ceratophthalama*) was only observed at Niu Stream, and individuals of an indigenous shrimp (*Penaeus marginatus*) were only present at Wai'alae Nui stream (Englund *et al.* 2000). An endemic prawn species, *opae 'oeha'a* (*Macrobrachium grandimanus*) was common in O'ahu, but not found at the study area (Englund *et al.* 2000). Indigenous crab species (*Metopograpsus messor*) and (*Calappa hepatica*) were observed at Paikō Lagoon, and individuals of indigenous crab species (*Portunus sanguinolentus*) were observed at the Waialenui Stream and the Paikō Lagoon sampling stations Englund *et al.* 2000).

Of all the streams on Hawaii's Islands, O'ahu's streams are probably the most affected by human-induced alterations. Introduced species, channelization and lining, and non-point source pollution, all contribute to loss of pools and riffles in streams, changes in stream temperature, flow, chemistry, water quality, and resource availability (Hawaii Stream Assessment 1990; Englund *et al.* 2000a). The affects of these alternations include the conversion of suitable habitat to unsuitable habitat for culturally important food fish. While some important food species remain, the productivity of these streams and estuaries has been compromised. For example, prior to the major disturbances mentioned above, great harvests of post-larval gobies called *hinana* were seasonally collected by Hawaiians using woven baskets and nets as the gobies ascended streams (Titcomb 1972).

The history of the land in the study area begins with the Ko‘olau Volcano, which began erupting from the sea floor ~4 million years ago, and surfaced between ~2.9 to 2.1 million years ago (Rowland and Garcia 2004). Successive erosional periods and stages of rejuvenated volcanic activity helped to shape the topography of the study area. The isolation of the Hawaiian Islands and their varied topography and climate extremes over short distances, facilitated adaptive radiation and created a high degree of endemism for the plant and animal species that established populations there (Reichard 2006).

Human induced changes to the Hawaiian landscape began with the first Polynesian settlers, and were significant in many areas. The effects on the land associated with human colonization contributed to the extinction of between 30 and 50 percent of endemic bird and mollusk species in Hawaii (Kirch 1982). The transformation or destruction of as much as 80 percent of native vegetation below 1,500 feet in elevation by A.D. 600 has been associated with the impact of human arrival and activity in Hawaii (Culliney 2006; Kirch 1982 in Athens *et al.* 2002). Thus, by the time Europeans arrived in Hawaii, the landscape had already been affected by centuries of modification, and in some cases, degradation (Kirch 1982).

The changes to Hawaii’s landscape that began with the arrival of Polynesians was followed by more landscape changes associated with the impacts that followed European contact. In addition to species introductions and development that have altered the terrestrial environment, urbanization in the last century has greatly affected estuarine environments with modifications such as dredging in aquatic areas, stream channelization, and non-point source pollution (Englund *et al.* 2000). Today, the freshwater and estuarine habitats in the study area are ecologically degraded as a result of habitat alteration and the presence of non-native species (Englund *et al.* 2000).

Despite the vast environmental modifications caused by humans, there are sites is the study area where remnants of native lowland dry, mesic and wet forest and shrubland zones persist, and where native aquatic fauna species are more numerous than introduced species (Englund *et al.* 2000). Individuals of the endemic, endangered O‘ahu `*elepaio* have been observed in the higher elevations of the study area. In addition, individuals of the native Hawaiian stilt and the native, endangered Hawaiian coot have been observed on human-made wetlands in the study area. The presence of these native species in the study area, despite the very high degree of landscape modification, is indicative of their resiliency and the potential of human intervention to help native species recover from threatened or endangered status.

III. THE BAY

The Study Site

Maunalua Bay is one of Hawaii's most shallow and broad fringing reefs (Fletcher 2005). Looking inland from the coast, commercial and residential developments dominate the landscape, while seaward, the coastline is dominated by sea walls and revetments that protect real estate. Many waterfront residences in the study area are built on sections of landfill that were sandy shoreline prior to development (Fletcher 2005) (Figure 18).

Figure 18. Maunalua Bay from Koko Head

Maunalua Bay's reef extends approximately 1,000 yards offshore. Water depth increases as one travels in a seaward, southward direction from the Bay's shoreline. Along the imaginary line across the mouth of the Bay between Koko Head and Black Point the Bay reaches depths of 50 to 60 feet.

The north-south boundaries of this study extend in an inland direction (*mauka*) to the shoreline of Maunlaua Bay and into Kuapā Pond; and in the seaward (*makai*) direction to the reaches of *Kūpikipiki'ō* and *Kawaihoa*. (we generally use these names to identify water locations- probably advisable to use either Koko head or Kawaihoa as a descriptor but not both- its kind of confusing. Same goes for Black Point/ Kūpikipiki'ō) *Kūpikipiki'ō* is located at the western boundary of this study at 21°15.51′N latitude and 157°47.63′ W longitude; and *Kawaihoa* Point is located to the east at 21°15.74′ N latitude and 157°42.59′ W longitude. The distance across the mouth of the Bay between these two points is approximately 5.46 miles.

Aquatic Habitats

In a 2005 study, coral cover, silt/clay substrate, and number of fishes were used to evaluate the overall "health" of Maunalua Bay's coral reefs. Rodgers, Jokiel, and Brown (2005) determined that compared to reference areas selected based on water depth and direction of wave exposure, Maunalua Bay's coral reefs are severely impaired by anthropogenic affects.

Maunalua Bay has been characterized as a fringing reef bay with generally low coral coverage near shore (Tait, Guinther, and Brock 1975). The highly urbanized Hawaii Kai Marina (Kuapā Pond) negatively impacts the water quality in Maunaua Bay, with some areas exceeding state standards for nutrient and turbidity levels for Hawaiian waters reserved for recreational and aesthetic enjoyment (Tait, Guinther, and Brock 1975). There is a higher sediment loading occurring across the center of the Bay from Wai'alae watershed to Kuli'ou'ou watershed, with eastern and western ends somewhat cleaner. Kuapa pond acts as a sink or filter, capturing a lot of the sediment and pollutants.

Suspended sediments in the Bay environment have been generated by natural processes for a significant length of time. Water currents move in and out of the Bay with the tides, and also eastward and westward, with surface currents following the prevailing wind direction. This means that while the prevailing trade winds are in effect, there is a certain amount of sediment transferred in a westward direction along the reef flat. Similarly, beyond the reef flat, sediments flow generally in a westward direction with the trade winds, along the southern coast of O'ahu, while a lesser plume of sediment splinters off eastward toward Koko Head. Near Koko Head, most of the sediments remain suspended in the water column as they pass *Kawaihoa* Point. In deeper areas protected by reefs, the sediment load is deposited through the water column to the sediment layer on the Bay's bottom (Tait, Guinther, and Brock 1975).

Kuapā Pond

The Hawaiian word for fish pond is *loko* (pond) or *loko i'a* (fish pond) (Summers 1964). *Loko i'a* were built and maintained by Hawaiians in pre-European contact times to provide an area to contain fish for fattening, and also to provide a source of fish during times when certain species were subject to a seasonal taboo (*kapu*) (Summers 1964). Because fish ponds were considered part of the land, fish harvested from them were not subject to taboos placed on open-water fish (Summers 1964). Fishing taboos were implemented in order to ensure that stocks were not overfished, and to prevent harvesting of fish during their spawning seasons to ensure fish recruitment for the following season (Summers 1964). Striped mullet, for example, spawns from November through March, so Hawaiians were only permitted to catch and consume open-water striped mullet from April through October (Summers 1964). Thus, during the five month taboo on striped mullet, they could still be harvested and consumed from fish ponds.

Prior to European contact in 1778 at the peak of fish pond production, O'ahu contained the most fish ponds of any Hawaiian Island, with 175 of Hawaii's total of 360 (Costa-Pierce 1987). Located either on the shoreline or more inland, fish ponds could either be entirely enclosed (*loko Kuapā*) or constructed with openings that allowed fish to enter and exit the pond at certain times (*loko 'umeiki*) (Summers 1964). The enclosed shoreline ponds were constructed in one of two ways (Summers 1964). One method was to construct a wall connecting two points of land, such as the points of the mouth of a small bay (Summers 1964). Alternatively, a wall could be constructed outward from two places along the shore, and then connected to form a semi-circular shoreline enclosure (Summers 1964).

While certain types of fish ponds are known to exist in other parts of Polynesia, enclosed fish ponds are found only in Hawaiian Islands (Summers 1964). Organized by chiefs on behalf of higher chiefs or kings, the construction of *loko Kuapā* was a communal undertaking with ‘the common people’ providing the labor (Summers 1964). The first estimated date of the construction of an enclosed fish pond is the mid-fifteenth century (Summers 1964). Construction probably took more than a year of work (Kamakau 1869), with the walls of some ponds stretching as far as 2,000 feet (Summers 1964). Enclosed fish ponds ranged in size from one to 523 acres. Over the past century, most have fallen into disrepair or been destroyed (Summers 1964).

An important feature of enclosed fish ponds was the grate (*makaha*) located at an opening in the fish pond wall that allowed for water and small or young fish to enter the pond, and kept predatory fish outside the pond (Summers 1964). *Makaha* could be opened like a gate or raised to allow fry and small fish into the pond when desired, and then closed again to trap the fish within the pond (Summers 1964). An alternative way to stock the pond would be to catch wild fry with a fishing net and transport them to the pond (Summers 1964). Often a thatched guard house (*hale kia‘i*) was built near the *makaha* where a keeper would stay during high tides to guard the fish from being stolen (Summers 1964) (Figure 19).

Figure 19. Kuapā gate house and makaha, circa 1925 (Hawaii State Archives 2005).

Fish attracted by sea water flowing through the pond wall grate would gather at the *makaha*, where the fish pond keeper would select the fish he desired with a net or by hand (Kamakau 1869a in Summers 1964; Costa-Pierce 1987).

Most fish pond walls were constructed in such a manner that water could seep in and out of the pond from the ocean through the walls (Summers 1964). However, some ponds walls, such as 2,500-foot wall at Wailupe Pond (now Wailupe Circle) were so compact that the flow of water into the pond only occurred through the *makaha* (Summers 1964) (Figure 20).

Figure 20. Photo of Wailupe fish pond with Koko Crater and Koko Head in the background. Date unknown (Hawaii State Archives 2005).

Striped mullet and milkfish were the most common fish raised in enclosed fish ponds (Summers 1964; Takemoto *et al.* 1975). Known to reach as much as 15.5 inches in length in ponds, these fish consume micro-benthos (Summers 1964). Micro-benthos thrive in shallow (not exceeding a depth of two feet), brackish water (Summers 1964). Thus, ponds were frequently located in sheltered bays at the mouth of a stream or fresh water spring (Summers 1964).

