‘IKE I KE AU NUI, ME KE AU IKI: MANAGEMENT IMPLICATIONS IN COMPLEX SOCIAL AND PHYSICAL SEASCAPES OF HAWAI‘I ISLAND

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Keywords: seascapes, local knowledge, scale, Hawai‘i, surf quality

DEDICATION

ʻIke i ke au nui me ke au iki, he alo a he alo

Knows the big currents and the little currents.

– *ʻŌlelo Noʻeau 1209*

In the native Hawaiian worldview, knowledge is treasured and valued. Accumulated knowledge is gained orally from elders and visually/sensually from the environment. This proverb signified that knowledge cannot be claimed if you only understand your small window; true knowledge has to also include the larger perspective (and vice versa). He alo a he alo translates as "face to face", and it is within this transfer of knowledge from one to another that I base this work. I came before my community wanting to hear their stories, understand their seascape, and from this begin to understand their relationships and appreciations of our precious coastline.

To be truly "knowledgeable" in the sense of my native Hawaiian community, I feel the need to have a much broader understanding and experience in multiple disciplines. As this quote implores, we need to dig deep to understand the larger implications, as well as out to see the appropriate local based solutions. As a native Hawaiian researcher, I want to swim in the big ocean yet be intimate with my own coast; I want to succeed and help protect our entire planet yet ensure that my island surrounded by the kai hohonu is healthy and abundant for future generations to inherit.

My inspiration, my foundation, is Hawaiʻi. I mahalo each and every one of you that has journeyed with me. As all currents must flow, without a start or end, without edges, so has my journey included innumerable people. To honor each of you, I honor our Hawai'i, and devote my actions to a pono future. Love always flows forward to my parents (Judy and Gary Puniwai) and kūpuna (Puniwai, Correa, Carvalho, Tavares, Kimi…), laterally to my siblings (Iwalani, Napualani, Kehaulani) and kāne (Lloyd Ganoot) and through us to our keiki (Ilihiaikapohu, Kaʻōnohikauiluna, Kaʻōpualani) and all our future generations.

Ua mau ke ʻea i ka ʻāina i ka pono

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ABSTRACT

Cultural seascapes are coupled systems that integrate both the physical dimensions of ocean and coastal areas, as well as the meanings humans ascribe to their observations, interactions, and relationships to the coast. In Pacific Island communities, the interactions between physical dynamics and social dynamics are particularly important given that coastal areas are: (1) socially valuable and contribute considerably to the well-being of coastal communities, (2) economically valuable where ocean industries meet land based management regulations, and (3) are threatened as our climate continues to change. Recognizing the complex physical and social seascapes of Hawaiʻi Island, I present three ocean management scenarios in which the biophysical processes in the marine environment are analyzed qualitatively and quantitatively through both human observations and instrumented sensor networks. I suggest that managing complex seascapes requires the integration of both human and mechanical observations to ensure that multiple systems of knowledge are included and valued; strengthening our understanding of seascapes and their resiliency in this changing climate.

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PREFACE

This dissertation is situated within “my community” of Hilo, Hawai‘i. I am born and raised on Hawai’i Island, and trained academically in natural resource management with a focus on marine science. “My community” can be defined in many ways depending upon individual context and perspective. In the dedication of this dissertation, I talk about my cultural foundations within the native Hawaiian community of Hilo, Hawai‘i. I use many references throughout these chapters that elude to a cultural foundational philosophy based on my native Hawaiian culture. Although I don’t discuss, compare, or contrast the values and perspectives of Hawaiian culture in this dissertation, I position my research within this community.

In chapter 2, I focus my research on the ocean observer community. I use the singular version of community to reflect my perception of their shared values and norms in regards to the ocean. Although this ocean observer community is comprised of many native Hawaiians, and others that may associate with the Hawaiian culture, I do not attempt to compare or contrast their ocean knowledge with cultural norms. This particular question is very interesting, as is the deep ocean knowledge held within native Hawaiians, and will hopefully be addressed in the future, by myself, or other such “inside” researchers.

In chapter 3, I continue my research in my community, yet the context has shifted to the community of coastal resource managers and scientists of Hawai‘i Island, of which I have been trained within, and the implications of our research on the management agencies and coastal communities of Hawai‘i Island. This may be a very different type of community, yet I use this research to highlight the bias of research that occurs within isolated “communities” and the implications of forgetting to assess scenarios from various perspectives.

In chapter 4 I focus on surf culture, of which I do not quite belong, yet that which has been well defined, both here in Hawai‘i, as well as worldwide. I tried to classify the surf community through tested demographic and specialization indices, but was largely unsuccessful. This shows that much work still needs to be done to understand recreational communities.

I move within these communities and overlapping cultures walking carefully as a boundary extender. As primarily an insider to most of these communities I am aware of the community dynamics, community concerns, and appropriate practices in which to work within. I find this boundary both purposeful and challenging as I try my best to represent each of these communities, and their valuable knowledge systems.

This thesis was designed to cross-boundaries between social and physical sciences to address management scenarios pertinent to my island of Hawaiʻi. I use the concept of seascapes to be a connector across the land-sea boundary, but also a connector across physical and cultural definitions of a place. I chose three separate management scenarios in which to test my ability to design and implement projects across these boundaries.

The three research chapters are therefore independent management scenarios and directed at various audiences for publication. Chapter 2 was submitted for publication in Human Ecology. Chapter 3 was accepted and published in International Journal of Geo-Information. Chapter 4 is intended for submittal in Environmental and Regional Change. The structure and audience of each chapter is written as an independent research paper and directed at readers within the intended journal. I apologize that this dissertation may not read smoothly as a traditional dissertation may, yet I challenge you to see how I believe there is much to be learned from these vastly different topics.

CHAPTER 1. INTRODUCTION

Natural resource management seeks to understand complex social-ecological interactions (Folke et al. 2005) in which integrated research is argued to be the answer to addressing the full complexity of environmental problems (Miller et al. 2008). Integrating different epistemological knowledge systems results in a more complete understanding of social-ecological issues and validates multiple ways of knowing (Aluli-Meyer 2008). Yet the production, interpretation, context, and valuation of knowledge are socially influenced and encompass layers developed in culturally complex environments, making knowledge not only complex but inherently personal (Raymond et al. 2010, Menzies 2006). Ignoring differences within and/or across perspectives has shown to be counter-productive in reaching management goals (Rotarangi and Russell 2009). A preemptive approach, however, can include an understanding of what is valued in each ecosystem, and by whom, therefore making management a complex, yet effectively local phenomena (Alessa et al. 2008). What is needed for the future of natural resource management is engagement with people's knowledge within their personal contexts to increase social capital in managing the future of our environment (Pretty 2011).

Coastal systems worldwide are areas of high productivity that contribute considerably to well-being of coastal communities. Understanding the dynamics of these areas in a manner that supports management decision-making, however, remains difficult given the complex interactions between human, biological and physical processes. This is especially true for nearshore environments where there is high overlap between social (fishing, transport, recreation, etc.) and ecological (upwelling, primary production, maintenance of juvenile habitat) processes which make governing these areas difficult (Crowder et al. 2006). In Hawai‘i, an entirely coastal state, nearshore processes are vastly understudied yet are undergoing constant flux in the current climatic conditions.

Science alone will not solve the environmental degradation problems seen today. Understanding the mindset of the community that interacts with each place will give meaning to that space and with meaning comes value. The problem in natural resource management is not the “lack of science” but the inability to understand the public perceptions and valuations of coastal and marine resources. Endter-Wada et al. (Endter-Wada et al. 1998) propose that data or science polarize stakeholders around plans and management actions. Understanding the social factors that underscores the values of these resources however will illuminate that resource use conflicts are not the source of division between stakeholders but the result of different values placed on these resources (Toupal 2003).

1.1 Seascapes

In the Pacific, the significance of the ocean is embedded in the language, in actions, and in the seascape (Ingersoll 2009). The idea of a seascape is complex, but it captures the sea and coastline as a cultural space and not a vast, empty expanse (D'Arcy 2014). Cultural seascapes are the multiple realities of a broad range of values, meanings, and assumptions that individuals and social groups place on the marine environment, where human relationships with the ocean are created. Similar in theory to cultural landscapes, “Culture anchors a people to a space-based reality” (Kanahele 2012), and it is this connection to place that provides meaning (Cheng et al. 2003). Knowledge regarding the seascape is all but invisible, erased with the movement of currents and passing of generations. When fisherman no longer use the seascape it will turn back to a ‘sea wilderness’ (Maurstad 2004).

Mental models about seascapes are one way to represent what is seen (or perceived). The mental map that fisherman use to find fish within a seascape and the homogeneity of these maps among fisherman may or may not be analogous to maps that others think of regarding the seascape. Mapping local knowledge therefore can be thought to encompass not only physically drawing lines on a paper, but understanding the mental models that exist in a shared knowledge framework based on their worldview. Management needs to consider this significant cultural variation by acknowledging and understanding the social and natural stories of a place.

1.2 Goals and Objectives

This dissertation addresses the intersection, miss-match, progress, and possibility of integrating multiple knowledge systems in three different seascape management scenarios in Hawai‘i. Understanding that the ocean is a central element in the lifestyle of Hawai‘i residents, I have focused my attention on the biophysical processes of the ocean and the interaction of communities with the ocean. To understand community ocean knowledge, I have interviewed and/or surveyed ocean users in Hawai‘i, a culturally diverse group that I *a priori* predict differ in perceptions and relate to the ocean in varying spatial and temporal dimensions. To complement and enhance the community conversation on the biophysical conditions of the Hilo marine environment, I also included datasets and models developed for this region from sensor networks in place.

The goal of this research is to understand biophysical processes in the marine environment qualitatively and quantitatively through both human observations and instrumented sensor networks (Figure 1.1). The following three chapters were designed to integrate varying levels of social and physical dimensions of the seascape as examples for coastal resource managers.

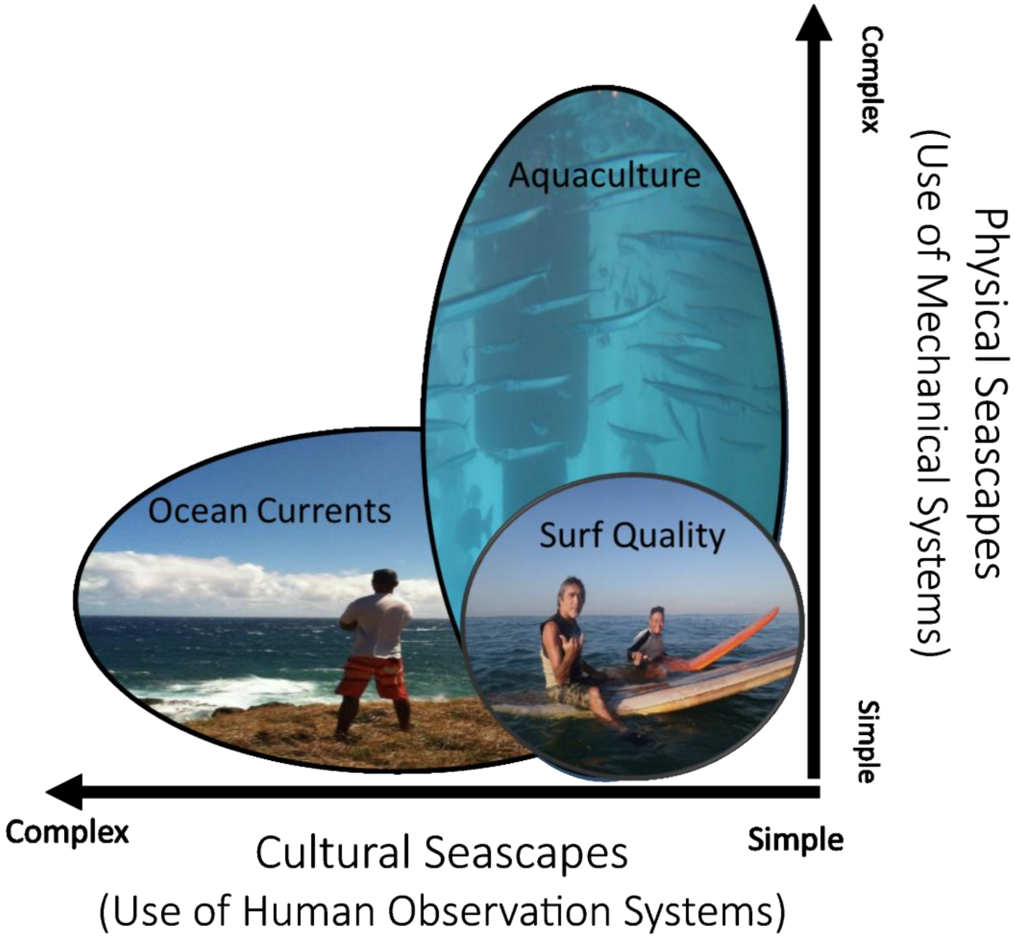


Figure 1.1 Scalar approach to understanding complex social and physical seascapes integrating both mechanical and human observations.

1.2.1 Mapping Ocean Currents through Human Observations

Complex systems, such as ocean currents, occur at multiple temporal and physical scales and need to be analyzed simultaneously across a range of geographic scales (Berkes 2009, Caselle et al. 2010). Presently, there are few available nearshore current maps or models accessible to managers or the public in Hawai‘i despite the fact that predicting nearshore currents and processes is important for understanding many other social-ecological interactions and the impact of climate change. I compared the scales and nature of human observations on ocean currents with instrumented sensors to understand the miss-match and possibilities of integrating these knowledge systems.

1.2.2 GIS as a planning tool for aquaculture development

Effective development along shorelines and in near shore waters requires the integration of physical, environmental and social factors in determining locations with minimal impact and highest return. The integration of these factors assume congruence of scale (spatial and temporal), robust, comprehensive and complete spatial data, and models that understand relationships within the system. Nearshore aquaculture on Hawaiʻi Island was shown to be limited by social and physical factors (prior development, depth of water, locations of harbors) yet also strengthened by the adaptability of social systems (scale of operations, highest potential located near other developments).

1.2.3 Projections of Surf Quality with a Changing Seascape

To anticipate the implications of future climate scenarios, the key resources communities need and value need to be understood. Biophysical values that describe the environment are readily available from in-situ data sources such as wave buoys, stream, rainfall and wind gauges. These same values are monitored by ocean communities through their daily interactions along the seashore and in the ocean. Understanding how these resources have, and have been perceived to, change in the past can assist in forecasting resilience, adaptability and future conditions. In this final chapter I implemented a survey designed to elicit hindcast and forecasts of surf conditions from surfers at Honoliʻi Bay.

CHAPTER 2. MAPPING OCEAN CURRENTS THROUGH HUMAN OBSERVATIONS

2.1 Abstract

Maps are symbols of our collective knowledge frameworks, representing various geographic areas and features that humans utilize. Maps of coastal ocean currents are hard to create because of their constant change and the limited availability of nearshore data. My objectives were to understand human observations of nearshore ocean currents and their ability to communicate this knowledge. In Hilo Bay, Hawai‘i, I asked 30 experienced ocean users, based on their observations, to create ocean current maps that share their knowledge of the seascape, and important processes that define each area. I then compared the scale of human observations of the seascapes with *in-situ* automated coastal observatories. Ocean observers were able to communicate their knowledge on ocean currents on maps at multiple spatial scales, and all observers commented spatially at a 1:5,000 map scale. Understanding differences and similarities between the human observation scale and the *in-situ* automated observatories enable a more complete understanding of small-scale oceanic environments.

2.2 Introduction

Humans have a unique capacity to process, encode, store, and retrieve environmental information they encounter as they engage in the complex activities that comprise their daily life (Scott 1998). This metis is especially true for communities that rely heavily on, and interact frequently with, complex ecosystems for their subsistence, commercial or recreational activities. Success in these activities requires mentally structuring physical environments and identifying ecosystem processes that are relevant to a certain activity or practice and that are reinforced and assigned meaning over time. Little is known, however, about how different types of human activities or practices influence the scale and type of information that is encoded and used by communities (Egenhofer and Mark 1995).

2.2.1 Knowledge Systems

Environmental knowledge is complex and inherently personal. The production, interpretation, context and values of knowledge are socially influenced and encompass layers developed in culturally complex environments (Menzies 2006, Raymond et al. 2010). Humans create local knowledge in the practice of daily life, and in response to a constantly changing natural and human environment (Scott 1998). Coastal areas, systems that lie at the interface of both marine and terrestrial forces, are examples of such changing environments where humans often play significant roles (Halpern et al. 2008). Tidal changes, seasonal fluctuations of foliage and marine life, resource collecting, trade winds, river flow, and ocean roughness are all examples of environmental phenomena that are experienced differentially based on the value or interaction humans have with these processes.

Knowledge is gained through repeated exposure, and findings shared through generations, both via written word and oral dialogue. The reliance of local knowledge on oral transmission is not merely based on lack of resources, but through recognition that an oral dialogue is responsive to the mutuality of knowledge and the difficulty in condensing into rules and codes what one has learned through practice (Scott 1998). Oral dialogue may include stories, legends, and chants, a common way of encoding practices and environmental processes (Johnson et al. 2005). Knowledge based on sensory experience, where accumulated intuition is used to define/regulate actions, differs from hypothesis-driven scientific methods that seek explanation of why things occur. In fact, partially as a way to help bridge the divide in interdisciplinary environmental research, academics have recently acknowledged the value of different ways of understanding social-ecological systems and begun to develop epistemic typologies in terms of how knowledge is generated (Miller et al. 2008). A simplified framework by Miller et al. (2008) shows that knowledge can be characterized through metaphors such as mechanistic, contingent or narrative knowledge viewpoints. These knowledge metaphors define disciplinary boundaries and the ways in which research questions are approached.

With developments in epistemic pluralism, researchers from many fields have begun to see how epistemologies are useful for understanding our environment and how different forms of knowledge can be integrated (Miller et al. 2008). Integrating different knowledge systems results in a more complete understanding of social-ecological issues and validates multiple ways of knowing (Aluli-Meyer 2008). There are vast quantities of knowledge that are not captured by scientific processes but are more personal and “mentally modeled” by individuals within a physical place (Gray et al. 2012). Mental models give meaning to places, organize our navigation through space, and tend to be functional (Jones et al. 2011). These mental maps of local knowledge can be complex, are often spatially explicit, and assist cultures in their exploration and settlement (Eley 2001, Brattland 2013). The observations required to process the vast quantity of data emanating from the environment allows only intent and focused audiences to understand and simplify the quantity of information that they are absorbing.

Humans who are natural observers synthesize information into variables in their mental models, similar to the variables used in data collection and computer models from mechanical instrumented conventions. Interacting/discussing with observant and immersed individuals can help us bridge these two worlds and understand which processes are important to those who are regularly active on the seascape.

2.2.2 Seascapes

The idea of a seascape is complex, but it elevates the fact that the sea and coastline must be seen as a functional, cultural space and not a vast, empty expanse, or just a physical location (D'Arcy 2014). The use of the term seascape in academic literature has primarily been limited to defining the biophysical habitats of marine organisms however recently this term has broadened to include geographical, cultural, and ecological components (Musard et al. 2014). A socio-cultural perspective of a seascape, or cultural seascapes, encompasses the broad range of values and meanings that individuals and social groups place on salient features of the environment. “Culture anchors a people to a space-based reality” (Kanahele 2012) and the sea is home to many cultures still surviving and connected to place today. This view of a seascape acknowledges that human activities, interactions, and values continually shape the seascape (Farina 2000) just as the seascape shapes our cultural perspective. However, seascapes provide very little long-term proof of their physical variations and change (Maurstad 2004).

Detailed knowledge of the socio-ecological seascape is of interest to natural resource management as managers are tasked with mapping and managing human uses and values (McLain et al. 2013). Mental models may include spatial observations and personal experiences, but also social relations, histories, events, and memories associated with those locations (McLain et al. 2013, McKenna et al. 2008). These models may include both the working memories and long-term memories that people use to understand their environment and also to “act” (Jones et al. 2011). Socio-ecological communities can therefore be identified through these spatial configurations.

Mental maps of the seascape represent what is seen (or perceived) which can be spatially represented in a map (Sletto 2009). The spatial and temporal mental maps that fisherman use to find fish within a seascape, and the homogeneity of these maps among fisherman may or may not be analogous to maps that we think of regarding the seascape. Cartographic practices based on contemporary technologies and Western philosophies may contrast ownership ideas with those of indigenous peoples which holistically denote sea space and land space (Aswani 2010, Feinberg et al. 2003). Mapping local knowledge therefore can be thought to encompass not only physically drawing lines on a paper, but understanding the mental models that exist in a shared knowledge framework. Cultural cartography recognizes that maps and the art of map making, both reflect and reinforce intrinsic values and beliefs (Rundstrom 1990). These need to be understood from the perspective of the socio-ecological community in which they were created. For example, little is known about the scales at which different user communities use and interact with the seascape and how their knowledge about seascape processes vary with this interaction (Freundschuh and Egenhofer 1997).

2.2.3 Nearshore processes

Coastline and nearshore seascapes are the best *ecologically* studied environment of the ocean because they are easily accessible to humans and easily measured with various sampling approaches. However, processes within the ocean are much harder to understand and examine due to the challenges of currents, pressure, and accessibility. Water circulation and movements have been studied at both micro- (within coral heads, and at short temporal durations) and macro-scales (sub-basins and gyres), but are not always easily studied across all scales because of economical limitations or highly-intensive field gathering components (i.e. stable isotopes, microwaves, high-frequency radar, satellite imagery, and drift cards) (Lumpkin and Pazos 2005, Shemer et al. 1993, Martin 2004, Pandian et al. 2010). Yet surface current information, which affects many other important parameters such as pH, nutrients, temperature, and salinity, “is one of the most sought after and difficult types of information to collect” (Morgan and Etnoyer 2002). Although nutrient and pH levels might be hard for humans to detect without instruments, other variables commonly observed such as currents, tidal heights, temperature, freshwater springs, as well as size and directionality of prevailing wind and swells are easier to detect.

Some ocean observers have daily, direct contact with this dynamic environment in which they have honed their observations and practice (Rundstrom 1990, Feinberg et al. 2003). Pacific Islanders in particular continue to enjoy the coast and spend a significant amount of time in this environment for recreational, spiritual, cultural, subsistence, economic, and career interests (Hauʻofa 2008). As such, these Pacific Islander communities have developed a sense of understanding and intimacy that modern oceanographers struggle to capture (Shackeroff 2011, Poepoe et al. 2001). The strength of Pacific Islander’s expert knowledge is in the processing and integrating of a large number of variables into simple language, facilitating the understanding of complex systems (Berkes and Berkes 2009). By integrating into a simple language there is potential for improving the information available to natural resource managers through the inclusion of this additional knowledge. The challenge, therefore, is to collect, assess, and communicate people's understandings of place and processes to include the complex physical factors such as winds, ocean currents, and rainfall.

In light of the difficulties in using human observing systems (HOS), coastal managers have relied on mechanical observing systems (MOS) and numerical models. In Hawai'i, visualization of the mechanical ocean observing systems and models are available through the Pacific Islands Ocean Observing System (PacIOOS: http://pacioos.org). Ocean currents can be depicted using high frequency Doppler radar (HFR), the Navy hybrid coordinate ocean model (HYCOM), and the Pacific regional ocean model (ROMS). HFR stations in Hawai'i Island are projected to collect data at 15 minute intervals at a spatial resolution of 30 m. These data are then synthesized and displayed at 1, 3, and 5 km resolutions on a 30 min average. HYCOM models ocean currents based on surface forcing and assimilation of satellite information and produces output at hourly, 10 km resolution. ROMS is an hourly forecast model with a 1 km spatial resolution around Hawai'i.

2.2.4 Objective

Understanding the full complexity of our environment requires engagement with multiple knowledge types (Miller et al. 2008) and specifically for natural resource management, within the context of their personal experiences to increase social capital in the future of our environment (Pretty 2011). However, the degree to which different knowledge types vary or have the ability to be translated or integrated is not well known. Through daily or continual contact, ocean observers have mentally modeled the movements of the ocean at spatial and temporal scales and variables important to their interactions, the Human Observation System (HOS). Ocean observer's mental models of local physical processes and their ability to translate this information are poorly understood. If public acceptance and adoption of human observations, the HOS, and/or mechanical scientific outputs, the mechanical observation system (MOS) is warranted, there needs to be a concerted effort to understand the applicability and potential inherent contribution of each "way of knowing." My three research questions are:

1) What is the scale of the HOS and how does it compare to the MOS?

2) Can this knowledge be communicated in a format useful for integration between HOS and MOS?

3) How does ocean knowledge differ across ocean users?

2.3 Methods

2.3.1 Site

I conducted this study in Hilo, Hawai‘i, a community of 43,000 residents with multiple cultural backgrounds. Hilo is a tractable case study site that includes both a human-observing system and a physical observing system, hosts multiple oceanic human activities, and represents long standing, multi-generational communities. The Hilo shoreline has a diverse physical and ecological environment, leading to a variety of ocean activities (Hawaii Office of Planning, Coastal Zone Management Program 2013), and is the most accessible shoreline for roughly 100 miles in either direction. Hilo Bay has been the topic of many past studies on circulation, tsunamis, cultural heritage and has a deep oceanic history extending back centuries (Flament et al. 1996, Gibbs 1977). Within Hilo, rain, wind, and stream gauges have monitored the environment for approximately four decades, yet within the ocean there is only a single wave buoy to measure the ocean swell strength and direction and provide estimates for the entire eastern shoreline.

Three coastal seascapes were chosen for this study: Honoli‘i, Hilo Bay, and Keaukaha. At Honoli‘i a perennial stream meets the ocean north of the break wall extension and is a popular surf spot (Figure 2.1). A lifeguard has been stationed along the shore daily during daylight hours since 1985, with estimates of approximately 200 beach-users present daily (County of Hawaii Lifeguard Counts, 2015).

Hilo Bay starts just south of Honoli‘i and is composed primarily of a crescent black sand and cobblestone beach stretching between two river mouths, Wailuku and Wailoa. The site of destructive past tsunamis, the bay has been designated a county park and hosts outrigger canoe and sailing clubs. An estimated 1,000 paddlers use Hilo Bay annually (Personal Communication 2014). The Bay extends east within the break wall to include the port of Hilo at the eastern edge, moorings for sailboats and traditional sailing canoes, and numerous fishing spots.

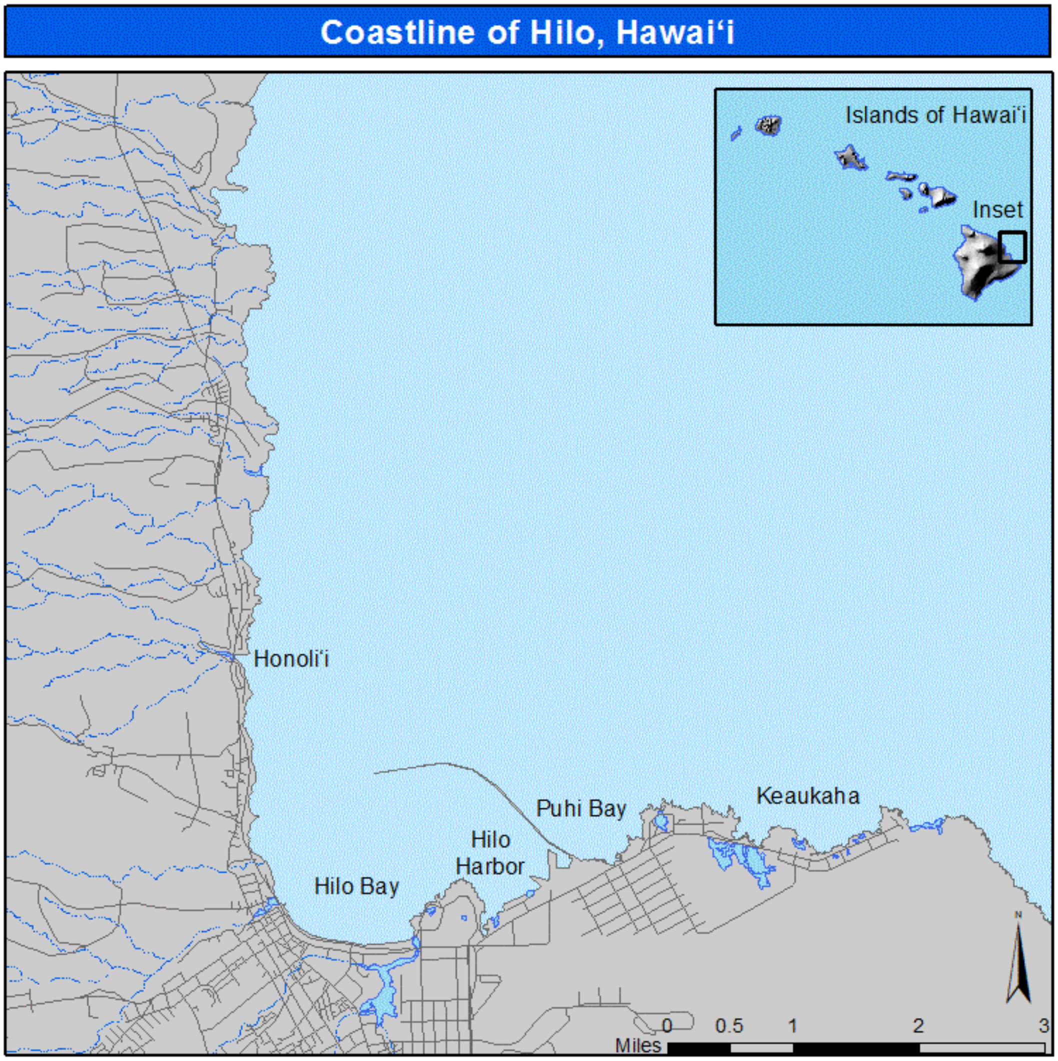


Figure 2.1. Map of Hilo, Hawai'i with areas of Honoli'i, Hilo Bay, and Keaukaha noted. Streams and freshwater ponds are shown in blue.