Kuapā Pond, located in the study area, was once the largest enclosed fish pond in Hawaii, and covered 523 acres (Figures 21 and 22). Once known as *Keahapua-o-Maunalua*, which means 'the shrine of the baby mullet of Maunalua', Kuapā Pond is one of the primary aquatic features and cultural symbols of the Maunalua Bay region (Handy,

Figure 21. Panoramic photo of Kuapā Pond with Koko Crater (left) and Koko Head (center) in the background. Photo undated (Hawaii State Archives 2005).

Figure 22. Aerial photo of Kuapā Pond with Lēʻahi in the background (far left). Taken during construction of the Hawaii Kai Marina in 1974 (Hawaii State Archives 2005).

Handy and Pukui 1972). Before this water body was transformed into a fish pond by Hawaiians in the 18th Century, Kuapā Pond was likely a broad, shallow inland bay. Around the year 1800, King Kamehameha I is said to have helped repair the wall when visiting the site during a trip around the Hawaiian Islands (Handy, Handy, and Pukui 1972). The original fish pond wall of Kuapā Pond was likely about 5,000 feet long, and was positioned where Kalaniana'ole Highway is now (Gill 1989). From around the mid eighteenth century until 1959, Kuapā Pond functioned as a productive fish pond. The Pond appears on a map created in 1883 as Maunalua Pond, and then after 1884 as Kuapā Pond, which translates literally to "fish pond wall" (Hand, Handy, and Pukui 1972; Takemoto *et al.* 1975; Stump 1981)

As he was conducting archaeological research in the region, McAllister (1933) interviewed the *konohiki* (fish warden) of Kuapā Pond, Kanae. Kanae told McAllister that there was an underground tunnel that connected Kuapā Ponds with Kaelepulu Pond to a pond in Kailua, to the north. Large schools of striped mullet would swim back and forth between the ponds (McAlliser 1933 in Takemoto *et al.* 1975). A water spirit (*mo'o*) named *Lau-kapu* resided in the pond, according to legend. *Lau-kapu* protected the fish, the chief and the people of the area and punished them if they were stingy (Summers and Sterling 1962 in Takemoto *et al.* 1975).

One of the many stories about Kuapā Pond is related to the origin of a large rock, four feet by three feet by six inches, that used to be located in the center of the pond. A man called Waiakaaia was so in love with his wife that he couldn't bear the thought of her with another man. When she went one night to be with another man, an enraged Waiakaaia went to Hanauma Bay and carried the huge stone all the way back to the fish pond and threw it in the center where it stood for many years (Stump 1981). According to legend, a freshwater spring at the west end of Maunalua Bay was named for Waiakaaia (Stump 1981).

At its western end, the constructed wall of Kuapā Pond probably curved inland, allowing small boats sent by whaling ships to collect water there (Stump 1981). Whaling ships from all over the world frequented the Hawaiian Island between 1820 and 1860 (Stump 1981). Whaling ships anchored off-shore to collect freshwater from a spring located about 1,400 feet from the beach near the western edge of Kuapā Pond, and to buy sweet potatoes grown in small valleys surrounding Kuapā Pond (Handy 1940; Takemoto *et al.* 1975; Gill 1989).

The spring, called *Waikaaia*, intermittently fed into Kuapā Pond. It was associated with a myth involving two significant Hawaiian gods, *Kane* and *Kanaloa*. These two brothers send their young brother, *Kane'apua*, to retrieve water for them, and warned him not to urinate as he carried the water. When the *Waikaaia* spring dried up, Kane and Kanola knew their brother had disobeyed them, so the brothers turned Kanepua into a hill (Takemoto *et al.* 1975). The Hawaiian name of Koko Head is *Mo'o-kua-o-kane'apua* (Backbonde of Kane'apua), indicated that this is the hill that *Kane'apua* became (Handy, Handy and Pukui 1972).

Kuapā Pond's size has decreased as it has gradually filled with sediment. In 1921, its acreage was reduced due to sediment fill to about 300 acres from its original 523 acres. Today, the pond, now a marine embayment and private boating marina, is 260 acres (Sakoda 1975 in Coles, DeFelice, and Eldredge 2002; Carter and Burgess, Inc. 2002). The dredging and conversion of Kuapā Pond from a fish pond to a boating marina in 1959 resulted in a new main channel created into Kuapā Pond (Carter and Burgess, Inc. 2002; Coles, DeFelice, and Eldredge 2002). Opening this new main channel to Kuapā Pond has increased water circulation within the pond, resulting in increased salinity levels within the pond (Sakoda 1975 in Coles, DeFelice, and Eldredge 2002). Today, Kuapā Pond's conditions are consistent with other harbor environments on O'ahu, and no longer support a hypersaline, hyperturbid, estuarine environment (Coles, DeFelice, and Eldredge 2002). A discussion of the effects of these changes on marine species follows this section.

Marine Species

The marine biota of Maunalua Bay have not been comprehensively studied over a long period of time, though there has been some baseline studies in and near Kuapā Pond, and also along the artificial reef at the eastern end of the Bay. A comprehensive survey of estuarine species on the south shore of O'ahu was conducted by the Bishop Museum from 1998 to 1999 (Englund *et al.* 2000). In 2002, Coles, DeFelice, and Eldredge (2002) examined the non-native marine species in Kuapā Pond. With a focus on relative abundance of non-native species to native species, and on water quality rather than marine species per se, a discussion of the results of these studies follows.

Using data collected at five stations in February 2002, Coles, DeFelice, and Eldredge (2000) conducted a survey of marine algae, invertebrates and reef fishes of Maunalua Bay and Kuapā Pond (Figure 23). Prior to this time, virtually no biological inventory of Kuapā Pond had been conducted, and no comprehensive survey of marine biota had been conducted in Maunalua Bay (Coles, DeFelice, and Eldredge 2002). This research revealed a pattern of non-native and native species assemblages of marine algae, invertebrates, and reef fishes in Kuapā Pond consistent with other semi-enclosed bays, harbors, and similarly urbanized coastal areas such as Waikiki (Coles, DeFelice, and Eldredge 2002). In addition, the findings supported other studies that found a reduced success rate for invasive species in areas with greater natural species richness. Thus, these findings support resource management plans that promote natural species richness as a method of restricting the successful establishment of non-native invasive species.

Of the 317 species collected at the five sites in Kuapā Pond and Maunalua Bay, 18 percent were non-native species, with 96 percent of these non-native species having been already observed at other locations in O‘ahu, primarily Pearl Harbor, Honolulu Harbor and Kaneohoe Bay. Within and adjacent to the mouth of Kuapā Pond, monitoring stations one and two measured relatively low numbers of total species, with nearly 40 percent of the species being non-native, constituting the highest level of non-native species recorded in Hawaii. This high level of non-native species presence (48 recorded

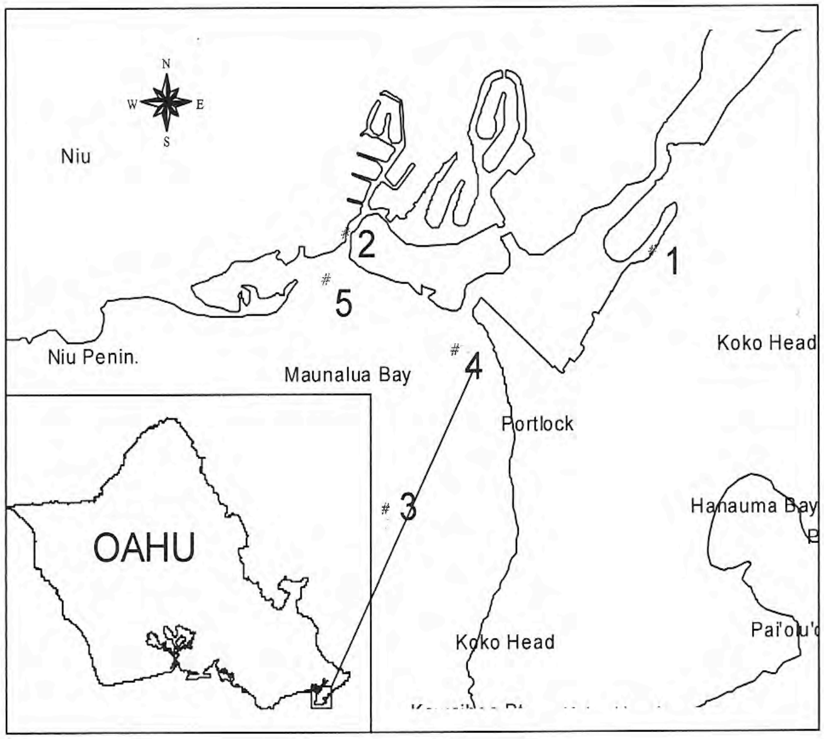

Figure 23. Sampling stations in and near Kuapā Pond for Coles study (Coles, DeFelice, and Eldredge 2002).

in 2002) is likely due to the effects of Kuapā Pond's long history of anthropogenic disturbance and its use as a boat harbor (Coles, DeFelice, and Eldredge 2002). Compared to sites in and near Kuapā Pond, much lower non-native species numbers were found as distance increased from Kuapā Pond. For example, at the coral reef sample station three, non-native species levels were at four percent. Other nearshore sampling sites showed intermediate levels of non-native species, ranging between 14 percent and 17 percent (Coles, DeFelice, and Eldredge 2002).

Coles, DeFelice, and Eldredge (2002) caution that despite low numbers of non-native species at some sampling stations, invasive algae appears to be spreading in the areas sampled. Three species of red algae, including (*Acanthophora spicifera*), (*Gracilaria salicornia*) and (*Hypnea musciformis*); along with a green algae called Mud weed (*Avarainvillea amadelpha*) pose a threat to local native marine systems by competing for space with native species (Coles, DeFelice, and Eldredge 2002; Mālama Maunalua 2006a). The most abundant non-native species in the nearshore monitoring sites of Manualua Bay was the common algae, *Avrainvillea amadelpha* (Coles, DeFelice, and Eldredge 2002). In areas between one and ten feet deep with low wave action, *Avrainvillea amadelpha* has thrived in O'ahu and has outcompeted native algae and Hawaiian seagrass (*Halophila hawaiiana*). Large beds of the endemic Hawaiian seagrass, a food of the Hawaiian green turtle, are now rare in southern O'ahu, though some Hawaiian seagrass beds persist in the study area (University of Hawaii, Botany Department 2001a; Coles, DeFelice, and Eldredge 2002).

Although the mechanism of introduction of *Avrainvillea amadelpha* to O'ahu is not known, it was first identified at Kahe Point in southwestern O'ahu, and at Koko Head in southern O'ahu, and it is believed that it was introduced sometime after 1981 University of Hawaii, Botany Department 2001). Often associated with the invasive spiny seaweed (*Acanthophora spicifera*), the blades of *Avrainvillea amadelpha* capture waterborne sediments (University of Hawaii, Botany Department 2001). Over time these trapped sediments alter the substrate as silt is layered upon the sandy bottom, creating a layer of mud where none previously existed under the native vegetation regime University of Hawaii, Botany Department 2001).

Another significant non-native species, the octocoral snowflake coral (*Carijoa riisei*), was pervasive on bridge pilings and other hard surfaces near the outflow of Kuapā Pond, though there is no evidence it has spread to nearby reefs (Coles, DeFelice, and Eldredge 2002). A native of the western Atlantic from Florida to Brazil, this soft, orange coral was first identified in O‘ahu in 1972 in Pearl Harbor, probably transported in ship’s hull (Hawaiian Biological Survey 2002). Its ecological impact is not well known, though it likely competes with other invertebrates for habitat (Hawaiian Biological Survey 2002).

The most widely spread invasive invertebrate in the study area is Phillipine mantis shrimp (*Gonodactylaceus falcatus*). First observed in O‘ahu in 1954, *G. falcatus* was likely introduced to Kaneohe Bay from concrete barges that were towed from the Philippines and the South China Sea to O‘ahu at the end of World War II (Kinzie 1968 in Hawaiian Biological Survey 2002a). This shrimp species is an aggressive, carnivorous predator that probably displaced the native stomatopod (*Pseudosquilia* ciliate) from the study area (Coles, DeFelice, and Eldredge 2002).

The results of Coles, DeFelice, and Eldredge (2002) study are consistent with Englund *et al.*’s (2000) findings in regard to decreased non-native species presence associated with more marine environments. Stations one and two are located inside

Kuapā Pond, the least marine of the sites sampled in Coles, DeFelice, and Eldredge (2002) study, and displayed the most similarity of the sites sampled. Species observed at sites one and two displayed relatively low total taxonomic distribution (89 and 101 respectively), with a higher percentage of non-native species (38 and 27 percent, respectively). Conversely, the more marine in character reef sampling station, number three, was notably more diverse, with 202 taxonomic groups represented, and with only four percent non-native species. The near shore sampling stations four and five displayed intermediate levels of non-native species (14 percent and 17 percent), with 117 and 54 taxonomic groups represented (Coles, DeFelice, and Eldredge 2002).

As discussed in the previous section on freshwater fauna, a comprehensive survey of both native and introduced freshwater and estuarine aquatic fauna, including insects, fish, crustaceans, and mollusks was conducted at the bases of streams and estuarine areas of the study area by Englund *et al.* (2000). Results of this study revealed fauna that has been degraded and is dominated by introduced species in less marine areas. But in ecosystems dominated by a more marine environment, native systems are more intact. Englund *et al.*'s (2000) study attributes the relationship of native species presence to salinity levels, to the multitude of impacts to near shore areas and stream mouths resulting from urbanization over the last century.

Stream diversion for agricultural purposes, removal of tree and grass cover near streams as a result of development, and stream channelization and lining for flood control purposes, all produce direct and mostly negative effects on stream ecology (Timbol and Maciolek 1978; U.S. Army Corps of Engineers 1994). Records documenting these types of modifications to streams within the study area begin in the 1930s (Timbol and Maciolek 1978; U.S. Army Corps of Engineers 1994). The results of these alterations to streams, particularly channelization and lining of streams, have negative effects for the marine environment. Channelization and lining of stream beds rapidly moves surface runoff water from the land into the Bay, and encourages the deposit of sediment and pollution in Bay waters (Mālama Maunalua 2006a).

Sediment deposits in the Bay are estimated to be as much as eight to nine times the natural rate of sedimentation (Mālama Maunalua 2006). Sediment can smother corals and other organisms, and hinder reproduction of some fish species (Mālama Maunalua 2006). The effects of sedimentation, that can be associated with disease causing bacteria, include altered and compromised marine habitats (Mālama Maunalua 2006). In addition to stream channelization, dredging, wetland filling, the effects of introduced, non-native species and pollution from non-point sources also affect the Bay's aquatic habitats (Mālama Maunalua 2006).

Englund *et al.*'s (2000) sampling stations in the study area around Maunalua Bay were located at Kuapā Pond, Niu Stream, Paikō Lagoon, Kuliʻouʻou Stream, Wailupe Stream and Waiʻalae Nui Stream. These samples indicated the presence of native species in greater numbers overall (52 percent) than non-native species (31 percent), with the remaining species either not identified to the species level (15 percent), or identified as new species (one percent). Native species were distributed unevenly among types of fauna. Twenty-five percent of aquatic insects were native, 69 percent of mollusks were native, and 72 percent of fish were native. The highest total number of native species was recorded at the Wailupe Beach Park, located within the Maunalua Bay watershed at the mouth of Wailupe stream (Englund *et al.* 2000).

These studies all indicate that while the marine environment of Maunalua Bay is impaired, there are areas, such as near the mouth of Wailupe stream, where robust numbers of native aquatic species are found. Additionally, there are opportunities to improve the ecological conditions of Maunalua Bay's near-shore environment to a level that would support greater populations of native fish. Efforts to effectively reduce sedimentation input into the Bay, pollution reduction, and the removal and control of invasive species of algae, would contribute to improving the ecological health of the near shore environment of Maunalua Bay and the return of greater populations of native aquatic species.

IV. THE PEOPLE

In the previous chapters on ‘The Land and ‘The Bay’, the unique geography and natural history of the Maunalua Bay region were explored. In this chapter on ‘The People’, the cultural heritage of the Hawaiian people is discussed. The natural history of the Hawaiian Islands is directly tied to the cultural heritage of the Polynesians, who adapted to life in Hawaii by organizing systems of government and production suited to the environment. Exploring human settlement and human land-use in Hawaii through time provides an important component of the natural and cultural history of Maunalua Bay. Since some significant archaeological findings and Hawaiian legends and myths relevant to the study area have already been presented in the sections on ‘The Land’ and ‘The Bay’, they will not be discussed in-depth again here. This chapter is a discussion of Polynesian settlement, Hawaiian resource management systems, European contact, and urbanization in the study area. This section is organized chronologically, and begins with a discussion of Polynesian settlement of the Hawaiian Archipelago.

Polynesian Settlement

While the timing of human settlement of the Hawaiian Archipelago has not been determined with certainty, it is generally accepted that there were two significant and distinct migrations from Polynesia to the Hawaiian Archipelago (Kirch 1985). The timing of these migrations are often discussed in terms of probable ranges. For example, the timing of the first migration of Polynesians to Hawaii ranges from as early as the first century (Hunt and Holsen 1991 in Athen *et al.* 2002), to as late as 700-800 AD (Athens 1997; Masse and Tuggle 1998; Tuggle and Spriggs 2000 in Athens *et al.* 2002). Kirch (1985) argues that first migration colonization probably occurred more precisely between 300 and 600 A.D. Linguistic and archeological evidence indicates that these early settlers came from the Marquesas Islands, located about 2,500 miles (4,023 kilometers) to the south of the main Hawaiian Islands (Kirch 1998). Archaeological research indicates that populations of the first migration settled on the wetter, windward shores, with the possible exception of a few areas in leeward regions with abundant freshwater sources (Maly and Smith 1998).

Hawaiian oral history and some linguistic and archaeological evidence indicate that the second migration of Polynesians came to the Hawaiian Archipelago from the Society Islands in approximately the thirteenth or fourteenth century (Kirch 1985). One Hawaiian legend supporting the theory of this second migration tells of a man named *Moikeha*, a Tahitian chief who came to the Maunalua area of O‘ahu, then returned to Tahiti, and brought his sisters Makapuu and Makaaoa back to Maunalua (Stump 1981). This is consistent with the theories of some historians, who believe the second migration of Polynesians to Hawaii landed first near Maunalua, and then spread throughout O‘ahu (Takemoto *et al.* 1975; Stump 1981).

High numbers of bird bones found in the lower layers of sediment inside a bluff shelter in Kuliʻouʻou Valley indicate that that this site may have been the location of an early temporary settlement of people (Kirch 1985). In 1950, Kenneth Emory recovered and analyzed charcoal remains found at the same sediment level with human artifacts within the bluff shelter (Kirch 1985). The recovered charcoal was dated to approximately 1100 A.D., and yielded the first radiocarbon dating from any Pacific island (Kirch 1985; Thomas 1995). Artifacts at this site, along with other nearby rock shelters (at Hanauma Bay and on Kaluanui Ridge in Hawaii Kai), reveal a pattern of early, occasional, and short-term use, followed by a period of more intensive use post-1450 A.D. (Kirch 1985; Thomas 1995). The variety of artifacts and the extent of midden remains found within the Kuliʻouʻou Valley bluff shelter, indicate that this site could have been a. part-time residence used for specific activities (Kirch 1985; Thomas 1995).

Some artifacts indicate that the Kuliʻouʻou bluff shelter may have been a workshop, because unfinished fishing equipment, tools for carpentry and woodworking, bark cloth (*tapa*) stamps, beads, bracelets and tattooing materials were all found in this shelter (Bonk 1964). Additionally, it could have been a temporary shelter for fisherman. According to legend, *aku* or skipjack tuna (*Katsuwonus pelamis*) fishermen would purify themselves the night before fishing by sleeping in a sanctuary, where they were forbidden to lie with their wives in order to ensure a successful fishing outing (Malo 1951).

In addition to the cultural artifacts found, human remains were also excavated from nearby the Kuliʻouʻou bluff shelter. Two infant burials were located near to each other above Kawaihae Street in Hawaii Kai. The infant remains were contained in wooden coffins that also contained matting, bark cloth, and woven cloth. These burials appeared to be post-1800 artifacts (Takemoto *et al.* 1975). In 1971, above the Hawaii Kai residential area, another burial shelter dated back to the early 1800s was found. It contained the wrapped body of an adult and some cultural artifacts, including a canoe (Takemoto *et al.* 1975). Despite these findings, Takemoto *et al.* (1975) concludes that compared to other areas, the region was probably not heavily populated prior to European contact.

Since Hawaiians had no written language and no contact with the western world prior to Cook's arrival in 1778, most of what is known today of prehistoric Hawaiian life has been gleaned from oral history and from archaeological excavations such as Emory's (La Croix and Roumasset 1990). This work is challenging, as most of the archaeological sites discovered before 1959 in the region have since been destroyed (Takemoto *et al.* 1975). The following discussion of Hawaiian resource management systems prior to European contact was constructed by examining existing archaeological evidence and historical accounts and texts.