Outside the break wall, Keaukaha is the coastal community along the shoreline. Keaukaha is largely a shallow rocky coastline, with pockets of intertidal embayments with large freshwater outputs. Numerous county parks are located along this coastline, and it is a popular site for fishing, swimming, diving, and occasional surfing.

2.3.2 Data Collection

To address my research objectives I used semi-structured interviews along with the presentation of satellite images of the shoreline on paper maps. To identify ocean observers I began snowball sampling by speaking with individuals well known within the ocean user communities (Davis and Wagner 2003, Shackeroff 2011). I was raised in this community and have been active within these ocean communities for the last two decades. I then conducted semi-structured interviews with highly recommended individuals (mentioned more than three times with confidence) to include a broad range of seascapes. Each interviewee was also given a demographic and ocean-use activity survey.

2.3.3 Interview process

In the fall of 2014, I contacted each ocean observer and organized between 15-45 minutes for each interview. The semi-structured interview had two parts. I audio recorded all interviews, and began the conversation by asking questions about their observations of ocean movements and currents. I asked interviewees to expand on this by including patterns of changes, important variables to ocean currents, the context in which their knowledge was formed, and the way they observed these forces. Additionally, I gave them each a map and asked them to represent their ocean current knowledge on the maps. Each individual was invited to select the map scale most analogous to the scale of their interactions and to document any spatial knowledge. Color maps printed on 8 ½” x 14” plain paper were available at five different scales, 1:1,000,000; 1:100,000; 1:20,000; 1:5,000; and 1: 2,500 (Figure 2). Each map included an aerial and/or satellite image, streets and coastal names, isobaths, a scale bar and a reference map. Each interviewee received an untouched paper with no prior markings.

Over a six month period, 75 individuals were approached for recommendations of people with high levels of ocean knowledge along the Hilo Bay coastline. Of 50 individuals recommended, only four individuals were mentioned more than three times by unrelated individuals; two lifeguards and two paddling coaches. All ocean observers contacted were willing and enthusiastic to share their stories and knowledge. I contacted and interviewed thirty individuals between July and December 2014, ensuring a high representation for all areas within Hilo Bay and from within each ocean activity community. Analysis of each interview on a scale of one to five revealed that ocean observers ranged in ability to share their knowledge on ocean currents (Table 1). Based on responses to the frequency of ocean activities data and recommendations by associates, each individual was categorized within a dominant ocean activity of surfer (n = 10), fisher (n = 10), paddler (n=5), sailor (n=2) or other waterman (n=3, none of the common ocean activities listed).

2.3.4 Data Analysis

All interviews were then transcribed and imported into QSR International's N-Vivo10 software for coding and analysis to identify major themes and respondent confidence. Grounded theory was used to categorize the range of ocean observer ability to describe ocean currents, employing an independent second analyzer. All maps were scanned at a 300 dpi resolution and the digital images were georeferenced through image-to-image registration with the previously georeferenced satellite imagery, ensuring that average RMS error was < 5 m within a geographic information system (GIS; ArcGISv10.2). After georeferencing, the current lines were traced using on-screen digitization techniques within the GIS that created polylines from each interview (Aswani and Lauer 2006). Data were analyzed using Microsoft Excel.

Figure 2.2. Maps of Hawai'i Island presented to ocean observers at five different scales.

2.4 Results

Recommended interviewees were primarily male (86%) and had a mean age of 48 years. Ninety percent have lived in Hilo for more than 19 years and two-thirds were of Hawaiian ancestry. Although most surfers focused on Honoliʻi, a few did elaborate on areas in Hilo Bay and Keaukaha. Likewise, although most paddlers talked primarily about Hilo Bay, a few did include currents along the Keaukaha coastline. Fisherman talked of both Hilo Bay and Keaukaha. Generally surfers comprise the youngest group while fisherman were mostly elder. Frequency of ocean activities ranged from “don’t participate” to “participate everyday” with all activities being conducted by at least one of the observers one to two times a week except free diving and jet skiing. Four observers (12%) were engaged in three or more ocean activities 1-2 times per week or every day.

Table 2.1. Range in confidence of ocean current knowledge as expressed by ocean observers during interviews (N = 30).

Ability to Communicate Ocean Knowledge	n; Activity Type	Quotes from Interviews
Limited Ability	9; 1 Other, 1 Paddler, 2 Surfer, 5 Fisher	“Like I notice when the river is really strong coming out and when like the high tide is coming out.”
General Verbal, Not Mapped	4; 3 Surfer, 1 Other	“I would think it depends on the months too. I didn’t track the months actually, but different times of the year, the winter, the summer, spring.”
General Verbal and Mapped	5; 1 Fisher, 1 Paddler, 1 Sailor, 2 Surfer	“I wouldn’t say my knowledge on the currents is, you know, is large, but I do know the basic current outline over here in Honoliʻi you know.”
Detailed Verbal, Not Mapped	3; 2 Fisher, 1 Other	“Okay, yeah. No I don’t know how to draw that kind current.”
Detailed Verbal & Mapped	8; 1 Sailor, 2 Surfer, 2 Fisher, 3 Paddler	…Q: How far would you say that this current is? “It’s probably about a 100 yards out. “

2.4.1 Temporal Scale

When asked to share their knowledge on ocean currents, ocean observers were specifically requested and reminded in the interviews to frame their recollections during specific timeframes. The interviewer emphasized the importance of specifying the timeframes, seasons, years, or moon cycles the observer used in describing currents. Ocean observers indicated no significant patterns of change in ocean currents in their remembered past. Each of the maps created were described as a general current map, although specifics for the effects of tides or swell direction were described as appropriate, and many times on the same map. The completed maps therefore do not have a temporal scale familiar to most scientists as there may be many timeframes included in a single map. For example, the current map created for Honoliʻi shows where the swell direction comes from during particular times of the year. Surfers reading these maps were easily able to associate with the map information, substantiating that the compiled maps are able to reveal the everyday space that ocean observers move within.

2.4.2 Delineating Marine Space

When presented with choices of satellite maps in which to explain near shore ocean currents, ocean observers selected maps at all scales (Table 2.2). Eight maps at the 1:20,000 scale were completed by those respected for outrigger canoe knowledge and shoreline fishing. Observers that surf or swam everyday documented currents at the 1:5,000 scale. Five people commented on maps at two different scales, both of these described as being on the water in multiple ocean activities. Many of the observers explained verbally the currents before or while they drew them on maps, some were able to explain and understand the ocean currents, yet unable to document them on the two-dimensional maps.

Table 2.2 Scale and sites of maps selected and annotated by ocean observers (n = 19).

Ocean Observers (n)	Amount and Scale of Selected Maps
Surfer (6)	1:5,000 (7), 1:20,000 (2)
Fisher (5)	1:5,000 (2), 1:20,000 (6), 1:100,000 (1)
Paddler (4)	1:5,000 (3), 1:10,000 (4), 1:20,000, (6), 1:100,000 (2)
Sailor (2)	1:5,000 (1), 1:20,000 (2)
Other Waterman (2)	1:5,000 (2), 1:20,000 (1)

At Honoliʻi, ocean observers talked primarily about the influence of the river and ocean swell direction in creating the dominant current pattern. They described the current directions as relatively stable in this location, however the strength of the various currents fluctuated due to the influence of the river and ocean swell. Three of the interviewees were able to speak with confidence about this process, whereas the other six were more hesitant and most likely represented the general population of surfers and swimmers in their knowledge content. A map compiling all the ocean current knowledge shared for Honoli‘i was generated and shared back with the original interviewers and a few other surfers (Figure 4).

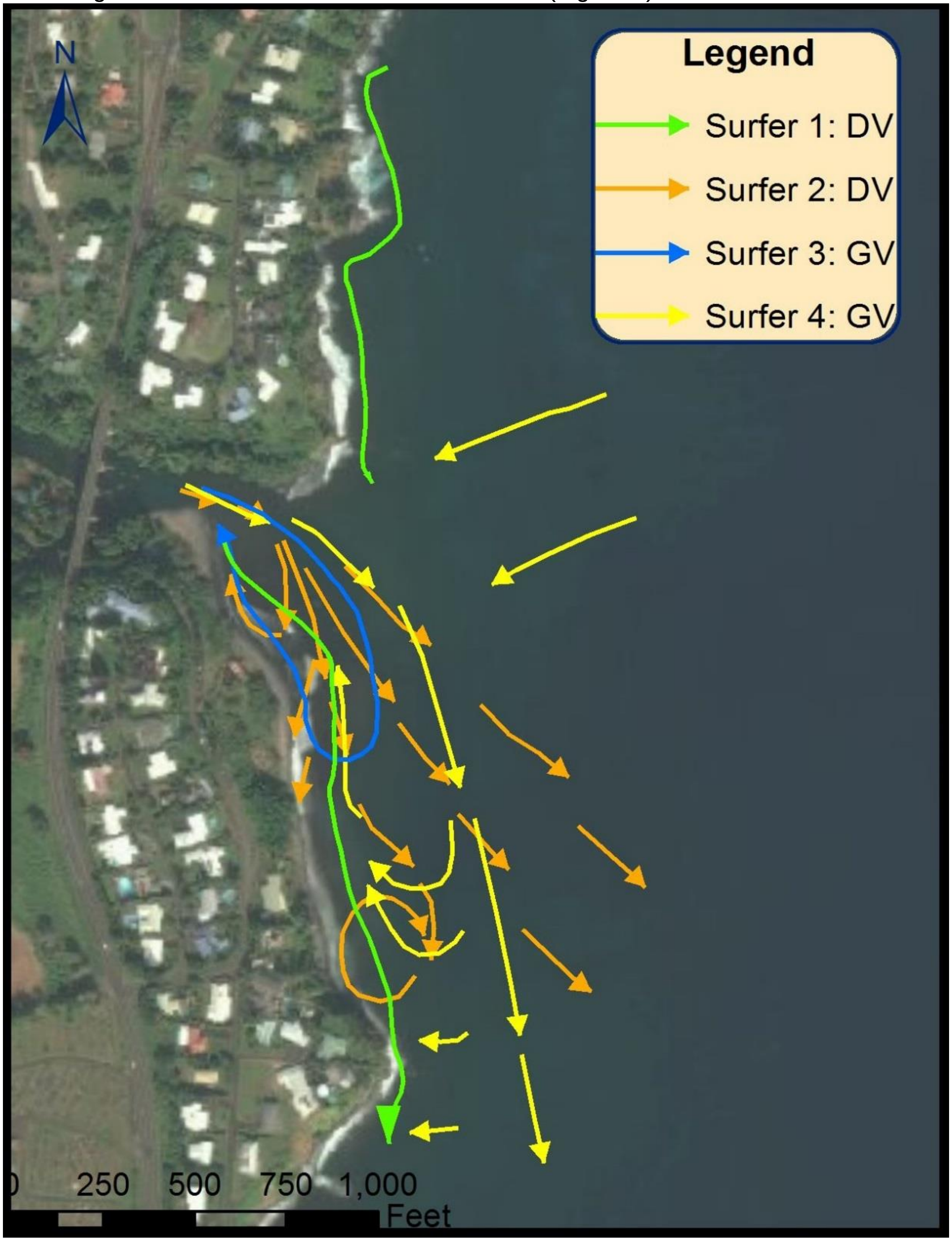


Figure 2.3. Currents alongshore Honoli‘i, Hawai‘i as described by ocean observers. DV – detailed and verbal observer; GV – general and verbal observer.

2.4.3 Observations of Near Shore Currents

Within Hilo Bay, a clockwise current pattern was described by paddlers, sailors, and a few fishers. Although they did not boast as much confidence in their observations as did the surfers, in general they shared similar recollections and could speak about some areas in Hilo Bay easier than others. Discussions regarding currents were not a regular topic for these ocean observers and they shared their hesitancy in recommending others with this knowledge. It was acknowledged that being on the ocean everyday does not make one observant, and only certain individuals take the time to observe, understand, and use the currents. Currents in Hilo Bay varied based on the river flow, dominant swell/wind directions, and tide/moon phase. Although the current was never described as reversing, different current lines would emerge based on these weather conditions. Some areas are known for having strong currents, and others are known to have little flow present. All of the ocean observers interviewed selected maps of Hilo Bay at the 1:20,000 scale and larger.

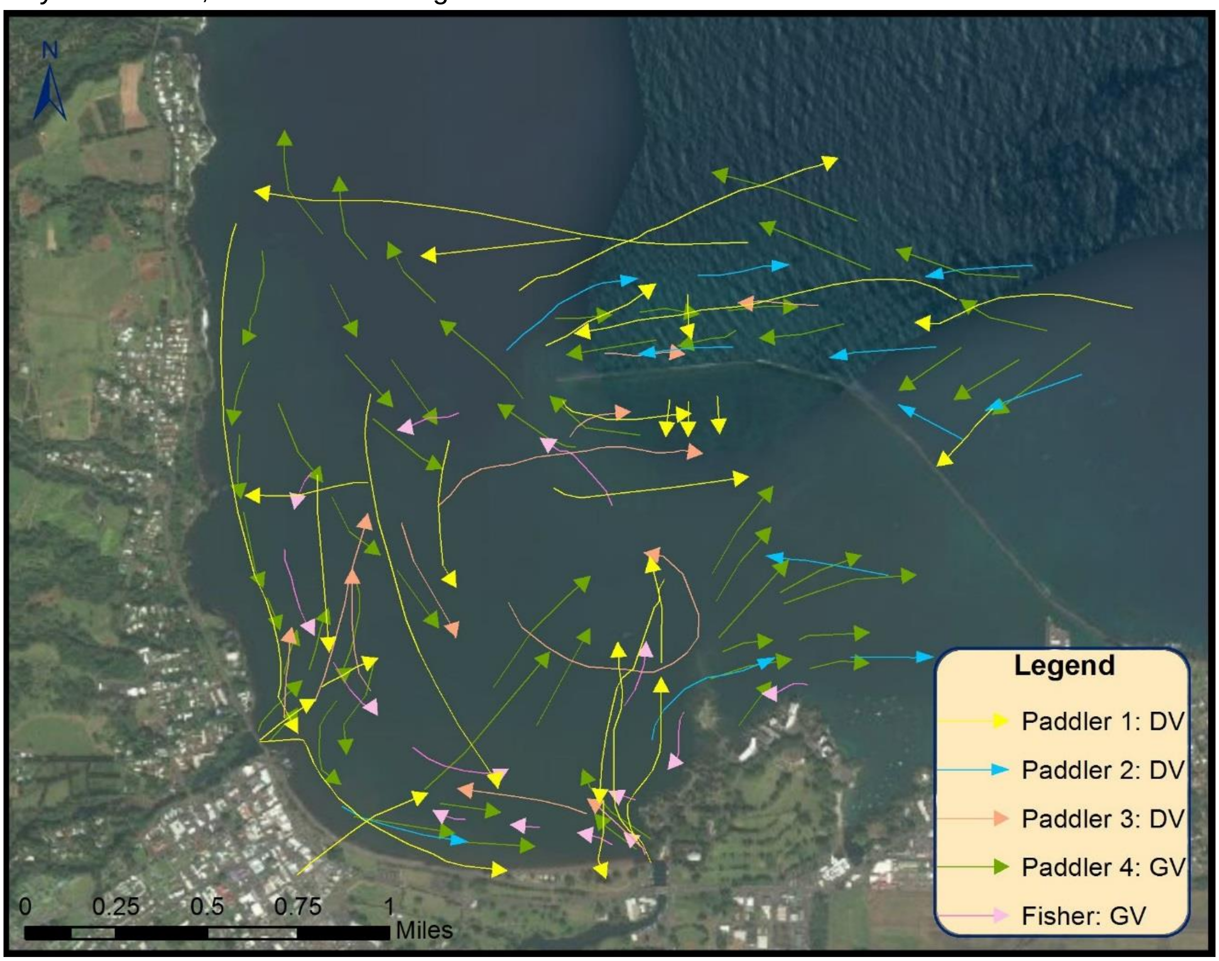


Figure 2.4. Observations of currents in Hilo Bay as mapped by ocean observers. DV – detailed and verbal observer; GV – general and verbal observer.

Along the Keaukaha coastline, general offshore patterns were described as following the trade wind flow at the large scale, 1:20,000. At a smaller 1:5,000 or 1:2,500 the currents varied and need to be described for each inlet and coastal area with no dominant pattern described. These currents were also described as being inconsistent and changing with the tide. Tidal currents could be strong, especially during changing tides, when freshwater coastal springs were flowing, and when strong swells from offshore flowed. No single individual was highly recommended that could describe all the bays along the coastline at the 1:2,500 scale, although a variety of people specific to places along the coastline were mentioned.

2.4.4 Process

Some ocean observers were interested and willing to share their experiences and knowledge gained while on the water. Their interactions with ocean processes occur at multiple spatial scales and the depth of their observations and scale at which they communicate ocean processes vary, yet ultimately can be shown to be useful for documentation. Although all of the ocean observers interviewed were respected and recommended, the context and timeframe in which they interact with the ocean are correlated with how well they observe different elements and variables of their environment.

2.5 Discussion

2.5.1 Feasibility

The maps generated by ocean observers are preliminary attempts at understanding local oceanic conditions from the viewpoint of humans that physically interact with this seascape. The process I used can serve as a model that oceanic data with specific temporal and spatial scales can be mapped with the assistance of ocean observers. Based on my results, once the appropriate network of individuals is identified, mapping can be directed to target the particular scale of inquiry in many locations where active ocean observers are present. As Alessa et al. (2015) have also shown, certain observers steeped in a place can create patterns from observations.

Mental modeling of oceanic processes occur in select ocean observers and can be shared with confidence (Alessa et al. 2015). The validity of the data is supported through the respect provided to each ocean user and in the constant testing and interaction with the ocean environment. Although it is uncommon to share these mental models in a verbal or mapped format, this exercise was feasible for some, but not all, ocean observers. Ocean observers were willing to engage in conversations regarding the ocean, because of their confidence in the knowledge and respect they received in the sharing of knowledge. Participatory processes build social capital in products such as modeled current maps and may lead to increased usage by ocean observers in the future (Menzel et al. 2013). Instead of investing continually in the latest technology, in rural and hard to access areas, mapping of local conditions by those who are connected with the resource can be a rigorous, accurate, and timely process. Additionally, data collection is a dynamic, iterative process in that updates to the data products can be created as changes occur or as more respected individuals come forward to share once the community becomes accustomed to and comfortable with the project and its data collection methods.

Surfers and lifeguards need to observe the ocean as a component of their recreation/occupation and are concentrated at surf breaks, making them easy to identify and target for interviews. Amongst surfers, the lifeguards are highly recommended for their observational skills, and a few of the older lifeguards in particular. Most paddlers are like many other serious recreationists and use their time on the water mainly for physical exercise. However those that paddle seriously over long time periods, and/or are steersmen or one-manners do use the ocean to their advantage. Knowing the dominant ocean swells and currents allows them to have a great experience and competence searching out the most energy efficient route through the seascape, which is what makes coaches respected for their knowledge. Coaches have to guide their crews and are known for their ability to choose a good course. Hence, many of the recommended ocean observers from the paddlers were all coaches or have paddled for more than 20 years.

Similarly, fisherman can be highly observant, and those that are highly respected are sometimes shy of communication yet show through action their skill and accumulated knowledge. Each type of fisherman (shore, net, boat, commercial, recreational, etc.) have different social groups in which they share their knowledge, and these may not overlap significantly (Barnes-Mauthe et al. 2013). They are also more hesitant to share or talk about their fishing activities because of their lack of trust with management agencies and objectives (Kaplan and McCay 2004). Yet I have shown that valuable data can be shared if a trusted local community member is involved in the interview process.

Through this preliminary process I have shown that ocean observers mentally map processes at different scales, and one way of identifying these different scales of interaction was by using ocean activity type as a variable of importance. Surfers and shore fisherman observe and interact with a limited spatial area of coastline and nearshore waters while boat fisherman and sailors interact with a large spatial area of ocean. This direct interaction with the ocean and not the temporal timescales of interaction seem to be important in their mental modeling of ocean processes in place.

2.5.2 Comparison of mechanical and human ocean observations

> "How I experience the world is different from how you experience the world, and both our interpretations matter. This is an important point as it… expands the idea of what knowledge is supposed to be and in truth is – vast, limitless, and completely subjective." (Aluli-Meyer 2008).

The map created to describe ocean currents at Honoliʻi differs from a map produced by models or radars because of the emphasis given to specific variables of importance to human recreationists. Surfers and paddlers focus on the currents that affect them the most: the dominant or regular currents, daily or seasonal variation in these currents, and adapting to the immediate current conditions they experience. Ocean observers only discussed currents which they had confidence describing and understanding. In no map did an ocean observer draw currents in which they had zero confidence or fill in space to make a complete raster map. Therefore many of the current lines ocean observers drew in overlapped with each other in the same areas (Figure 4), building confidence in the maps created. These maps can also be viewed as a consistency measure for normal ocean currents. Only those currents that flow regularly and with particular strength are remembered and represented on these maps. Weak currents are not depicted or described, which is in contrast to common oceanic models in which all areas are given a current value, regardless of the confidence or consistency in that value.

Automated models and observing systems are collected at distinct spatial and temporal scales as defined by the sensor or the theoretical model. These systems provide large spatial resolution and collect data about processes for which researchers later ascribe meaning or characterize dynamics. Conversely, human observing systems attend to the small scale and begin with cultural meaning (relevant to the activity) as a way to understand what processes should be encoded, or included in their mental models. Complexity at small scales make it difficult to map, but as we've seen, it is this small scale that is important to managers and ocean users.

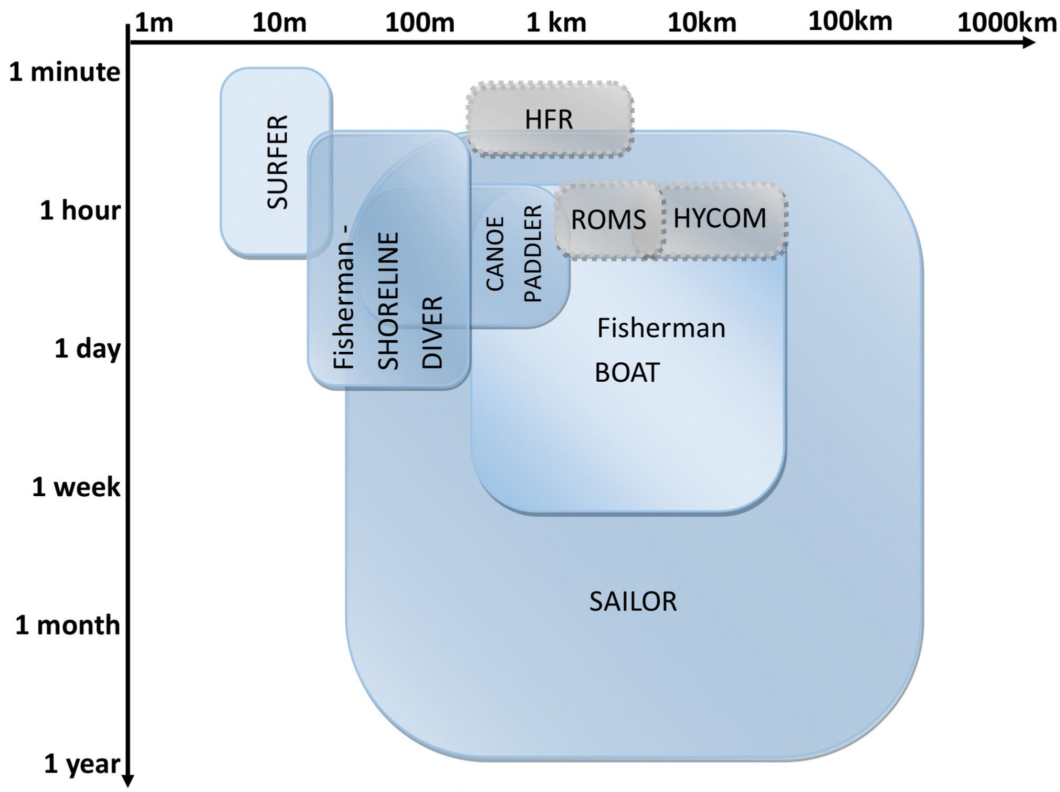


Figure 2.2. Resolution of initial observations by ocean observers; Gray - observations made by mechanical devices, blue represents human observations.

Comparison of these ocean observations scales with those collected by the Doppler radars and created by models show the spatial overlap and gaps of knowledge (Figure 5). Worldwide, most surface current information is derived from models, with the exception of recently deployed high frequency Doppler radars (HFDR). Models are available with a 15 m to a 9 km resolution and the HFDR at a 40 m resolution for selected areas along the coastline where transmitters are secured. As the information derived from these radars are not quality controlled, accuracy and generalization of their outputs is unknown. Doppler radars appear to have potential in providing appropriate spatial information on near shore currents to seascape participants when compared to other model outputs.

Spatial accuracy of the human observation maps is not currently understood as seen in the presence of contrasting current lines. In this research, sharing of the compiled maps did not occur, but to refine and further assess the accuracy and confidence that ocean observers had in their maps this should be the next step. Also, a HFDR has been recently installed for Hilo Bay, and direct comparison of human observation and mechanical observations can be implemented in the future.

2.5.3 Cultural Seascapes

The context and utility of local knowledge in natural resource management and environmental decision making has been growing and allowing managers access to not only the data, but the processes by which actors create this knowledge source, their mental models. I've shown that different ocean user groups, and/or practitioners' relationship to the ocean can be spatially viewed through many lenses. The seascape, the spatial and temporal scales of their knowledge system, is dependent on their interactions and their cultural lens. Even though surfers and paddlers spend upwards of three times a week on the ocean, they encode ocean processes in the same places at different spatial scales. Yet, the importance of interactions among knowledge holders, not just the sharing of the knowledge, creates the ability and capacity to integrate knowledge sources (Fernandez-Gimenez et al. 2006). As I've shown, ocean observers with the highest confidence in their knowledge on ocean currents and the most extensive knowledge interact with the ocean through multiple activities; surfing, lifeguarding, and fishing. It is this duplication of interactions at varying temporal and spatial scales that give them the confidence to understand the movements of the ocean in their mental models. Therefore, it is the mismatch in the scale of data sources that results in mechanical ocean models being irrelevant to most ocean observers. Managers needs to consider this significant cultural variation to gain a practical understanding of how a place is utilized socially/culturally and thereby optimize the relevance and utility of data products.

CHAPTER 3. DEVELOPMENT OF A GIS-BASED TOOL FOR AQUACULTURE SITING

3.1 Abstract

Nearshore aquaculture siting requires the integration of a range of physical, environmental, and social factors. As a result, the information demand often presents coastal managers with a range of complex issues regarding where specific types of aquaculture should be ideally located that reduce environmental and social impacts. Here I provide a framework and tool for managers faced with these issues that incorporate physical and biological parameters along with geospatial infrastructure. In addition, the development of the tool and underlying data included was undertaken with careful input and consideration of local population concerns and cultural practices. Using Hawaiʻi as a model system, I discuss the various considerations that were integrated into an end-user tool for aquaculture siting.

3.2 Introduction

3.2.1 Aquaculture and GIS

Rapid coastal development has increased concerns of sustainability and the compatibility of the multiple uses of marine resources. In particular aquaculture development, like other ventures that involve the use of public lands or resources, is seeing a rush of development interest, yet is subject to a complex and often confusing system of regulations at local, state and federal levels (Jarmon et al. 2004). Because coastlines are transition zones between terrestrial and marine environments, they have unique challenges both because of their physical nature and the way in which they are used and perceived by people (Jarmon et al. 2004; Fletcher & Neyrey 2003). Although frameworks that integrate the necessary biological, physical, and social dimensions for facilitating aquaculture planning exist, there is a lack of knowledge associated with the scale of these datasets, case studies that identify barriers to public decision-making, and how Geographic Information Systems (GIS) approaches can provide decision-support to resource managers, aquaculture industry representatives, and local community stakeholders.