Hawaiian Resource Management

For many years, it was thought that pre-contact Hawaiians lived in relative harmony with nature, and caused only minimal disturbance to the natural environment (Kirch 1982). Most of the flora and fauna extinctions, habitat alterations and introductions of foreign species were attributed to European arrival and colonization (Kirch 1982). While Hawaiians did practice conservation in their management of resources and placed a high value on maintaining productive ecological systems, and indeed, the European introductions of plants, animals and customs had dramatic effects on the land, some important modifications to the biophysical environment made by Hawaiians pre-European contact have recently been uncovered through archaeological work (Kirch 1985).

Evidence indicates that ancient Hawaiians cleared lowlands and terraced valley slopes for agricultural production, converted reefs to fish ponds, harvested medicinal plants and forests for firewood and timber, harvested fish and shellfish, and hunted birds for their feathers and as a food source (Kirch 1985). The Polynesian voyaging canoe bearing the first settlers to the islands, also likely contained crop plants, pigs, dogs and chickens, and other unintentional introductions such as the Polynesian rat (*Rattus exulans*), geckos and lizards (Kirch 1985). The offspring of these first pigs eventually became feral and damaged forests with their rooting and grubbing behavior (Kirch 1985). Weeds such as east Indian crabgrass (*Digitaria setigera*) were also brought to the islands and have been uncovered at archaeological sites (Kirch 1985). Other activities of the ancient Hawaiians also altered habitat: these include clearing native dry forest or scrubland and replacing them with cultivated fields, and burning of landscapes to optimize conditions for *pili* grass (*Heteropogon*) used for thatch (Menzies 1920 in Kirch 1985).

The traditional Hawaiian systems of extracting life sustaining resources from the land developed over centuries. These systems are specific to particular places, involve ritual and spiritual components, and are based on centuries of observation and adaptation to seasons and other environmental patterns. Hand, Handy and Pukui (1972) describe this belief system in this way: "To comprehend the psyche of our old Hawaiians it is necessary to enlarge the implication of the word "relationship" beyond the limitations of the "interpersonal" or social. The subjective relationships that dominate the Polynesian psyche are with all nature, in its totality, and all its parts separately apprehended and sensed as personal" (Handy and Pukui 1998, 117-118).

The people of the first migration, are thought to have participated in a communal, subsistence economy, involving the sharing of resources among extended families (*ohana*) (Kirch 1985; Buck 1993). Kirch (1985) believes this first population of people in Hawaii organized their cultural life around the ancient Polynesian concepts of hereditary chiefdoms (*ali'i*), and a population of commoners (*maka'āinana*). Relatively small population size likely functioned to minimize rank differences between chiefs and commoners (Kirch 1985). While little is known about the resource use systems of the people of the first migration, it is believed that they imported with them pigs, dogs and chickens for food, and that they brought crop plants with them (Kirch 1985). They likely relied heavily on found resources, such as birds, fish and shellfish (Kirch 1985). Their communal, subsistence mode of production was use-driven, and likely operated with a spirit of reciprocal relationships among people and the non-human natural environment (Buck 1993, 47). First-migration settlements were likely small, clusters of dwellings (initially, probably pole-and thatch constructions with pebble floors) located in the ecologically favorable, wet, windward coastal areas (Kirch 1985). A probable cause of the migration from the Marquesas to the Hawaiian Islands may have been drought that devastated the Marequesan Archipelago periodically (Kirch 1985).

The second migration or Polynesians to Hawaii is believed to have occurred around 1300 A.D. (Buck 1993), and likely preceded a period of expansion that occurred between 1100 and 1650 A.D. During the expansion period, Hawaiian populations increased and expanded dramatically (Kirch 1985). Settlements were established in previously unoccupied leeward areas, such as near fish ponds or in rock shelters (Kirch 1985). Irrigation works, dryland farming, and aquacultural production all arose in Hawaii during this time (Kirch 1985). Fish and shellfish continued to provide an important source of protein for people, while dryland forests and scrublands were cleared and replaced with terraced irrigation systems in interior valleys (Kirch 1985). A more hierarchal system of production introduced by the people of the second migration (circa 1300 A.D.) became the dominant system, almost entirely supplanting the existing communal mode of production (Buck 1993).

In addition to more hierarchal systems of production, the second migration to the Hawaiian Islands from the Society Islands has been linked to the introduction of a more hierarchal chiefly class (*ali'i*) structure, priests (*kahuna*), more extreme taboos (*kapus*), and rituals of human sacrifice (Buck 1993). Kirch (1985) argues that forces within the Hawaiian system itself—such as competition for resources and between chiefs—together with new socio-cultural introductions, combined to transform the production and consumption of resources from communal systems to more hierarchal systems following the second migration (Buck 1993; La Croix and Roumasset 1990).

The new hierarchal system of production involved "enforced tribute and surplus appropriation" (Buck 1993, 47). This resulted in commoners producing food, labor and other products for the chiefly class. The hierarchal system of production functioned to affirm social status and structure, and was not necessarily use-driven. As population expanded and settlements became more decentralized, a transition occurred after which the common people no longer traced their lineage back to the same ancestors as the chiefs, and thus became known as a separate class from the chiefs, known as *maka'āinana*, or 'common people' (Kirch 1985).

The three primary social classes in Hawaii at the time of European contact were the *ali'i* (chiefs), *maka'aiana* (commoners) and *kahuna* (priests) (La Croix and Roumasset 1990). *Ali'i nui* (ruling chiefs) governed jurisdictions composed of an island or portions of an island, usually divided into six or eight small kingdoms (La Croix and Roumasset 1990). The rights to the lands within each kingdom and the goods produced there were under the rule of the *ali'i nui*, who could give land grants to *ali'i*. *Ali'i* in turn granted management of land parcels to lesser chiefs, called *konohiki* (land managers), who managed the tenure of the commoners, who worked and resided on the lands (La Croix and Roumasset 1990).

Commoners were overseen by chiefs, and these two groups were ruled by the King who was the owner of all the lands under his jurisdiction (Chinen 1958). All people had certain rights to food resources gathered or grown, and although the pre-European contact land tenure system in Hawaii was a feudal system, commoners were not serfs. Commoners were relied upon for their labor, but not for military services, and were allowed to move freely between the territories of chiefs (Chinen 1958).

An expansion period following the second migration was accompanied by the struggles for power within chiefly families (Buck 1993). As the expanding population settled into the previously uninhabited lowlands and leeward areas, a need likely arose for a new political and territorial organizational systems, as competition for lands and resources increased (Kirch 1985).

<u>Ancient Land Tenure and Management</u>

Changes in land settlement patterns and tenure were concomitant with the changes to the social structure and systems of production, and accompanied stratification and ranking of the chiefly class, a more elaborate system of laws, and the development of a system of collecting tribute to secure land rights (Kirch 1985). Kirch (1985) dates the establishment of the new land tenure system to around 1450 A.D. Under the newer, more hierarchal system, the chiefs were given control of the land, which was divided into units (*ahupua'a*) and monitored by lesser chiefs (*konohiki*) appointed by the chiefs (Kirch 1985). *Konohiki* were land managers who possessed knowledge passed down from previous generations about the boundaries, components and resources of these land divisions (Kuykendall 1938; Chinen 1958). These land managers were responsible for overseeing the sustained production of resources, and ensuring that the commoners occupying the land were productive (Osorio 2002). Land managers were also responsible for collecting tribute (*ho'okupu*) (in the form of labor or goods, such as bark cloth, feathers, crops, or livestock) to the chiefs, required of common people in exchange for the right to live on and cultivate the land (Handy, Handy and Pukui 1972; Kirch 1985; Osorio 2002). In return for tribute from the commoners, a chief would be expected to utilize his spiritual power (*mana*) to interact with the gods on behalf of his people to secure a good life for them (Kirch 1985). The tributes were symbolic offerings to Lono (the god of agriculture, fertility, music and peace) and were collected during the four–month *Makahiki* harvest in the rainy season (from mid-October to February) at alters bearing the pig-head symbol of Lono (Handy, Handy and Pukui 1972).

Moku are the large land districts into which entire islands were divided, while *ahupua'a* are the secondary districts of *moku*. *Ahupua'a* are units of land that extend from the ridge-top out toward the shallow waters or fringing reef, and typically include several ecological zones that provide a range of natural resources (Kirch 1998). *Ahupua'a* generally share their boundaries with watersheds and are typically wedge-shaped, though some *ahupua'a* are not wedge-shaped and do not include coastal areas. These divisions were frequently along physical boundaries, such as watershed, individual valleys, ridges and rivers, but also included boundaries established by zones where particular trees or grass grew, or by a stone demarking the boundary of a division (Chinen 1958). *Ahupua'a* are typically marked by alters symbolized by a representation of a pig (Maly and Smith 1998). The pig god *Kamapua'a* was associated with Lono, the god of agriculture and fertility (Kawaharada 2001).

Some *ahupua'a* didn't contain the smaller divisions (*'ili*), while other *ahupua'a* contained as many as 40 *'ili* (Chinen 1958). One *'ili* could be comprised of several sections (known as *leles*) located in various parts of an island, and may include shoreline land parcels, lowland parcels and mountainous parcels (Chinen 1958; Pukui and Elbert 1992). *'Ilis* could either be under the jurisdiction of the chief or lesser chief of an *ahupua'a*, or an *'ili* could be managed by its own chief and independent of any *ahupua'a* (Chinen 1958). These *'ilis* were known as *'ili* kupono, or *'ili* ku (Chinen 1958).

'Ili were further divided into their arable portions, called *moos* or *mooainas* (Chinen 1958). Established for cultivation, *moos* were divided further into cultivation tracts called *pauka* (Chinen 1958). Areas of land cultivated by tenants for their chiefs or landlords were called *koeles* (Chinen 1958). Because Fridays were the day of the week that tenants worked *koeles*, they became known later as *poalimas*, the Hawaiian word for Friday (Chinen 1958). The smallest unit of land, known as the *kihapai*, was the unit cultivated by a tenant for the purposes of sustaining himself and his family (Chinen 1958).

Until the privatization of common Hawaiian land in 1848 (the *Mahele*), the *ahupua'a* land unit designations and system of land management were the persistent units of territorial and chiefly power distribution (Buck1993). The privatization of communal lands is arguably the most significant event to effect land tenure and the lives of native Hawaiians, as it marked an end to the feudal system of *ahupua'a* land tenure (Chinen 1958).