The recent increase in aquaculture development is driven by large external factors such as population growth and an increased demand for protein, coupled with no efforts to slow fishing pressures across the world's wild-capture fisheries. By 2050, Food and Agricultural Organization estimates global population will reach 9 billion people, requiring a 60% increase in food production (FAO 2013). Although food consumption has risen, the amount captured through fishing has been stable for the last 20 years, with aquaculture providing 47% of all fish consumed, highlighting the role aquaculture has played in supplying the additional fish protein needed to meet growing demand. This growth in demand has been facilitated through substantial advances in recent years in breeding technology, system design, and feed sources (Bostock 2011; Klinger & Naylor 2012).

Although aquaculture production around the world is expected to increase along with the human population, the economic, social, and environmental benefits and costs of aquaculture continue to be debated by a broad range of stakeholders. Even with technological gains, such as refined fish welfare techniques and reduction of input-heavy production, many environmental, indigenous, and marine stakeholders worry about access, tenure, and sustainability of the resources (Gullet 2012). In fact, many stakeholders believe that the costs of aquaculture development are internalized locally and not felt by communities that consume the farm-raised species (Belton & Little 2008; Bergquist 2007; Rivera-Ferre 2009). One common issue often cited by local community groups is aquaculture's negative environmental impacts, particularly with marine and pond-raised fish farming (Klinger & Naylor 2012; Mazur & Curtis 2008). Cage farming can potentially result in waste offloads, introduction of alien species, genetic interactions, disease transfer, release of chemicals, use of wild recourses, alterations of coastal habitats, and disturbance of wildlife (Grigorakis & Rigos 2011). Similarly, environmental health risks associated with aquaculture may include elevated levels of antibiotic residues, antibiotic-resistant bacteria, persistent organic pollutants, metals, parasites, and viruses in finfish and shellfish (Sapkotaa et al. 2008). Environmental benefits, on the other hand, are mostly seen in the reduction of fishing pressure on these specific stocks due to the availability of farm-raised species as well as other commonly caught species. Understanding these costs and benefits, are further complicated for management agencies given regulatory permitting, and jurisdictional issues and who receives the benefit of development, taxes, and increased revenue.

In addition to reducing pressures on wild caught fish populations, research has also shown that there are a number of economic benefits associated with aquaculture, especially for communities in remote and rural regions (FAO 2012). For example, assessing the benefits of two different scales of aquaculture, Bergquist (2007) showed that small-scale aquaculture provides greater benefit to local communities while large-scale shrimp aquaculture has larger short-term benefits as well as environmental costs. Understanding how these costs and benefits exist in a spatially explicit manner is important when outlining the potential for aquaculture growth, and more importantly, in discussions with local decision-makers and where and how to implement aquaculture in different areas.

As a way to provide some decision-support to the complex issues of aquaculture and coastal planning, GIS is often used as a tool to develop spatially explicit approaches to natural resource decision-making scenarios (Nath et al. 2000). In the case of coastal areas, GIS can be used to balance divergent interests and has been applied in a variety of contexts including aquaculture, energy production, conservation, fishing, and recreation (Sanchirico et al. 2013). For instance, GIS has been used to comprehensively assess and direct aquaculture development worldwide, both inland in ponds and reservoirs, and in coastal areas in Ireland and China (Nobre et al. 2010). These examples required both sound scientific knowledge of species and habitats and an effective GIS geodatabase that provides the spatial component to integrate biophysical and socio-economic characteristics (Nath et al. 2000). However, data products that can support aquaculture decision-making across multiple stakeholder interests are generally unavailable, with the ones that do exist often developed for a specific client, thereby limiting the use of GIS as data product that can be used by a range of different stakeholders. Furthermore, there are a number of drawbacks that have limited the usefulness of GIS data products to date, including: (1) the amount of technical expertise required; (2) poor levels of interaction among GIS analysts, subject matter specialists, and end users of the technology; (3) continuity of GIS products and results; (4) communication of results back out to the community; and (5) the disconnect of researchers from the actual systems under study (Schuurman 2009; Weller 2009). Although such limitations have been identified, there is a need for GIS to play a larger role in enhancing the participation of community members in management decisions. Given such need, the goal of this study is to understand the benefits and limitations of using GIS in understanding aquaculture siting on the Island of Hawaiʻi in the context of marine spatial planning, integrating biophysical, regulatory, and social aspects.

3.2.2 Case Study: Aquaculture in Hawaiʻi

Aquaculture in Hawaiʻi offers an ideal case study to look at the complexity that surrounds aquaculture planning and the creation of GIS data that can be used by a wide range of stakeholders. Like many island communities, there is growing interest at the local, state, and federal levels in developing the aquaculture industry as it is already a significant contributor to the economy with more than 100 aquaculture farms in the State. Hawaiʻi County, located on

Hawai‘i Island, hosts about 75% of total aquaculture production in the state, with a highly diverse assemblage including ornamental freshwater and marine fishes, off-shore cage culture, two of the largest bivalve (clam and oyster) seed production facilities in the state, algae culture for food and nutraceuticals, and abalone. The aquaculture sector of Hawai‘i Island is also unique since it was one of the pioneering sites for the off-shore cage culture of marine finfishes (Kona Blue Water, Inc., Kailua, HI, USA) as well as hosting some of the most technologically advanced farms in the U.S. In addition, given its unique marine environment, aquaculture production in Hawai‘i County has the potential to utilize its 266 miles of coastline for off-shore cage culture of marine fishes, off-shore and near-shore culture of invertebrates (e.g., bivalves), culture of macroalgae, and production of non-food products (e.g., pearls), biofuels and nutraceuticals.

Future expansion of aquaculture in Hawai‘i presents managers with complex issues regarding siting given the significant use of the public nearshore and littoral (coastal) areas. Since 1986, leasing of nearshore areas has been legally possible, but remains fraught with difficulties. For example, site selection and orienting prospective investors is difficult as there is no single, unified database that can be examined or queried for these purposes. Even more problematic are the nearshore areas, as the ability to legally utilize them still lacks clarity and site selection is more difficult because of competing coastal uses, compared to off-shore aquaculture. Hawai‘i, as one of the few tropical areas of the U.S., stands to capture offshore investment as it offers large tracts of undeveloped coast line along with advantages offered by the U.S. legal system as compared to foreign nations where investment is still often risky. Development of a GIS database and tools which facilitate characterization of aquaculture sites based on technical, social, and legal implications would be the first step in allowing for identification of appropriate sites. In Hawai‘i, even though the aquaculture industry has roots in cultural traditions, development of a large-scale open ocean industry has been a controversial issue (Food & Water Watch 2010).

The collective choice rights of community members’ involvement in the process are an intangible part of the debate, although what is commonly touted and emphasized by external interests are the environmental effects (Food & Water Watch 2010). Successful suitability assessments depend on how the activities and interactions of the relevant interest groups are included in the analysis, and that the decision rules are constructed in a way that all of the stakeholders’ land use criteria are satisfied.

With increasing attention focused on Hawaiʻi Island's potential for open-ocean aquaculture, the objective of this study was to develop an interactive, user-friendly database to identify potential areas for nearshore marine aquaculture that can be used by a range of management, industry, and community representatives. I expected that this interactive database planning process would identify key needs and gaps for the County of Hawaiʻi and its partners in future research and economic development initiatives.

3.3. Methods

The suitability database was completed in nine iterative steps (Table 1), with each step including relevant stakeholders. In consultation with County of Hawaiʻi Research and Development officials, I identified the extent and scale of modeling. State boundaries extend from the upper reaches of the waves on shore seaward three nautical miles (HdoA 2010), the County of Hawaiʻi does not have any jurisdiction over this area, but does conduct permitting and zoning on adjacent land-based activities. Since waters outside state zone are considered Federal jurisdiction (the federal Exclusive Economic Zone), I limited the scope of the project to State waters, three nautical miles offshore. No zoning designations exist for locations seaward of the shoreline. After multiple conversations between County officials, and aquaculture development experts, a 100 ha matrix of hexagons were overlaid from the shore seaward resulting in the creation of 4504 unique cells. Each 100 ha hexagon included unique attributes for that given geographic location, creating a spatial extent where modeling took place. Hexagons have been shown to create a standard for integration of shoreline, discrete points and habitat scale information (Ferdana 2002) and a 100 ha size was deemed the appropriate resolution for modeling.

3.3.1 Aquaculture Systems

Appropriate aquaculture systems for nearshore waters of Hawaiʻi Island were identified as: (1) line culture; (2) intertidal/subtidal bottom culture; and (3) moored, caged culture by the experts and methodology described in Table 1. Cage culture is present in one location in Hawaiʻi and demonstration of line and intertidal/subtidal bottom culture exist throughout the tropical Pacific. A multi-sector focus in contrast to individual cultured species allowed us to model the potential of aquaculture without limiting ourselves to known species in production. Stage 3 in the model development consisted of a series of workshops where the literature was used to inform the identification of variables of interest (Table 2).

Table 3.1 Stages of model development.

Stage	Procedure	Source
1	Define extent, scale of nearshore area	Managers at the County of Hawai‘i, Research and Development office [1]. Aquaculture experts [2].
2	Creation of a marine aquaculture reference database	Literature search using keywords: aquaculture, mariculture, intertidal/subtidal, fishponds, cage culture, nearshore, modeling and multiple search engines
3	Define potential aquaculture systems	Aquaculture experts [2] on Island
4	Define biophysical limitations of each system	Aquaculture experts [2] on Island and Literature Search
5	Gather appropriate supporting data	GIS technicians & Oceanography experts [3]
6	Analyze scale, extent, and accuracy of data	GIS technicians & Oceanography experts [3]
7	Develop and run models	GIS technicians [3]
8	Analysis of results	Aquaculture experts, industry, and community members
9	Publication of results	Model results and supporting layers of information

The modeling team considered the potential to understand species or systems requirements and concluded that the largest limitation would be placed on the biophysical requirements of the technology and system, not on the biological requirements of a particular species. Biophysical system requirements, such as water quality, water quantity, and climate, were considered as well as socio-economic characteristics, such as administrative regulations, competing resource uses, and infrastructure support (Nath et al. 2000). Finally, social values were included as public resistance and support for new ventures have resulted in limiting current aquaculture development (Food & Water Watch 2010; Suryanata & Umemoto 2003).

A comparative case study of mariculture in Hawai‘i revealed that a large measure of public concerns focused on collective choice rights (who has a right to make which decisions on behalf of whom) and the more intangible impacts to the social or cultural environment (i.e., Suryanata & Umemoto 2005). Parameters that were considered possibly unfeasible for operations and/or permitting, but not an outright constraint, were included in a Cautionary Layer (Table 3). The bounding criteria noted with each of these parameters were researched and indexed to individual aquaculture system types as identified in the literature. This information was crucial in the creation of the model parameters, in understanding the scale of each dataset, and the subsequent ability to use the parameter in a specific model.

Table 3.2 Biophysical and socio-economic constraints to aquaculture development.

Biophysical Constraints		Socio-Economic Constraints		
Biological	Physical	Regulatory	Accessibility	Cultural Use
Salinity	Tidal	Marine Protected Areas	Distance to Harbor	Recreational Use
Turbidity	Wave Height	Fishery Designated Areas	Shoreline Access	Cultural Presence
Chlorophyll	Flushing	Recreational Areas	Shore-based Facility	Viewshed
Temperature	Wind Speed	Shipping Lane Buoys		
Oxygen	Current Speed	Military Dumping Area		
Pollution	Ocean Depth			
Living Features	Ocean Slope			
	Substrate			

Table 3.3 List of parameters excluded or labeled as cautionary from all nearshore aquaculture models including buffer distances and total area.

Excluded Areas	No. of Hexagons	Buffer (m)	Total Area (ha)
Mooring and Navigational Buoys	14	100	1400
Underwater Cables	26	500	2300
Sewer Lines	2	100	2000
Lava Zone 1	28	0	2800
Marine Life Conservation Districts (No Take)	20	0	2000
Offshore Installations	10	100	1000
Cautionary Areas	No. of Sites		Total Area
County Parks	Terrestrial		506
State Parks	Terrestrial		231
Federal Parks	1		93,655
Precious Coral Locations	3		(point data, no associated area)
Dolphin Resting Areas	14		(point data, no associated area)
Fishery Managed Areas	10		22,646
Ocean Designated Recreation Areas	2		280,313,442
Hawaiian Islands Humpback Whale National Marine Sanctuary	1		38,631
Identified Recreational Sites	202		(point data, no associated area)
Fish Aggregation Devices	10		(point data, no associated area)

Line culture in Hawai‘i is the raising of aquatic organisms on suspended, moored cables at depths ranging from 30 to 200 m. Common species raised in such systems include large algae, sponges, bivalves, and mollusks. Using the system parameters outlined in the literature and through technical expertise, I identified potential criteria for the deployment of line culture (Table 4). Moored cage culture occurs in similar conditions as line culture with cables mooring the suspended cages. I modeled the potential for moored cages in nearshore waters of 30 to 200 m using the same parameters as listed for line culture with the exception of removing freshwater influence. The final system, intertidal/subtidal bottom culture, comprises of cages secured or placed on the bottom of the ocean and used for the raising of bivalves and algae. Organisms may be exposed to oxygen intermittently during tides, cannot be placed on live coral, and do not thrive in areas of low salinity.

3.3.2. Input Data

3.3.2.1. GIS Layers

The nearshore aquaculture models comprised of 82 different GIS data layers for use specific to Hawai‘i Island. Metadata accompanies the GIS and all data were projected into a common datum (NAD 83 UTM Zone 5N), and clipped to an extent three nautical miles offshore. All layers and their respective metadata are viewable on the website http://geodata.sdal.hilo.hawaii.edu/aquaculture/. Majority of layers were publically available, yet a few layers were accessed through the GIS technicians and made available on the website. Aquaculture experts, GIS technicians, and Oceanographers vetted all information for scale, extent, and accuracy of layers. Of the 82 GIS data layers collected and stored within the Geodatabase, a collective of 26 were used in direct creation of the final results. This geodatabase creation process was crucial in highlighting to industry and County officials the existence (or lack thereof) of information at appropriate spatial and temporal scales.

3.3.2.2. Geophysical Data

Another component of the operational GIS system included physical parameters such as ocean temperature, wind speed, and wave height. These parameters were thought to be essential input components to the GIS model, and data were reformatted spatially for compatibility with the GIS application. Several different satellite and model-derived estimates of ocean properties were used to describe the biophysical environment around the island of Hawai‘i. Specifically, I analyzed satellite estimates of ocean color (chlorophyll-A; mg/m^3) and sea surface temperature (°C), and model estimates of wind speed (kts) and direction, ocean current speed (kts) and direction, ocean tidal amplitude (m) and currents (kts), and wave height (m) and direction.