Land Tenure and The Mahele

At the time of the privatization of land in Hawaii in 1848, O‘ahu was divided into six *mokus*: Ewa, Kona, Ko′olau loa, Ko′olau poko, Waialua, and Wai′anae (Chinen 1958) (Figure 24). *Ahupua‘a* within these larger districts could be further divided into land divisions called *ili* (Chinen 1958). Land privatization affected the study area in two important ways: 1) the *ili* of Maunalua, formerly part of the *ahupua‘a* of Waimanalo, was incorporated into the boundaries of the *moku* of Kona, and 2) the name of the *moku* Kona was changed to Honolulu (Chinen 1958).

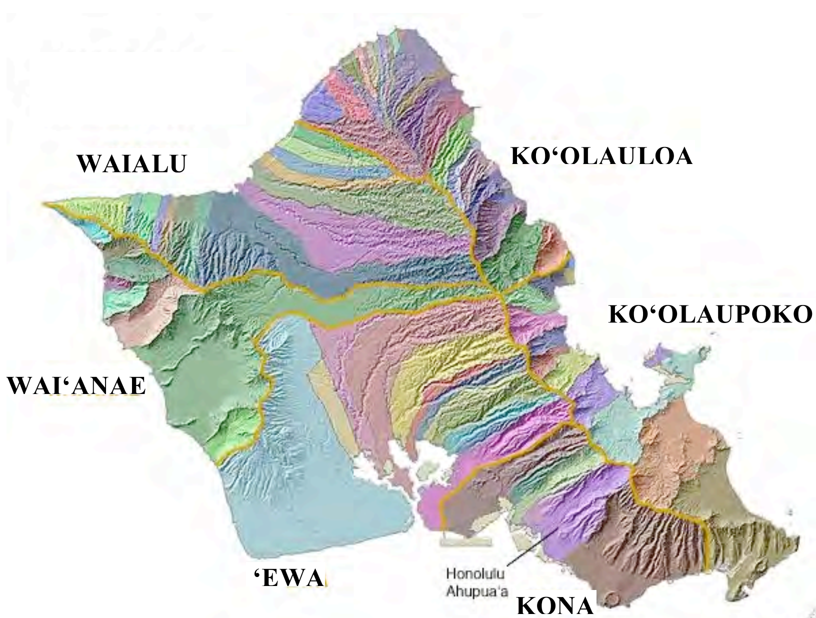

Figure 24. O‘ahu land districts (*moku*) and *ahupua‘a* prior to the Mahele (Pacific Worlds 2003).

As part of the privatization of land in Hawaii, land was granted to the government, to the ruling monarch, to the chiefs, and to commoners (Waihona ʻAina 1996). Between 1848 and 1892, land managers and commoners could make a claim to the land they farmed or otherwise occupied with the Land Claim Commission (Waihona ʻAina 1996). If the Commission awarded their claim, the applicant received title and fee ownership of the land (Waihona ʻAina 1996). In the study area, some *ahupuaʻa* were divided among many claimants receiving land title, while others went to one or two claimants. The *ahupuaʻa* with the most people granted land title in the study area was Wailupe (formerly Aina Haina), which contained land parcels divided among 35 claimants (Figure 25) (Waihona ʻAina 1996a). Waiʻalae Iki was divided among 16 claimants, Waiʻalae Nui among two claimants, and Maunalua, Niu and Kuliʻouʻou were awarded to one claimant each (Waihona ʻAina 1996a). Alexander Adams was awarded Niu (a land tract that was once occupied by Kamehameha I as a summer home), while a female named Waiaha was awarded Kuliʻouʻou, and Maunalua `ili was awarded to Queen Victoria Kamamalu (Waihona ʻAina 1996a; Sterling and Summers 1978). The heirs of the royal family following Victoria Kamamalu to receive ownership of Maunalua were in order: Mataio Kekūanaoʻa , Lot Kamehameha, Ruth Keʻelikōlani, and Bernice Pauahi Bishop (Kamehameha Schools 2007).

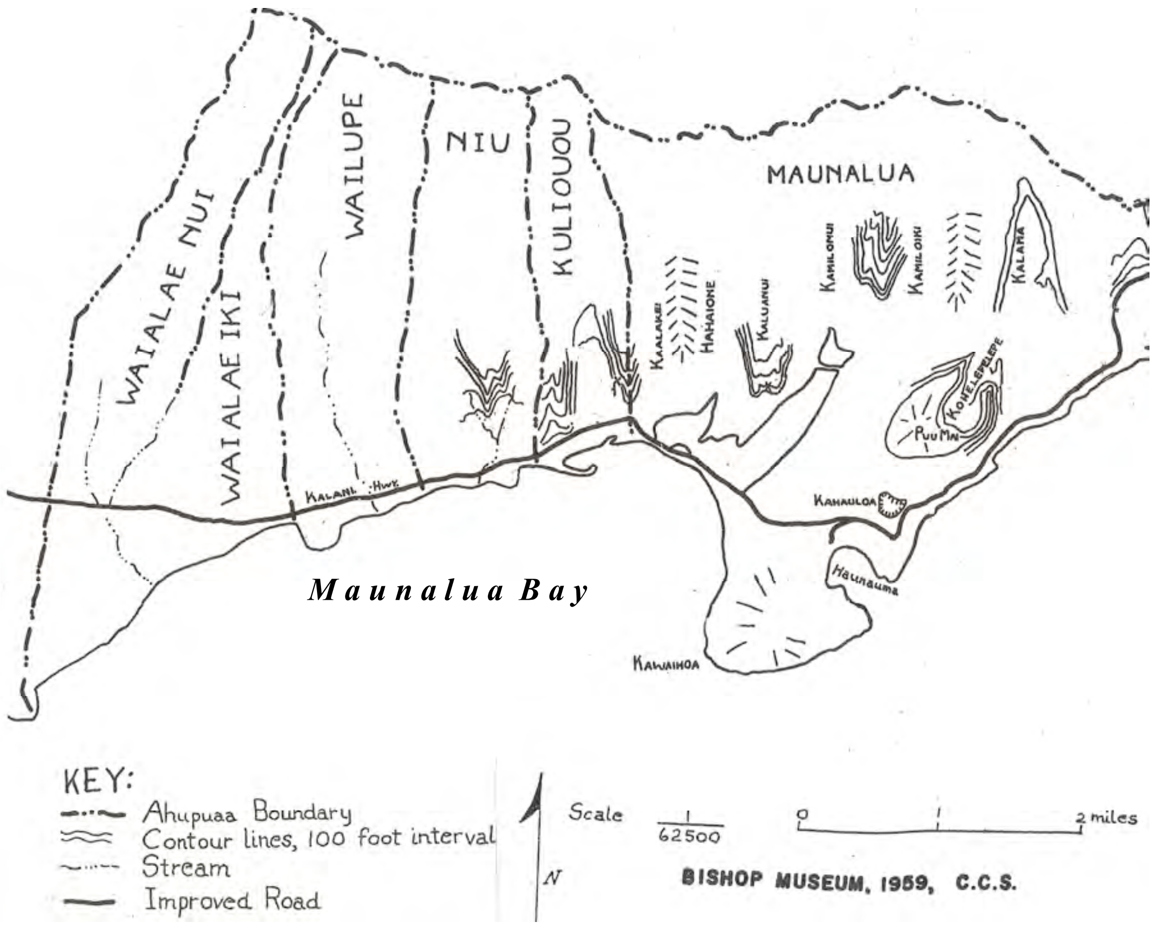

Figure 25. *Ahupua'a* of the eastern portion of the *moku* of Kona (now known as Honolulu) (adapted from Summers and Sterling 1962).

Early Local European-Hawaiian Contact in the Maunalua Bay Region

While engaged in an exploratory voyage in the Pacific Ocean, Captain James Cook discovered Hawaii in 1778 while on his way from the south Pacific to North America. The Hawaiian society Cook encountered was socially and politically similar to other Polynesian societies he had encountered (La Croix and Roumasset 1990). These similarities were evident in the distinct social classes of the *ali'i* (chiefs), *kahuna* (priests) and *maka'āinana* (commoners) described in the previous section (La Croix and Roumasset 1990). Thus, Cook and the Europeans who followed him to Hawaii shortly after his discovery of the Islands, encountered a highly organized, thriving society with ample food most of the time, and leisure time to pursue cultural activities, sports and games (La Croix 2001)

The first English ships to reach Hawaii following Captain Cook's first arrival there in 1778, were under the captaincy of American Nathaniel Portlock (Coles, DeFelice, and Eldredge 2002). Portlock had previously been to Hawaii with Captain Cook on Cook's last exploratory voyage, when Cook discovered the Hawaiian Islands. While on a fur trade expedition to the northwest coast of North America, Portlock wintered his ship in Hawaii in 1786. Portlock anchored in Maunalua Bay, and wrote in 1789 about the dearth of fresh drinking water in the region and the need to go to Waikiki in search of water (Coles, DeFelice, and Eldredge 2002). Portlock described a sparsely populated region of tattooed, physically strong, friendly and curious people eager to trade vegetables, water and pigs for nails and metal pieces (Stump 1981). Portlock also mentioned a "salt river", probably Kuapā Pond (Stump 1981).

One of the earliest descriptions of Kuapā pond is from an 1821 first-hand account by Chamberlain and Mathison, who observed a village called Keawaawa- comprised of

100 huts near the inland end of Kuapā Pond (Stump 1981). Chamberlain, a missionary, was sent to an unknown location in east O‘ahu to preach at a mission school that had been established there, but found his timing was bad (Stump 1981). The King’s order to collect sandalwood, an export item, meant that his audience was smaller than expected (Stump 1981). He did note that between 1826 and 1828, the pupils at the east O‘ahu’s school declined from 65 to only 19, and steadily declined further after that time (Stump 1981). In 1855 there were 38 households and 99 people living in Maunalua, but five years later, only sixteen households reminded (Takemoto *et al.* 1975). The land manager (*konohiki*) of Maunalua at that time, Pehu, recorded fourteen people on his tax records (Takemoto *et al.* 1975). In 1860, the land manager of Kuli‘ou‘ou, Noa, noted that residents there were more numerous at 31 households than in Maunalua (Takemoto *et al.* 1975).

Year	Total Population	Native Hawaiian Population
1778	110,000-1,000,000	110,000-1,000,000
1831-32	130,313	Na
1853	73,137	71,019
1872	56,897	51,531
1890	89,990	40,622
1900	154,001	39,656
1920	255,881	41,750
1940	422,770	64,310
1960	632,772	102,403
1980	964,691	115,500
2000	1,211,537	239,655

Table 1. Population of Hawaiian Islands (La Croix 2001).