The constraint on geophysical data was data that included the domain of interest, but also had sufficient spatial (resolving necessary features) and temporal (meaningful climatologies) resolutions and extents. Ocean color was obtained from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Mission that is part of NASA's Earth Science Enterprise and was designed to measure ocean color at a spatial resolution of 4.5 km. Data are freely available at the NASA/GSFC (http://oceancolor. Gsfc.nasa.gov/). Higher-resolution data (e.g., MERIS 300 m) were not used since at the time of development no level 3 products were available. Ocean sea surface temperatures were obtained from the NOAA Geostationary Operational Environmental Satellites (GOES). The SST data for this study are from the imager, and provide about a 5.5 km resolution SST field. Monthly means were used.

While *in situ* and remote observations are preferable, there was insufficient coverage at the space and timescales required for the analysis. Instead, numerical models were used to provide estimates of ocean currents and sea level variations (both tidal and wave driven). The Navy Layered Ocean Model (NLOM) and the Navy Coastal Ocean Model (NCOM) were used for ocean currents. For atmospheric circulation and tides, regional models run at the University of Hawai'i were used. Finally, wave estimates were obtained from the NOAA National Center for Environmental Prediction (NCEP) operational model.

NLOM is a global-ocean model that was run daily by the US Navy. The horizontal resolution is relatively high at 3.5 km near the Hawaiian Islands, but somewhat coarse in the vertical; the upper layer represents the mean conditions in the top 100 m of the water column. As a computational trade-off, NLOM uses a layered approximation in the vertical (the assumption is that ocean, in the vertical, acts as a series of finite layers). The upper layer from NLOM is approximately 100 m thick and represents the upper ocean.

NCOM is similar to NLOM in the sense that it is run operationally (each day) and provides global output. However, NCOM differs in that it has a much higher vertical resolution and employs a fixed vertical grid (40 levels). Thus, the upper level is the top 5 m of the ocean. Again, because of computational limits, the horizontal grid is coarser (14 km).

For tides, the University of Hawai'i (UH) runs a regional tidal model. Eight tidal harmonics are used to compute the baroclinic and barotropic tides around the Hawaiian Islands. The harmonics are based on climatological mean stratification (temperature and salinity) and are computed at several depths. The resulting velocity and surface elevation are computed on an hourly interval at the surface, subsurface and bottom.

Similarly, UH runs a regional atmospheric model based on the fifth-generation NCAR/Penn State Mesoscale Model (MM5), with output generated daily and archived. The model has different grids for each island, with the Hawai‘i Island grid being 1.5 km. The MM5 model was used for both wind speed and direction and precipitation estimates. In the case of winds, daytime means were constructed from the model hourly output.

The final model results to be utilized came from the NOAA/NCEP operational wave model, which is based on Wave Watch III, with and hourly results archived at the NCEP data center. The model is necessarily coarse to accommodate the high frequency needed for wave forecasting. Output is available at approximately 125 km. The result is that the entire Island of Hawai‘i shoreline is represented by four model grid points. Nonetheless, the output provides useful information about the large-scale, off-shore wave field, particularly in a climatological sense.

3.3.2.3. Data Layer Selection

A total of 109 hexagons (128,000 ha) from within the three nautical mile boundary were excluded as part of the final selected sites because of the presence of one of six cautionary parameters (Table 3). These parameters were chosen based on their incompatibility with aquaculture, additional permanent structures, or because of legal limitations. A cautionary layer does not exclude site selection from the model but is available for users to understand pertinent information regarding socio-economically important sites which may influence their desire to develop aquaculture initiatives. These include such variables as public recreation sites and marine managed areas.

3.3.3 Modeling

3.3.3.1. Scale and Extent of Data

Analysis of aquaculture system requirements and spatially explicit data led us to combine datasets to be able to simplify the attribution of the hexagons dataset. Values for the bathymetry came from two sources, a fine-scaled, but spatially patchy, multi-beam dataset and a modeled bathymetry recording 20 and 200 m contour lines. A combination of these datasets was used to designate the mean depth of each hexagon (m). Presence of coral substrate and heavy freshwater influence were also identified. Distance traveled to a potential aquaculture development site is limited by personnel access time required. A one hour boat ride was determined as the furthest an operator would envision to travel from shore to aquaculture site. Larger boats could use harbors and reach 25 nm in this time while smaller boats could access sites from a boat ramp and travel about 10 nautical miles within an hour (Figure 1).

Satellite imagery and modeling datasets went through extensive processing to create relevant data layers to be used in the systems modeling. Wave height satellite information was at an inappropriate spatial scale and ocean current speed models do not have accurate data nearshore that could represent ocean conditions in the locales of interest. However, wind speed was determined to be a good proxy for surface roughness. Through expert interviews, the limitations of wind speed were determined. Wind speed was queried to calculate the number of days a ≥ 15 knot wind blew over a surface patch for 4 h straight during daylight hours. The chlorophyll-A dataset went through similar analysis, reviewing monthly means (based on a 4 year average) to identify the time with the least concentration of chlorophyll A (October) and the number of weeks that chlorophyll A is below a minimum of 0.05 mg/m3.

Spatial correlations were used to attribute data from the appropriate GIS data layer into the hexagon shapefile for each aquaculture system modeled. Unique identification values can therefore be queried by location for specific variables and to view the results of the models. The models for each aquaculture system were based on a simple query to identify the criteria for pertinent variables (Table 4). Additional columns were also included to reflect the results of the models. Finally, viewshed models from numerous locations were run using Esri® ArcGIS 9.3.1 applications to understand the social impact on community's seascape.

3.3.3.2. Stakeholder Input

Results of the models were shared at three community meetings (September 2010) and multiple informal public presentations in fall 2010 and spring 2011. Two public meetings were held in areas identified through the models as having high potential for future aquaculture development, Waimea and Kawaihae. During the meetings, construction and availability of the GIS maps were discussed, including discussion of each coastal dimension modeled and model results. The third meeting was an invitational meeting for employees of the County Economic Development held in Hilo, Hawai'i. These focus group meeting were useful in understanding the actual benefit and applicability of the modeling exercise and comments were included in reports prepared to the

County. Field notes from each of these structured and informal discussions were transcribed for analysis.

3.4 Results

3.4.1. Applicability of Datasets

Analysis of all accessible datasets and their availability statewide resulted in the use or combination of nine variables in the model development. The majority of data layers were used in the socio-economic cautionary (8) or excluded (9) data layers but little data were available to identify pertinent biophysical characteristics. The majority of biophysical oceanographic information had data modeled or sampled at incompatible scales. The number of days the site would be inaccessible by boat, due to sea roughness, ranged from 0–135 days. Aquaculture sites need to be visited, maintained, or fed at least four times/week. The results show that two of every three days, a site would be accessible by boat and wind speed would not be a limiting factor in any of the models. Chlorophyll A data analysis shows that the abundance is always above the minimum threshold to provide food and nutrients to shellfish and other filter feeders. Shared parameters to all models included depth and bottom substrate, distance and accessibility for boats, nutrient availability and water quality (Table 4). Accessibility by boat was seen to be a limitation (Figure 1) in identifying potential aquaculture sites, as was appropriate reef-free shallow water habitat, and available depth habitat.

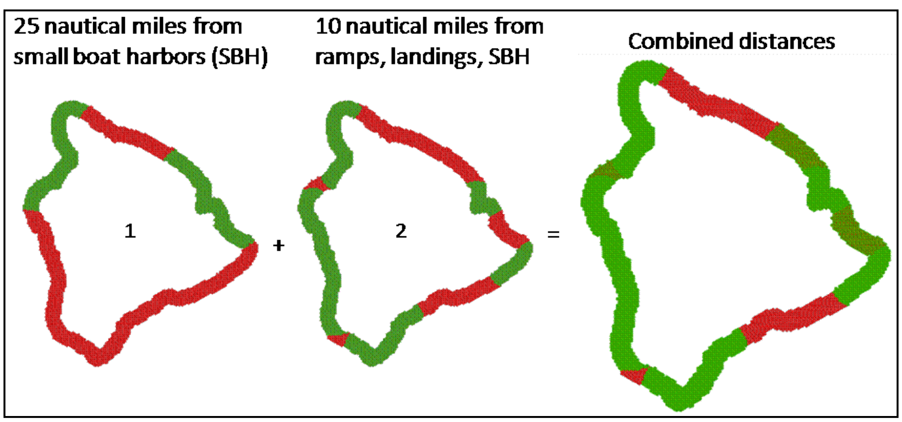


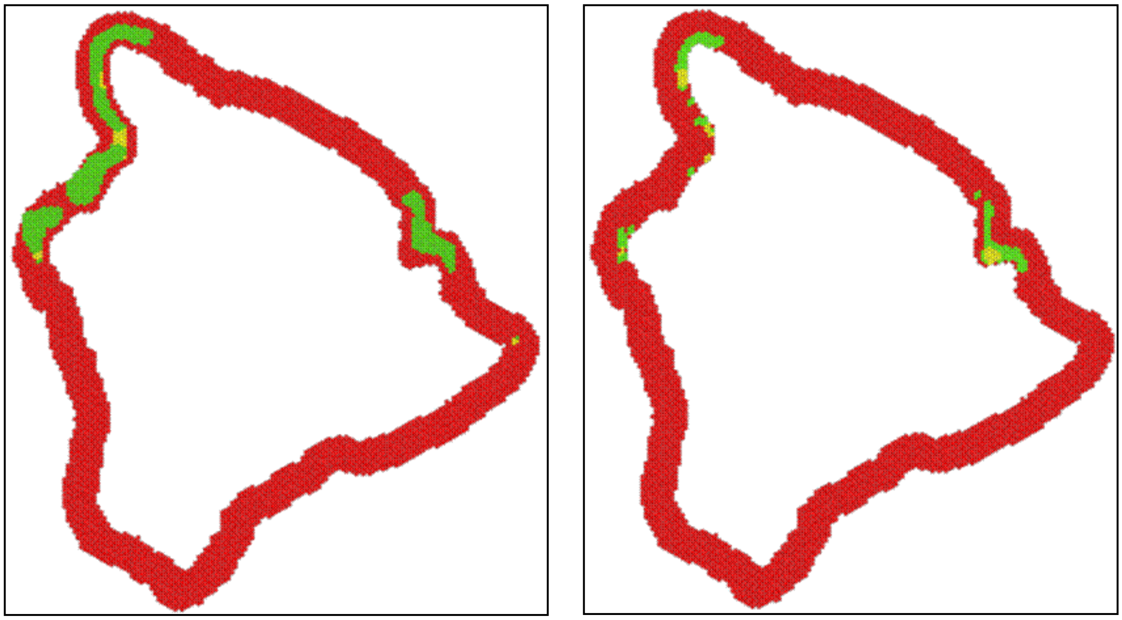
Figure 3.1 Accessibility of possible nearshore aquaculture sites by boats. Green areas depict sites accessible by boat and red are inaccessible based on the distance travelled.

Table 3.4 Parameters used in the final models and associated scale (temporal and spatial).

Variables	Resolution	Criteria		
		Intertidal	Moored Cage	Line Culture
Depth Biological Habitat	Various	4–30 m No Coral Presence	20–200 m No Coral Presence	20–200 m No Coral Presence
Distance to Site	m	25 nm from harbor, 10 nm from ramp	25 nm from harbor, 10 nm from ramp	25 nm from harbor, 10 nm from ramp
Salinity	Line and Point data	No Perennial Streams or known SGD	not applicable	No Perennial Streams or known SGD
Wave Height	250 × 250 km	not applicable	not applicable	not applicable
Wind Speed	1.5 × 1.5 km Hourly means			
Chlorophyll-A	5.5 × 5.5 km Monthly means	not applicable	not applicable	Weeks Chl-A less than 0.05 mg/m^3

3.4.2. Models

Line culture models identified 5180 ha (518 hexagons) as having potential for aquaculture development (Figure 2a). Thirty hexagons were not selected because they had a direct conflict with the obstruction layer (Figure 2). Even with the removal of freshwater impacted sites in the moored cage models, the results of the two models were the same (Figure 2a). Areas highlighted to support moored cage aquaculture in North Kona and South Kohala currently house one functioning cage and a tuna farm has been proposed. The potential to support intertidal/subtidal bottom culture was identified in 1750 ha (Figure 2b). Only 13% and 4% of areas were identified with the appropriate depth within the spatial scale of hexagons I used in the analysis for the development of line and moored cage or intertidal bottom culture, respectively.