This population loss could be attributed to diseases introduced to the Hawaiian Islands at the time of European contact, which took a huge toll on the Hawaiian population between 1778 and 1900 (La Croix and Roumasset 1990). Diseases that devastated the Hawaiian population spread in a series of epidemics, and included measles, influenza, dysentery, and whoping cough (La Croix and Roumasset 1990). In addition, European-introduced venereal diseases negatively affected birth rates. In 1849, a census accounted for 80,641 people in Hawaii (La Croix and Roumasset 1990). Fifty-one years later in 1900, a census counted only 39,656 full or part Hawaiians (La Croix and Roumasset 1990). While there is much debate about the population of Hawaii at the time of European contact, it was believed to be between 110,000 and one million people

(La Croix and Roumasset 1990). What is not debated, is that European contact had a devastating affect on the Hawaiian population.

The major loss of Native Hawaiian lives was followed by periods of colonization by Americans, Chinese, Japanese, Portuguese and other immigrants (Table 1). New industries in Hawaii, particularly plantation agriculture, required large labor forces and thus businesses encouraged immigration to Hawaii. This influx of people and new industries to the Hawaiian Islands resulted in the development of large population centers in areas such as Honolulu. The following section discusses the process of urbanization that occurred in the Maunalua Bay area beginning in the late nineteenth century.

Urban Development

Maunalua Bay's shoreline and drainage basin have been modified since human occupation of the area, beginning with Polynesian agricultural practices, including the construction of the Niu, Wailupe, Paikō and Kuapā fish ponds. Today, suburban development of the area extends along the beachfront, into the valleys, and up onto the ridges of the Bay's drainage basin (SOEST 1999).

Information on the development of the study site comes from many sources, including government agencies such as the U.S. Census Bureau, the Hawaii State Department of Taxation, and private agencies such as the Bishop Estate. While an in-depth analysis of these documents is beyond the scope of this study, it is understood that the population of the region has expanded dramatically since the 1950s. In the region of Maunalua now known as Hawaii Kai, Henry (1959) estimated the regions population to be about 2,005 people in 1959. In 1999, the estimated population of Hawaii Kai was over 27,000 with an estimated population of 50,000 for the entire Maunalua Bay area (CCHDPP 1999). Following a boom in population and housing construction in the 1960s and 1970s, the region's rate of growth has slowed significantly, as most land suitable for building construction has already being developed (CCHDPP 1999).

At the western end of the study site in Kahala, the serene surroundings were eyed by Conrad Hilton in the early 1960's. Hilton wanted to create a classic hotel removed from the crowds of Waikiki (Fischer 2006). In January 1964, Kahala Hilton opened and featured a sandy beach and private golf course (Fischer 2006).

Moving towards the east, the neighborhoods of Wai'alae Nui and Wai'alae Iki can be found. These lands were bequeathed by Bernice Pauahi Bishop (great granddaughter of Kamehameha I) to her husband's (Charles Bishop) estate, and then to the Bishop/Kamehameha Estate. Bernice Pauahi Paki Bishop (1831-1884), inherited large amounts of land, including crown lands, her personal holdings as a chief, and lands bequeathed to her by her cousin, Princess Ruth Ke'elikōlani (1826-1883). In 1953, the Bishop Estate/Kamehameha Schools were established by Bernice Bishop to educate Hawaiian children to become "good and industrious men and women" (Kamehameha Schools 2007a). In 1926, officials with Kamehameha Schools established an agricultural school in Haha'ione Valley, which operated for ten years teaching hennery and pigpen construction, as well as crop planting. It was closed in 1936 (Stump 1981).

In the 1930s and 1940s, 'Aina Haina Valley was occupied by the Hind-Clarke Dairy Farm ('Aina Haina 2007). Hind-Clarke's Ice Cream Parlor, milking parlors and offices were all in the Valley, and were a last stop for travelers moving east from Honolulu before entering the agricultural areas between 'Aina Haina and present day Hawaii Kai ('Aina Haina 2007). Named after Robert Hind, the owner of the Hind-Clark Dairy and the surrounding area, 'Aina Haina and can be loosely translated as 'Hind's' land' ('Aina Haina 2007). Prior to Hind's residence there, the ahupua`a was known as Wailupe, which means "kite water," indicating that this was a good spot for flying kites (*lupe*), an activity reserved for specific times and events in Hawaiian times (Reynolds 2005). The Hind-Clark Dairy closed in 1948, and that year, Robert Hind had Wailupe fish pond filled and a five-foot tall sea wall erected around it so homes could be built on the site (CCHNCO 2007; 'Aina Haina 2007) (Figure 26). In approximately 1957, 'Aina Haina Valley was developed into a residential subdivision by Mr. Hind's son Robson ('Aina Haina 2007).

Figure 26. Wailupe peninsula (formerly a fish pond) (SOEST 2003).

Figure 27. Niu peninsula (formerly a fish pond) (SOEST 2003a).

In the 1930s, Niu fish pond was filled and houses were constructed along with associated commercial development in the Niu and Kuli‘ou‘ou valleys (Miller 2006a) (Figures 27 and 28). The population of the region generally increased in the 1940s, but still included agricultural lands (Miller 2006a). The post-war 1950s brought continued urbanization and population increases as wealthy investors bought second homes in the region (CCHDPP 1999).

Figure 28. Niu fish pond, circa 1925 (Hawaii State Archives).

Significant changes to Kuapā Pond had their origins in 1888, the year Charles Bishop leased the land around the pond for ten years to S. M. Damon and G.J Campbell for the purpose of raising cattle (Takemoto et al. 1975). By the 1920s, the land in Maunalua surrounding Kuapā Pond was leased by Honolulu Honey Company, Ltd, who operated eight apiaries there. A Japanese charcoal burner harvested Kiawe or albarroba (*Prosopis pallida*) wood from the land, with some Hawaiian tenants working one day per week for the leaseholder at the time, the Maunalua Ranch Company. These tenants paid $1 per year for the right to live on the land and fish Maunalua Bay. Joseph Lukela was the land manager (*konohiki*) with the rights to the Maunalua Bay fishery in the 1920s (Henry 1959; Takemoto et al. 1975; Stump 1981). The holdings of the Maunalua Ranch Company, established by the Damon family and in operation between 1900-1926, included mules, pigs, horses and cattle and horses (Takemoto et al. 1975; Stump 1981). By the 1930s through the 1950s, about 15 percent of the area around Kuapā Pond was used by ranchers, flower growers and truck farmers responsible for producing 60 percent of Oʻahu's flowers, pigs and lettuce (Silver and Melkonian 1995). First-hand accounts of people who know the area during the late 1940s and early 1950s, have described it as an odiferous 'country' or 'boondocks', emitting a distinctive smell generated by the marshland surrounding Kuapā Pond, pig farms, and flower growers (Stump 1981, 18).

Flower farmers grew chrysanthemums, orchids, roses, gladiolas, carnations, dalias, plumerias and birds of paradise; and truck farmers occupied the area growing corn, lettuce, string, lima and soy beans, eggplant, tomatoes, peanuts, peas, potatoes, carrots, turnips, cabbages, onions, radishes, squash, sorghums, watermelons and papaya (Henry 1959). Cattle, pig and poultry ranchers were also leaseholders and operated in and around the area (Henry 1959). The majority of farming and ranching leases were set to expire on January 1, 1960 (Henry 1959). By 1959, some farmers' land was idle, as they were anticipating the expiration of their leases and had already sought work outside the region (Henry 1959).

Kuapā Pond was leased by a Japanese fisherman who stocked the pond with mullet caught in Maunalua Bay until the late 1950s. The mullet were raised for about three years in the pond where they reached between one and one-half pounds in weight. They were then brought to the Honolulu market for sale (Henry 1959). Kuapā Pond began to be transformed in the late 1950s to a private boating marina for the first master planned developments in the State of Hawaii: Hawaii Kai.

Conceived by California entrepreneur Henry J. Kaiser, who had retired to O'ahu in 1954 at the age of 72, the Hawaii Kai development was the largest master planned community in Hawaii at the time it was built (Foster 1989 in Silver and Melkonian 1995; Clark 2005). Work on constructing the marina began in 1959 when the seawater entrance to Kuapā Pond and parts of Maunalua Bay were dredged, transforming the area into a marine embayment from a wetland habitat. The wetland environment had been frequented in winter seasons as late as the 1950s by migrating birds such pin-tail ducks (*Anas acuta*), canvas back ducks (*Aythya valisineria*) and Canadian Black Brant Geese (*Branta bernicla nigricans*). The dredged materials were deposited onto the low-lying areas along the shoreline surrounding the entrance to Kuapā Pond. Kaiser installed picnic tables, a boat ramp and bathroom facilities, and dedicated the newly created Maunalua

Beach Park to the City and County of Honolulu in 1960 (Clark 2005). Today, Maunalua Bay Beach Park is a popular destination for jetskiers, surfers, scuba divers, fishers and paddlers. In April 1961, Kaiser signed a lease agreement for the 521 acre land parcel with the Bernice Pauahi Bisop Estate. Kaiser built the Hawaii Kai residences around the marina, and on peninsulas of land within the marina created from the dredged material (Tait, Guinther, and Brock 1975).

Some residents who leased agricultural and residential land from the Bishop Estate were displaced by Henry Kaiser's Hawaii Kai development, and protested their evictions to no avail. These resistance efforts culminated in a series of protests from 1970-1971 known as the Kalama Valley struggle (Trask 1993).

The Kalama Valley Struggle is widely acknowledged to mark the beginning of the Hawaiian Sovereignty Movement (Trask 1993). The evictions associated with the Hawaii Kai development were part of trend that began in the late 1960s, when agricultural land occupied by Hawaiian communities on Moloka'i, Maui, O'ahu and other islands was rapidly developed (Trask 1993). This trend towards development was resisted by some Native Hawaiians who recognized these rural communities as important for the continued retention of Hawaiian practices (e.g., taro farming, fishing and the use of the Native Hawaiian language) (Trask 1993). The development of these formerly Native Hawaiian communities was perceived by some as a threat to Native Hawaiian land rights (Trask 19993). Following the Kalama Valley struggle, Native Hawaiian land use and tenancy was increasingly brought to the fore of public debates (Trask 1993). The development trend continued into the 1970s, when the valleys, ridges and low-lying areas around the Hawaii Kai Marina that once supported agricultural activities, continued to be developed into residential neighborhoods (Miller 2006a). By the 1980s, more investments in real estate (particularly from Japanese investors) spurred housing developments on the ridges of the study area (Miller 2006a). Fuelled by a strong U.S. economy, in the 1990s, U.S. investments in real estate experienced another boom in the region (Miller 2006a).

Paikō Lagoon, located to the west of the entrance to the Hawaii Kai Marina, is named after a former landowner, Manuel Pico (Lassalle 2003) (Figure 29, 30 and 31).