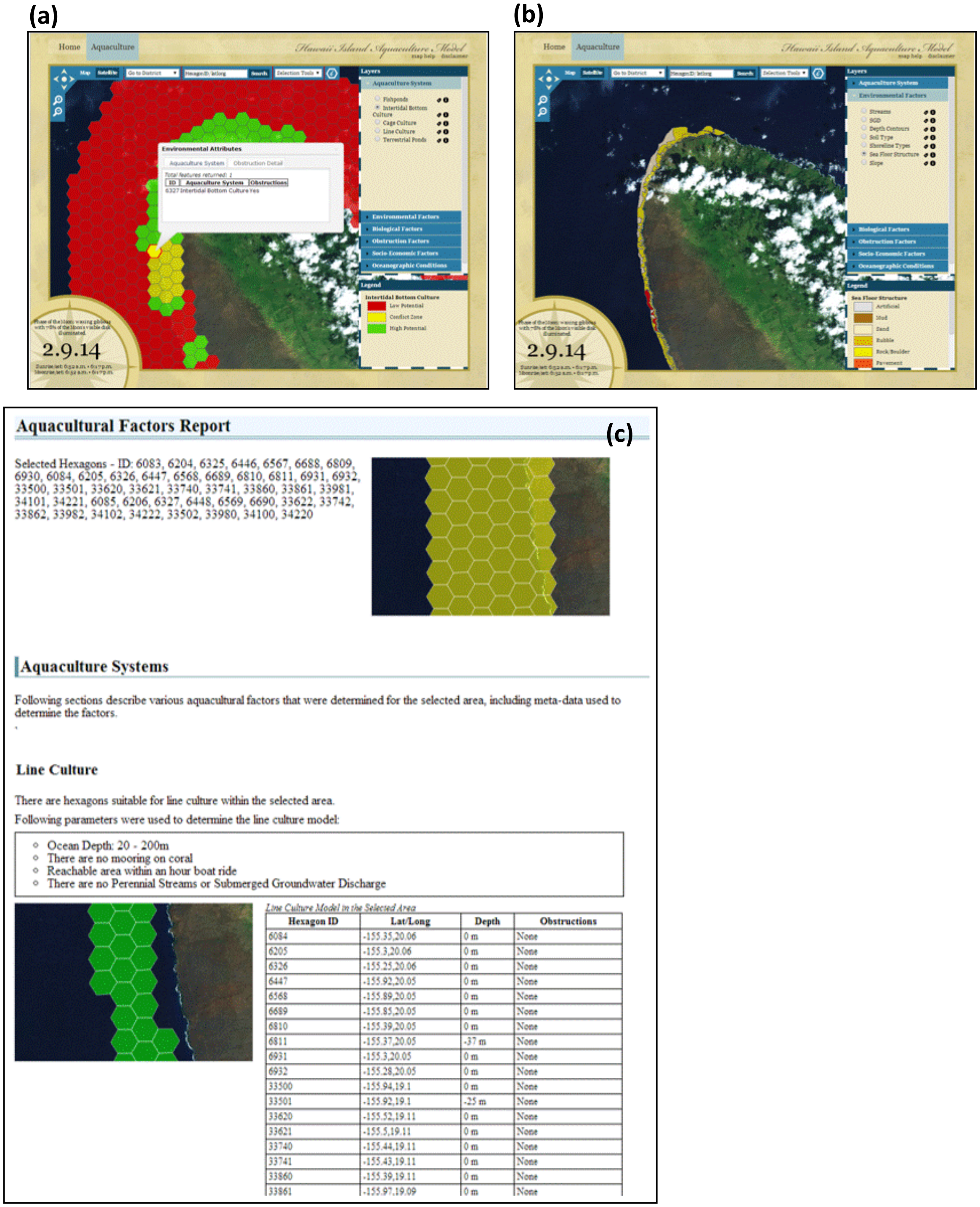


(**a**) (**b**)

*Figure 3.2 Suitability of sites for line culture, moored cages, and intertidal/subtidal bottom culture. Green hexagons identify areas suited for marine aquaculture, yellow hexagons include cautionary areas, and red hexagons are unsuitable. (**a**) 5180 ha are suitable for Line Culture and Moored Cages; (**b**) 1750 ha are suitable for Intertidal/subtidal Bottom Culture.*

3.4.3. Web Interface

A considerable effort was taken to publish the modeling and GIS data sources on a public internet ArcGIS mapping site http://geodata.sdal.hilo.hawaii.edu/aquaculture/. The results of each model developed are available as individual shapefile layers, and access to each of the individual GIS layers compiled. The website allows spatial queries, the overlay of various layers, and a report function that outputs a summary of selected hexagons. The models and available data are available to the public, industry representatives, and government agencies for scrutiny and adoptability as needed. The resulting sites and background information can be used in understanding aquaculture in the context of marine spatial planning as well as for other coastal or marine management objectives.



Hexagon ID	Lat/Long	Depth	Obstructions
6084	-155.35,20.06	0 m	None
6205	-155.3,20.06	0 m	None
6326	-155.25,20.06	0 m	None
6447	-155.92,20.05	0 m	None
6568	-155.89,20.05	0 m	None
6689	-155.85,20.05	0 m	None
6810	-155.39,20.05	0 m	None
6811	-155.37,20.05	-37 m	None
6931	-155.3,20.05	0 m	None
6932	-155.28,20.05	0 m	None
33500	-155.94,19.1	0 m	None
33501	-155.92,19.1	-25 m	None
33620	-155.52,19.11	0 m	None
33621	-155.5,19.11	0 m	None
33740	-155.44,19.11	0 m	None
33741	-155.43,19.11	0 m	None
33860	-155.39,19.11	0 m	None
33861	-155.97,19.09	0 m	None

Figure 3.3 Sample screen shots from the web interface. (**a**) Summary of attributes for selected hexagons with legend and layer options visible on the right; (**b**) Sample aquaculture factors report, pg.1 of 14 summarizing selected hexagon attributes; (**c**) Selection of one feature layer, sea floor structure with legend and layer options visible on the right.

3.4.4 Stakeholder Response

3.4.4.1 State, Federal and Industry Response

Industry and agency stakeholders were easily engaged since they regarded the result as a functional product and had invested in the process. The models presented at the conclusion were based on their individual feedback and reflected what they had intuitively forecasted. Environmental assessments are required by state and federal laws for permitting and applications of new ventures and most of the available information that a company would require to complete these assessments were provided in the GIS maps thus saving both government and industry officials' time and financial investment.

The analysis enabled agency officials to systematically service potential businesses and inform the public of the implications for future aquaculture development in their communities. Aquaculture industry participants also responded that the availability of the results on an external server increased the benefits of these public resources on data products accessible to many (Figure 3).

3.3.4.2. Community Responses

Two well-attended community meetings were held in locations most affected by the growing pressure for aquaculture development, and consequently, areas identified in the research as primary locations for all three types of systems; Waimea, located centrally on Hawai'i Island and Kawaihae, located on the northwest coast. Participation from the community at the meetings varied from technical agency members to aquaculture supporters and skeptics, with over 75 individuals participating. Community members received the modeling attempt and result with mixed reactions. Having the result accessible through an ArcGIS website allows community access to information and knowledge that are normally technically too advanced for them to acquire. The model results allowed community members to know that as aquaculture pressures grow, they could use the web tool to query, understand and present information on their behalf. This accessibility was an unintended result that served not only the aquaculture industry but also the communities faced with development on their local coastal areas. Critical feedback was shared in relation to the coarseness of the model results. Community members are interested in areas at much finer scales than the models showed, and in aquaculture systems that were irrelevant to these nearshore models, such as inland fishponds and salt beds.

3.5 Discussion

The overarching results highlight nearshore aquaculture‘s need for large areas with shallow depths, and access from nearby harbors and boat ramps. Hawai‘i’s waters were also shown to have great potential to host future aquaculture development, especially with increased development along the South Kohala, North Kona coastline. Of the multitude of GIS data layers publicly available, 24 were not available at the appropriate spatial and/or temporal scale but likely would have contributed significantly to the results of the modeling exercise. Even with more robust spatial data, the limiting factors for developing off-shore aquaculture are likely to be depth and availability of prime habitat. The final results were useful for county/industry representatives but the products have not shown to be useful for community decision-making.

The County of Hawai‘i, with little GIS expertise, gained a valuable tool in assisting planning, and development. Though industry and agency experts deemed this project resourceful and useful, comment from individual community members and response from public presentations highlighted the limitations by exemplifying the inability of the data products to serve the needs of all stakeholders. Particularly, I was unable to: (1) identify data products at the scale most pertinent to use both temporally and spatially; and (2) modify the scale of the model to reflect levels of development universally applied to varying economic scales of operations.

3.5.1 Temporal and Spatial Scales

I was unable to use 24 GIS layers, including incomplete bathymetry and benthic habitat maps, location of underwater obstructions, socio-economic variables, and oceanic conditions as measured by satellites. As can be expected, many of these data are a priority for management agencies and their availability has improved over time. Importantly for this modeling exercise, however, is that most biophysical oceanographic parameters have spatial resolutions that are not applicable for coastal applications. Many ocean satellite data and ocean models have outputs at very fine temporal scales (hourly, daily, weekly) but at large spatial scales (5.5 km^2, 14 km^2) and thus their resolution along the coastline when projected was inaccurate (e.g., some satellite imagery overlain on the terrestrial landscape). As satellite and remote sensing technology continues to increase in resolution, models will be able to incorporate these new datasets. Although I was able to query and transform the wind speed and ocean color datasets, understanding the pertinent temporal and spatial scales in which to use the data was dependent on industry experts.

3.5.2 Economic Scales of Operation

As with any geographic analysis, data resolution (e.g., pixel size) matters. Specifically, using smaller hexagons may have identified additional areas suitable for aquaculture at a smaller scale of development. Hence, the scale of analyses inadvertently was skewed towards support of industrial scale aquaculture and not small scale growers. This skew particularly affected the modeling results of intertidal bottom culture. Hawaiʻi Island has very limited shallow areas and by using a hexagon grid size of 100 ha, shallow areas that did not extend through a majority of a hexagon were determined too deep while concurrently, areas too close to the shoreline were identified as terrestrial. Using hexagons of scalable size may increase the amount of potential sites identified for intertidal bottom culture and should be considered for future research.

3.5.3 Community Involvement

Approaching this exercise with the knowledge that aquaculture development is a contentious yet feasible area of current and future development there was a guided effort in involving stakeholders ranging from industry experts to community groups throughout the process. Planning increasingly involves non-experts (public, communities, and stakeholders) in the planning and decision making process and this evolution has been paralleled by the increasing accessibility (user-friendliness) of GIS technology (Bugs et al. 2010). Presenting the process and the results in a non-biased approach from a research group not tied to the results was received neutrally as hoped. Many projects such as these are completed by interest groups tied to either development or anti-aquaculture perspectives and residents are hard-pressed to be educated with an open approach. Ball (2002) states that participation by stakeholders in the process of the planning phase ensures cooperation by local inhabitants in the final plan and serves as a vehicle to gain access to local knowledge, complementing scientific knowledge.

3.6 Acknowledgments

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CHAPTER 4. PROJECTIONS OF SURF QUALITY WITH CLIMATE CHANGE

4.1 Abstract

Human perceptions of climate change are influenced by shifting baselines of resource abundance. I used this theory to drive questions of surf quality as assessed by surfers at a unique surf spot in Hilo, Hawaiʻi; Honoliʻi Bay. Climate change effects on coastlines are expected to impact humans' ability to recreate. Ocean observers, those with daily, direct contact with the seascape, mentally model the changes, both social and physical, they perceive. Surfers are a model group of resource users because they regularly interact with a resource that is undergoing constant change, the ocean, and are expected to have knowledge about this change. By interviewing surfers, I can understand their preferred surfing conditions, the changes they have witnessed over time, and how climate change predictions are likely to influence their surf quality. I administered a survey to 102 surfers at Honoliʻi to understand surfer demographics, place dependence, and predictions about past and future surf quality. I found that people's dependence on place provide them with the resiliency to adapt to future coastal conditions allowing their preferred surfing recreation to persist.

4.2 Introduction

As climates change, the need to observe and document past and current states of the ocean become increasingly relevant for our ability to predict and prepare for those changes. Coastal systems worldwide are areas of high productivity that contribute considerably to well-being of coastal communities. Understanding the dynamics of coastal areas in a manner that supports management decision-making however, remains difficult given the complex interactions between human, biological, and physical processes. Nearshore environments, in particular for the ocean, have high overlap between social (fishing, transport, recreation, etc.) and ecological (upwelling, primary production, maintenance of juvenile habitat) processes. This high overlap of social and ecological processes makes governing coastal areas difficult (Crowder et al. 2006). The impact of climate change in the coastal environment is frequently viewed as primarily the effect of sea level rise and coastal storm run-ups. Yet coastal environments also feel the effects of upland changes, such as decreased streamflow and trade winds and changes to ocean regimes, such as warmer, calmer waters and extreme events. Because coastlines are at the intersection of these two environments, and at a scale difficult to include in modeling and forecast scenarios, impacts due to climate change are unclear. Further confounding the modeling of climate change impacts are their island ecosystems, scale mismatch, windward and leeward effects, and also because of the simple boundaries between terrestrial and marine environments.

4.2.1 Recreation in the Pacific; Surfing

In the Pacific, Hawaiians and other recent immigrants often recreate and work on the coast and in the nearshore waters of the islands (Wiener et al. 2015). Hawaiʻi's coastlines are used by tourists and residents alike and are of tremendous social and economic importance, with net benefits totaling $360 million annually for Hawaiʻi's economy (Cesar and Van Beukering 2004). Reliance of tourism on Hawaiʻi's beaches is commonly publicized, and therefore research regarding visitor statistics and activities are well known (dbedt.hawaii.gov/visitor). Yet the importance of beaches and in particular, ocean recreation activities such as fishing, diving, paddling, and surfing, to residents are rarely discussed. Surfers in particular are an interesting recreational group because their reliance on ocean conditions may be affected by climate change. Since surfing is one of the oldest Hawaiian recreational traditions, it is widely enjoyed throughout all the islands. Surfers, as a sector of coastal user groups, is often neglected in management scenarios but has been a vocal and organized group in past mobilizations to protect coastal sites from development and zoning (Walker 2011, Kelly 1973). Starting with the Surfrider Foundation in the 1970's, surfers have been a politically active recreational group that depends on healthy, undeveloped coastlines and strong social communities.

Although a plethora has been written about surfing's history (Clark 2011), the science of surf (Butt and Russell 2004), surfing as a religion (Taylor 2007), a means of resistance (Walker 2011), and as a culture (Kampion and Brown 2003), very little has been done to learn about their perceptions of environmental quality and change. Most research regarding surfers centers on their ability to describe the perfect breaking wave so that humans can recreate these environments artificially (Scarfe et al. 2009a). However, surfers are a type of recreationists that depend on particular environmental conditions for the ability to engage in the act of surfing, similar to skiers and snowboarders' reliance on particular snow conditions. This reliance on the environment makes them attuned to changes and patterns, becoming amateur meteorologists and oceanographers (Caldwell 2005). Surfers understand swell period, height, direction, and timing as well as seafloor structure and use these environmental parameters to mentally model specific conditions aligned to each surf site (Scarfe et al. 2009b). The congruence of these conditions along the coastline produce surf sites that are resilient through time. In Hawaiʻi, the same surf spots spoken about in oral legends and stories are the same popular surf spots of today (Clark 2011). Common websites such as Surfline (www.surfline.com), Magic Seaweed (magicseaweed.com), and National Oceanic and Atmospheric Administration weather forecasts (http://www.prh.noaa.gov/hnl/pages/surfreports.php) are frequently accessed as surfers' model the conditions appropriate for their surfing preferences.

4.2.2 Climate change in Hawai'i

Over the last 30 years Hawai'i has seen a significant increase in air and sea temperatures, sea level, and rain intensity (SEAGRANT 2014). Conversely, the islands have seen a significant decrease in wind strength and duration, and ocean wave heights (Figure 4.1a & b), and rainfall and stream flow (Figure 4.2). Trade winds in Hawai'i show a significant decline in northeast frequency and an increase in east winds (Garza et al. 2012), which is of particular importance since trade winds are responsible for cooler temperatures, increased rainfall, and localized swell creation (Sanderson 1993). Whether or not these environmental changes influence actual conditions or perceived surf conditions is unclear.