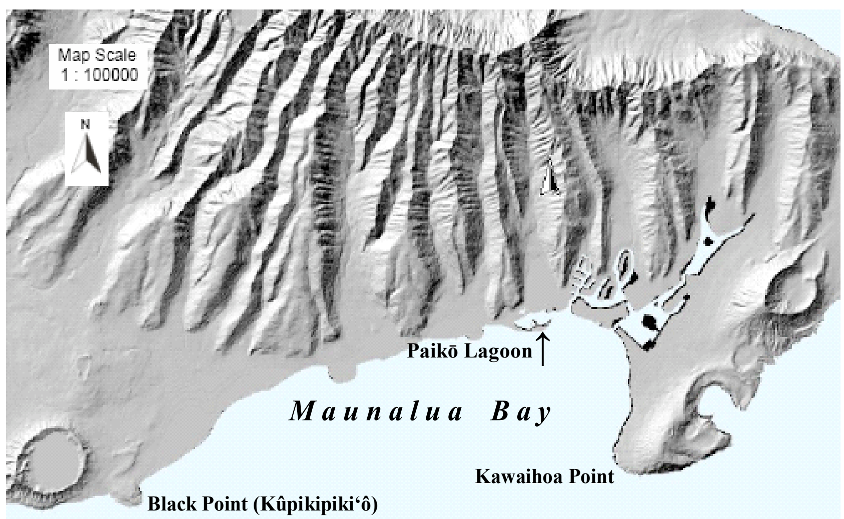

Figure 29. Paikō Lagoon and the study area (PBIN 2005).

The Lagoon is a naturally occurring sand peninsula surrounding a wetland that is fed by a nearby freshwater spring (Shallenberger 1977; Stump 1981; Lassalle 2003). In the early

20th century, the fishing rights associated with Manuel Pico's land extended from the shore to the reef and

Figure 30. Paikō Lagoon, circa 1925 (Hawaii State Archives).

included Paikō Lagoon. During the time they operated the fish pond, the Paikōs vigorously guarded their fishery, and local stories of hearing gunshots at night from the area were not uncommon (Stump 1981). Paikō Lagoon is now a wildlife sanctuary, and provides an example of how, despite the development boom that began in the 1960s, some community efforts to stop development at that time were successful.

In 1959, the City and County of Honolulu sought to create a 25-acres housing development, harbor and small boat marina at Paikō Lagoon (Lum 1978). In response, the Conservation Council of Hawaii and the Hawaii Audubon Society asked to have the Lagoon designated as a bird sanctuary in 1961, to help compensate for some of the coastal bird habitat sacrificed to the Hawaii Kai development. As this proposal was being considered, local residents asked the State of Hawaii to dredge the Lagoon to remove the presumably unsightly inter-tidal flat and eliminate noxious odors (Lum 1978). Despite the Division of Fish and Games objection that dredging the Lagoon would eliminate shorebird habitat, the dredging project went forward in 1972 (Lum 1978). The dredging by the Division of Fish and Game converted Paikō from an intertidal lagoon into a marine embayment, resulting in less habitat availability for shorebirds and for prey species such as shore crabs (*Metapograpsus messor*) (Lum 1978). Once the dredging project was completed in 1974, the site was designated as a bird sanctuary for the native endangered Hawaiian stilt and other native birds (Komoto and Gombos 2007).

Like Kuapā Pond and other regions in the study area, the transformation of Paikō Lagoon over the past two centuries indicates how changing human needs and perceptions have affected land use. From a productive fishery at the turn of the nineteenth century, to an area described as a "stinking mudflat" destined to be dredged and developed in the 1950s, and finally to a protected wildlife sanctuary in the 1970s, Paikō Lagoon now provides a local vestige of formerly abundant coastal habitat for birds (Lum 1978).

Today, Paikō Lagoon is vegetated primarily with non-native mangroves and pickleweed, and to a lesser extent, native beach *naupaka* (*Scaevola sericea*) and *milo* (*Thespesia populnea*), and invasive *kiawe* (*Prosopis pallida*) (Englund *et al.* 2000). Paiko Lagoon's benthic habitat has been significantly altered due to coastal development (Komoto and Gombos 2007). Its proximity to residences, human intrusions, and the intrusions of domesticated animals may threaten the sanctuary in the future (Komoto and Gombos 2007). However, in spite of its modification by humans, Paikō Lagoon once again provides important mudflat habitat for the Hawaiian stilt and other native shorebirds, and for migratory birds such as Pacific Golden Plovers, Ruddy Turnstones, and Sanderlings (Komoto and Gombos 2007).

Since the first humans arrived in the study area, the landscape has been altered to accommodate human needs. The scale and scope of landscape alteration has changed over time with succeeding eras. Beginning with the importation of plants and animals brought to Hawaii by the first Polynesian settlers, introductions continue to alter the landscape of the study area (Kirch 1982). In addition to the biological introductions they bring with them, colonizers also bring to Hawaii their concepts of landscape (Kirch 1982). These concepts, held in the minds of the first settlers in Hawaii and those that have followed them, probably included ideas about how to best extract a livelihood from the land (Kirch 1982). These ideas have been extremely varied, as exemplified by the subsistence activities of the people of the first migration, to the conceptualization of Hawaii Kai by Henry Kaiser (Kirch 1982; Altonn 2003).

The resource use systems of the people of the first migration were likely use-driven, and their settlements were likely small, clusters of dwellings located in the ecologically favorable, wet, windward coastal areas (Kirch 1985; Buck 1993). The second migration of Polynesians to Hawaii likely preceded a period of expansion, when the Hawaiian population increased and expanded dramatically (Kirch 1985). During this time, settlements were established in previously unoccupied leeward areas, such as near fish ponds or in rock shelters (Kirch 1985). A more hierarchal system of surplus production was introduced during this era, along with terraced irrigation systems, aquaculture production, and swidden agriculture in interior valleys (Kirch 1985; Buck 1993).

Sweeping changes followed the discovery of Hawaii by Europeans in 1778, beginning with a steady increase in the overall population of Hawaii, but a devastating decrease in the population of Native Hawaiians, who were not immune to introduced

European diseases. In the nineteenth century, whaling, ranching, and plantation agriculture were established in Hawaii, and large population centers were developed. Land privatization in 1848 changed the way land was managed, and undermined the *ahupua'a* system of resource regulation and use. Throughout the twentieth century, urbanization continued in many areas, including Honolulu and surrounding areas on O'ahu.

Built upon a formerly remote, sparsely populated agricultural area, the Hawaii Kai project ushered in a new era for the entire Maunalua Bay region, and served as a catalyst for the residential development of most of the ridges and valleys in the region throughout the 1960s and 1970s (CCHDPP 1999). Since then, the pace of development has slowed, as almost all suitable land in the study area has already been developed (CCHDPP 1999). Today, there is an emphasis on preserving the remaining undeveloped scenic ridges, upper valley slopes and shoreline areas, and on protecting the region's remaining natural, cultural and historic resources (CCHDPP 1999). In the following section, this new direction in preservation and protection is discussed.

V. THE FUTURE BAY

Community Efforts and Regional Vision for the Future

With its pleasant climate, beautiful beaches and scenery, Hawaii is known to many around the world as an island paradise and a highly valued tourist destination. Yet what is invisible to many tourists in Hawaii, but voiced as a major concern for many Hawaiian residents, is a marked decline in the number of fish and general quality of the near shore marine environment over the past decades. This concern has led some local residents to form grassroots organizations, including Livable Hawaii Kai Hui and Aloha 'Aina 'O Kamilo Nui, to help protect and preserve the region's remaining natural and cultural resources.

One of these local organizations, Mālama Maunalua, is focused on revitalizing the ecological functions of Maunalua Bay through reducing sedimentation and pollution in the marine environment, reducing the presence of invasive, alien marine algae, evaluating and monitoring fish populations, and engaging the community with public outreach programs (Mālama Maunalua 2006a). Organized in 2005 by local community leader Nainoa Thompson and others, Mālama Maunalua's goals are to promote more abundant marine life, cleaner waters, and enhanced citizen stewardship in caring for and protecting the Bay (Mālama Maunalua 2006a). Mālama Maunalua has asserted that the fisheries of the Bay are under stress, and that, based on information gathered from local bay fishers, fish stocks generally have been declining since the 1950s (Mālama Maunalua 2006). Mālama Maunalua contends that despite the problems in the Bay caused by invasive algae, pollution and sedimentation, the Bay's near shore reefs and habitats have good potential for recovery once pollution and sedimentation are reduced (Mālama Maunalua 2006a). The Bay's large area, good water circulation and current recruitment of fish bolster this contention (Mālama Maunalua 2006).

Mālama Maunalua has identified reducing siltation and pollution of the marine environment as one program area where progress in improving the health of Maunalua Bay can be achieved. First, Mālama Maunalua will identify and rank sites where high levels of pollution and sediment are discharged into the Bay. Then, a plan will be developed in collaboration with Federal, State and other agencies to reduce pollution and sediment discharges in the Bay. Mālama Maunalua's hope is that these efforts to reduce will result in improved water quality that will support conditions suitable for the recovery of coral reefs and other important habitats. In turn, the organisms that depend upon these habitats will benefit (Mālama Maunalua 2006a).

As part of their efforts to increase fish populations, Mālama Maunalua seeks to evaluate and monitor fisheries, and to promote sustainable fishing in Maunalua Bay. Part of this effort involves facilitating a fisher advisory group or *Hui Mālama ʻIa. Hui Mālama ʻIa* is a Hawaiian name that can be translated to mean "group to take care of the fish". This collaborative group of fishers knowledgeable about the area will be organized with the goal of developing *pono* (correct, proper, fitting) fishery practices and management for Maunalua Bay. As active stewards and observers, members of the *Hui Mālama ʻIa* will advise the community on human activities that are problematic for Bay fisheries and best practices for monitoring, addressing and educating the community about those problems (Bartlett 2006; Mālama Maunalua 2007a).

To reduce sedimentation and to encourage the recovery of endemic sea grass and other native marine vegetation, Mālama Maunalua is supporting efforts to remove species of invasive marine algae, such as *Acanthophera spicifera*; *Avrainvillea amadelpha* and *Gracilaria salicornia*) from the Bay (Bartlett 2006; Mālama Maunalua 2006a). A partnership including experts from the University of Hawaii, the Hawaii State Department of Land and Natural Resources, and others, will develop an action plan to reduce the presence of alien invasive algae. Mālama Maunalua's strategic objective is to reduce the cover of invasives in three target areas in the Bay to five percent by the year 2010. This work will involve community members, school children, and others, and will include a monitoring plan, public awareness campaign and potential program expansion by the year 2016 (Bartlett 2006).

Mālama Maunalua also seeks to develop public awareness campaigns about its goals and will investigate the potential for developing a public education site near Maunalua Bay. The organization will also pursue efforts to make the Hōkūle`a (a replica of an ancient Polynesian double-hulled voyaging canoe) a symbol of Maunalua Bay

(Polynesian Voyaging Society 2007) (Figure 32). The Hōkūle`a is a highly regarded cultural symbol in Hawaii. In 1976, the Hōkūle`a's first expedition from Hawaii to Tahiti and back was successfully completed without the use of navigational instruments, demonstrating to skeptics that it was indeed possible for ancient Polynesians to intentionally navigate the Pacific Ocean, and to conduct two-way, long distance voyages (Polynesian Voyaging Society 2007).

Figure 32. Mālama Maunalua logo with silhouette of voyaging canoe

Nainoa Thompson, a resident of the Maunalua Bay region and one of the founding organizers of Mālama Maunalua, is Hokule'a navigator and president of the Polynesian Voyaging Society. While it is not sailing, the Hōkūle`a is docked in O'ahu where it will be available for environmental and cultural education programs for school-age children, who will have the opportunity to stay overnight on the canoe while it is anchored in Maunalua Bay. During the day, Hōkūle`a will be used as a classroom, where students can learn about ancient Polynesian techniques of ocean navigation from Nainoa Thompson or other navigators, techniques for water quality testing, mapping, invasive algae removal, and other topics.

Finally, Mālama Maunalua seeks to accomplish its goals partly through organizing and inspiring community stewardship while conveying respect for culture and community. Efforts to increase community responsibility are focused on promoting a sense of place and spirit of stewardship, and developing partnerships and awareness through outreach and education programs that demonstrate how impaired, coastal resources can be restored by an urban community (Mālama Maunalua 2006).

VI. CONCLUSION

People from diverse cultures have occupied and utilized the resources of the Maunalua Bay region for nearly two thousand years. The intent, world-views, and economic systems of the people occupying this region have been varied, and these differences are reflected in the landscape in various forms. Some clues to understanding the way pre-European contact Hawaiians lived can be found by examining imprints on the landscape that are (or were) visible in modern times. These imprints include fish ponds, cultural remains discovered in caves and shelters, archaeological indications of agricultural remains, and evidence of alterations to floral and faunal species assemblages. After European contact, new ways of living in Hawaii were introduced and eventually became dominant. The emergence of these European systems of living and production were accompanied by a devastating loss of life of Hawaiian people, who perished in great numbers due to introduced diseases from the western world. Western notions of production that include fee simple land ownership, and the desire to accumulate capital, set in motion a new social economy in Hawaii that makes different types of imprints on the land. The impact of European-contact, followed by contact with Americans and the rest of the world, have made visible imprints in the landscape in the form of development and urbanization, the influx of non-native aquatic and terrestrial species, and in the sheer number of people living in the region.

The Maunalua Bay area has been transformed into a highly urbanized suburb of Honolulu. The historic and ongoing species extinctions, habitat alterations, pollution, sedimentation, and invasive species common to the rest of O‘ahu, and the Hawaiian Islands, all plague this area. However, as land that can be developed has becomes scarce in the area, and concern increases about the quality of the natural environment there, the future of the region may be shifting away from a trajectory of ever-increasing population and development.

Mālama Maunalua represents a community concerned about the quality of the natural environment and interested in developing appreciation and enhancing the stewardship of the region (Miller 2006). Their efforts can help reverse the trends of increasing pollution, overfishing, and invasive species invasions observed elsewhere in O‘ahu.

The decision to produce a natural and cultural history of Maunalua Bay and its watershed was inspired by the spirit of both the people and by the place—which are both imbued with a spirit of resilience. The challenges to achieving Mālama Maunalua goals are considerable. However, the people who care about Maunalua Bay understand those challenges and are prepared and eager to obstacles. By partnering with scientists, non-profits, government agencies, schools and businesses, Mālama Maunalua will undoubtedly make progress toward achieving its goal of improving the local marine environment, and renewing values of community responsibility in the region.

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APPENDIX I
GLOSSARY OF HAWAIIAN TERMS

‘aina	Land, earth (Pukui and Elbert 1992).
ahupua‘a	A basic land division of ancient Hawaii, typically a pie-shaped valley extending from the mountain top to the sea. *Ahupua‘a* were formerly denoted by a heap of stones or a pig burial (Kanahele 1995).
ali‘i	Chief, chiefess; royal; to rule or act as chief (Kanahele 1995).
ali‘i nui	Great, ruling chief. Big, important. (Pukui and Elbert 1992).
heiau	A Hawaiian temple, a place of worship, offering or sacrifice (James 1991).
ho‘oilo	Winter, rainy season (Pukui and Elbert 1992).
hula	Dance, dancer, song or chant. (Pukui and Elbert 1992).
‘ili	A land division, usually a subdivision of an *ahupua‘a* (Kirch 1985).
kahuna	Priest, sorcerer, expert in any profession (Kanahele 1995).
Kamapua‘a	Pig god.
kapu	Prohibited, forbidden; sacred, holy; a religious tabu.
kau	Period of time; any season, especially summer (Pukui and Elbert 1992).
Kawaihoa	Point beyond Portlock in southeastern O‘ahu. The god *Kane* brought forth water here. Literally translates to mean: the companion’s water (Pukui, Elbert and Mookini 1974).
Kona	Leeward sides of the Hawaiian Islands. Name of a leeward wind; to blow, of this wind (Pukui and Elbert 1992).
konohiki	A headman of an *ahupua‘a* who managed the land, water and other assets under the control of a chief; a land agent or manager (Kanahele 1995).

kuleana 1. A plot of land occupied or cultivated by commoners for themselves.
2. Right, privilege, responsibility.

Kūpikipiki‘ō Hawaiian name for Black Point. Literally means: rough sea (Pukui, Elbert and Mookini 1974).

kupuna Grandparent, ancestor, relative or close friend of the grandparent's generation (Pukui and Elbert 1992).

Lē‘ahi Hawaiian name for Diamond Head, O‘ahu. The mountain was compared by Pele's sister, Hi‘iaka, to the brow of the tuna fish (Pukui, Elbert and Mookini 1974).

***lele*(*s*)** 1. To fly, hop, jump, leap. 2. A detached part or plot of land, located in one *‘ili* but belonging to another *‘ili* (Pukui and Elbert 1992).

loko A fish pond or any body of enclosed water, such as a lake or pool (Kirch 1985).

lupe Kite, to fly a kite (Pukui and Elbert 1992).

maka‘āinana Commoner, populace, people in general (Kirch 1985).

makaha A sluice gate or grate in a fish pond wall (Summers 1964).

makai Towards the sea (Pukui and Elbert 1992).

moku An island or independent chiefdom (Kirch 1985).

mana Supernatural or divine power; universal energy (Pukui and Elbert 1992).

mauka Towards the mountains (Pukui and Elbert 1992).

mo‘o A small unit of land, a subdivision of an *‘ili* (Kirch 1985).

moku District, island, section, fragment (Pukui and Elbert 1992).

‘ohana Family, kin, group, relative (Pukui and Elbert 1992).

APPENDIX II
DISCUSSION OF LITERATURE REVIEW

The subject of the literature review for this research project, environmental history, may lead the reader to expect more cultural analysis than I was able to provide. Typically, environmental histories focus on the role of human values, attitudes and beliefs in shaping the human impact on a particular region's biophysical history (Wilkinson 2007). While this project includes some discussion of cultural phenomena, it does not provide detailed analysis, linking human perceptions and values to landscape and ecosystem-level changes. Archival research and personal interviews with individuals knowledgeable about the history of the study area could have helped reveal these linkages, but time and travel constraints precluded me from exploring these options. For those interested in pursuing environmental inquiries in the study area, following are some suggestions for future research.

While there are some existing personal interviews available for analysis (see Takemoto et al. 1975), little has been published that would be useful for an in-depth examination of human-nature relationships specific to the study area. Future studies of Maunalua Bay and its watershed that are guided by environmental history's focus on human-nature relationships could benefit from personal interviews with individuals knowledgeable about the study area. Personal interviews have the potential reveal ways that Native Hawaiian values contrast with the values of subsequent immigrant cultures to Hawaii (Europeans, Chinese, Japanese, Portuguese, Americans, etc.), and how these human attitudes and beliefs have shaped the way land was used and managed through time in the study area.

Land privatization in Hawaii had dramatic impacts on social structure and land-use, and provides a rich topic for environmental historians interested in focusing on localized trends over time. Analysis of mid-19th century land claims and awards in the study area could uncover cultural trends that have implications for land use, for example: What demographic trends can be observed in the size of land claims and their likelihood of being awarded? How does the size of a land grant affect its likelihood of being developed? What broader cultural explanations are there for Native Hawaiians deciding not to file land claims? On what basis were land claims awarded? Who was awarded claims and who was denied? Exploring the processes, values, attitudes, and implications surrounding land privatization in the study area could provide a useful backdrop to understanding the present state of the Maunalua Bay region.

The Hawaii Kai development provides a centralized example of the implications of residential development in the region. With the benefit of hindsight, one could explore whether or not the stated goals of the project were realized (e.g., affordable housing and job creation), and discuss who benefited and who lost as a result of the Hawaii Kai development. Since environmental historians are interested in the perspectives of minorities and those not in positions of power, exploring the perspectives of those displaced by the Hawaii Kai development might help uncover an untold story of the region.

Along with overfishing, pollution, and coastal development, climate change will continue to affect the ecological health of shallow coral reef ecosystems (ENS 2005). One possible avenue of research for environmental historians is to examine how Maunalua Bay's coral reefs are likely to respond to predicted levels of climate change. Does the past offer clues as to how near-shore marine environments in the study area will respond to climate change? What are current perceptions about mitigating marine ecosystem damage caused by climate change? Who will likely benefit and who will likely lose if the predicted ecological changes related to climate change take effect in the study area?

Finally, conducing research and writing about Native Hawaiian perceptions is inherently problematic for an outsider, or a person of non-native descent. Hanlon (2003) proposes that the results of academic research on historical topics typically reflect a European understanding of social structures, race, evolution, and progress. Native Hawaiians have many ways of understanding, defining, and transferring historical knowledge (Hanlon 2003). In the process of constructing a western-style academic narrative on Native Hawaiian history, much can be lost or misunderstood when translating the historical perceptions of another culture (Thaman 2003). Future studies of local Hawaiian history with a post-colonial perspective could help to unravel the cultural, temporal and physical distance between the western academic methods of constructing history and the perceptions of the Native Hawaiians of the past and present (Hanlon 2003; Thaman 2003). Analyzing Native Hawaiian methods of learning, understanding, and organizing information would provide a counter to the narratives written through a western-academic lens of perception, and provide an important contribution to environmental history (Hanlon 2003).