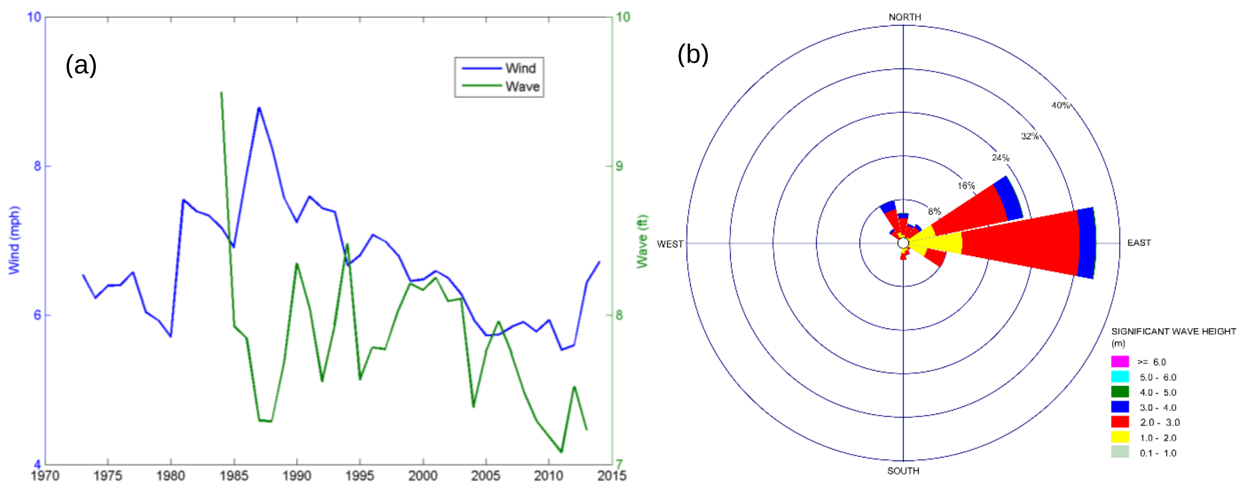


Figure 4.1 (a) Wind (blue) in miles per hour at Hilo, Hawai'i since 1972 from NCDC, and Wave (green) in feet from the National Data Buoy Center, since 1984. (b) Wave swell direction and height in feet; National Data Buoy Center.

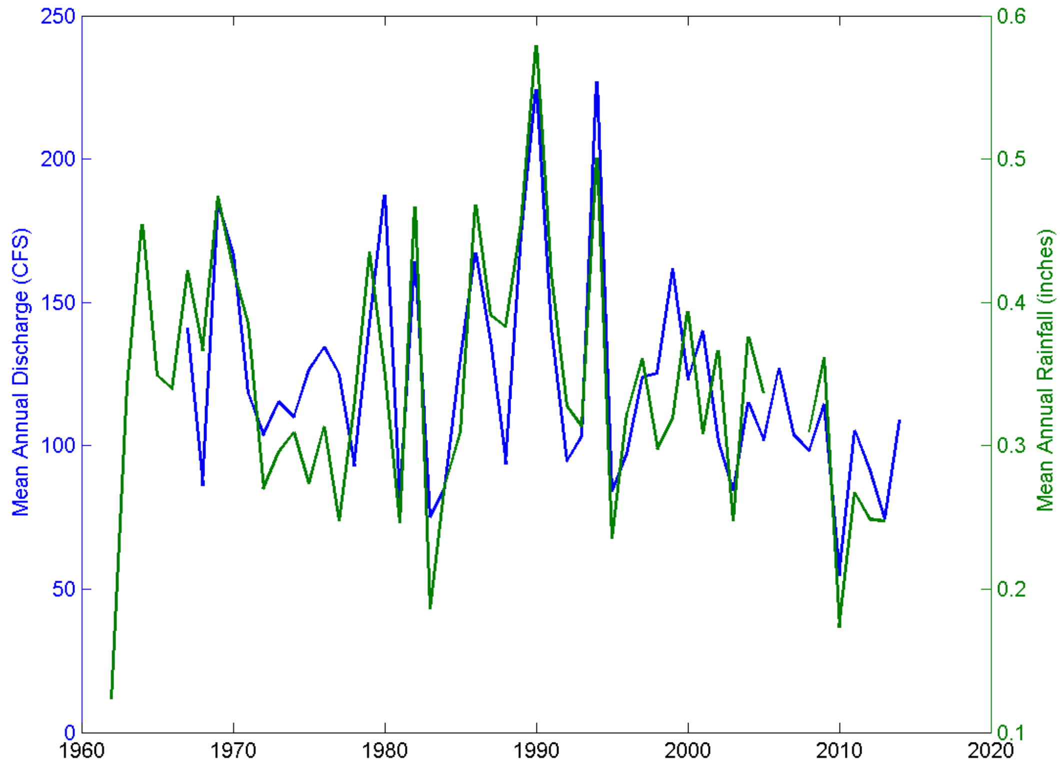


Figure 4.2 Stream flow (blue) in cubic feet per second at Honoli‘i Stream since 1968. Rainfall in inches as recorded at the Hilo International Airport since 1962.

Biophysical values that describe the coastal environment are readily available from *in situ* data sources such as wave buoys, stream, rainfall and wind gauges (Table 4.1). Socio-ecological implications include understanding the community of coastal recreational users, their values, and attachment to place. These coastal ocean communities monitor physical oceanic conditions through their daily interactions of surfing. To understand the implications of climate variability on coastal areas I need to identify the variables of climate change that have significance to the mental models and decision processes of each user group.

Table 4.1 Sources of data used to create climate graphs as presented to surfers.

Type	Interval	Time Range	Latitude	Longitude	Organization
Stream (cfs)	daily	1967 - 2014	19.7643	-155.1518	USGS
Wave (ft)	half-hour	2012 - 2014	19.7814	-154.968	SCRIPPS Institute of Oceanography Coastal Data Information
Wave (ft)	hourly	1984 - 2013	17.602	-152.395	National Data Buoy Center (51004)
Rainfall (inches)	monthly	1920 - 2008	19.72	-155.05	UH Geography
Rainfall (inches)	hourly	1962 - 2013	19.71667	-155.067	*National Climatic Data Center (NCDC) HILO(511492)
Rainfall (inches)	hourly	1965 - 2013	19.68333	-155.15	*National Climatic Data Center KAUMANA (513510)
Wind (mph)	half-hour	1973-2014	19.719	-155.053	*NCDC HILO (912850)
Tide gauge (mm)	hourly	1927-2014	19.73	-155.07	UH Sea Level Center

At Honoliʻi, historical and/or contemporary quantification of wave regimes, stream flow, rainfall, and wind can be analyzed for patterns that are relevant at temporal and spatial scales to identify physical characteristics of surf quality. Lifeguard observations of Honoliʻi are available digitally since 2008 and archived since 1985. Coupling historical data with the human observer perceptions of environmental change and conditions, I should be able to understand human perceptions of past climate change effects on surf and infer potential changes in the future due to climate predictions. My four research questions are:

1. Are surfers in Hilo a heterogeneous population?
2. What constitutes surf quality physically and socially at Honoliʻi?
3. What are surfer's hindcast of the physical and social conditions at Honoliʻi?
4. What are surfer's forecast of the physical and social conditions at Honoliʻi?

4.3 Materials and Methods

Modeling the effects of climate change on a community's recreational ability requires three things: (1) defining the preferred environmental conditions, and understanding the anticipated (2) empirical and (3) perceived changes. I interviewed surfers at Honoliʻi to test the ability to predict climate change effects on ocean recreationists. Important to this discussion, surf quality, the variable of interest, is not the dynamics of a breaking wave, but how waves interact with conditions on the shoreline, both physically and socially to create “surf” (Lazarow et al. 2007). Surf quality is therefore how both the wave quality, water quality, and social conditions of a site all interact to create conditions “felt” by a surfer, and used to define a surfing session. These different measures of surfing are key to understanding perceived conditions of surf quality. Surf quality is expected to be heterogeneous among surf locations, and possibly within sites, based on physical site characteristics, experience, and connections to place as perceived by individual surfers.

4.3.1 Honoliʻi

Honoliʻi is a perennial stream that meets the ocean slightly north of Hilo Bay, facing east (Figure 4.3). Surf breaks along the North Hilo coastline are primarily in estuarine environments where outgoing rivers deposit sand and rocks to create a relatively shallow sandbar offshore in these normally deep waters. Incoming swells meet the coastline, and the sand deposits and create about five named surf spots in Honoliʻi Bay. Water quality at Honoliʻi is dependent upon the conditions of the river. Streamflow drives the sediment input and therefore the sandbar cycle. The bacterial and phytoplankton populations are associated with varying streamflow (Strauch et al. 2014) and are all conditions felt and observed by surfers.

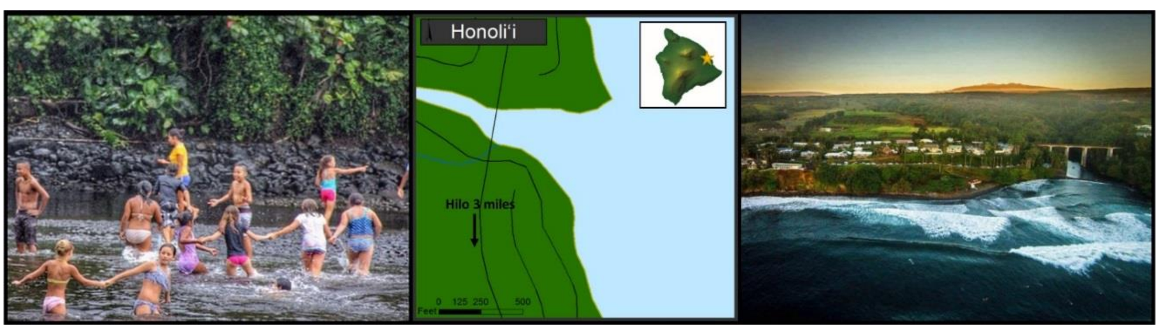


Figure 4.3 Honoliʻi is located 3 miles north of Hilo on the Island of Hawaiʻi. Social and physical conditions make Honoliʻi a unique surfing site. Photographs courtesy of Keith Nehls and Greg Ruhland.

Honoliʻi was recounted as a surf spot in historical Hawaiian literature dating back centuries (Clark 2011). The Hilo shoreline is primarily cliffs and young, rocky lava substrates, which are not ideal for creating good surfing spots in contrast to the numerous river mouths along the shore making Honoliʻi a unique spot. Honoliʻi is noted for its consistency of waves because the river mouth opens to the east north east, facing the direction of the incoming trade winds which produces the majority of wave swells onsite. Surfers at Honoliʻi are faced with limited opportunities at other sites and are therefore thought to have high site fidelity. Although lifeguards are stationed onsite and estimate annual visitor counts of 126,000 in 2013, these numbers do not account for the numerous repeat visits of individual people.

4.3.2 Survey Development

The survey consisted of four sections: demographics, recreation/place attachment, knowledge of past surf conditions, and predictions on future conditions based on prescribed climate forecasts. I designed these sections to assist in understanding heterogeneity among surfers, the ideal physical and social characteristics of surf quality at Honoliʻi, and if the hindcast and forecasts of surf quality differed by surfer type. A total of 55 questions were asked, with an additional 16 questions requesting further explanations; such as 'Please explain why'? Thirty-three questions were nested within the above 55, for a total of 104 potential responses (see Appendix A).

Demographic, place attachment, and recreational specialization questions were used to deduce sub-groups of surfers (Needham and Vaske 2013, Kyle et al. 2004). A place-based involvement scale for surfing measured seventeen items on a 5-point Likert scale (1= strongly disagree to 5 = strongly agree). Centrality refers to the extent surfing is central to ones' life. Self-expression looks at how surfing defines oneself. Attraction references the peace one gets from surfing. Place dependence and identity refers specifically to Honoliʻi as it is tied to surfing and the individual. Activity substitutability was measured using the direct question method with an open ended question "what one outdoor activity would you likely do instead of surfing" followed by "is this activity a substitute that would give you the same level of satisfaction or benefit that you get from surfing" (Needham and Vaske 2013).

Five variables addressed the behavioral dimension. I asked surfers how many years they have surfed at Honoliʻi and then to control for age, experience was expressed as a percentage and calculated with the following equation: Proportion of life surfed at Honoliʻi = number of years surfed at Honoliʻi/age $*$ 100.

Twelve questions were used to understand the perfect surf quality conditions at Honoliʻi, including four questions which asked about the social environment. To create appropriate questions to understand how surfers could recount past conditions, 17 open ended rankings and specific time frame questions were presented. I also asked surfers seven questions to estimate the amount of people at Honoliʻi. Climate change forecast questions were based on published predictions for rain, wind, and storms in Hawaii (Elison Timm et al. 2015, Elison Timm et al. 2011, Chu et al. 2010, Garza et al. 2012). Graphs and regression lines were produced that showed annual trends through time for rainfall, streamflow, wave height, wind speed, and sea level rise and used along with words to illustrate the question (Kruk et al. 2013).

4.3.3 Survey Implementation

Surfers at Honoliʻi Beach Park were asked to complete this anonymous questionnaire onsite between the time periods December 21, 2014 and February 28, 2015. The winter season was selected due to the large variety of surf conditions and the higher availability of beach goers. In general, there is no seasonal change in recreational activities in Hawaiʻi (Friedlander et al. 2005). Six surveyors intercepted available surfers over the age of 18 from dawn to dusk on various days of the week over this time period, taking approximately 20 minutes to complete. This convenience sampling method focused on Honoliʻi but surfers were also approached at other locations, asked to take the survey and also to pass it along to other surfers they knew. Codes on each survey noted the location, date, and interviewer.

4.3.4 Survey Analysis

Descriptive statistics were computed to understand the demographics of surfers interviewed and the variance of specialization. I tested the reliability of the specialization and place-based questions by calculating a Cronbach's alpha for each category; centrality, attraction, place dependence, place identity, self-expression, and surf behavior. A Cronbach's coefficient between .6 and .9 ensures questions are reflective of the category being assessed. I summed all surf factors (centrality, attraction, place dependence, place identity, self-expression, and behavior) to create a specialization index. The specialization index was used to represent the population sample and to understand variation in responses to the surf hindcast and forecast questions. I ran a linear regression with least squares of the specialization index against the future surf prediction questions to see if there was a trend in responses. A one-way t test was used to see if forecast responses were significantly different from a no change response of 5.5 on a surf quality scale of 1 to 10. A one-way ANOVA was used to see if the amount of surfers, and the change in surf quality, mean responses were significantly different than each other over the last 5, 10, and 20 years.

4.3.5 County of Hawai‘i Lifeguard Statistics

The County of Hawai‘i lifeguards have been estimating the amount of beachgoers at stations where lifeguards are present since 1985. Counts are made at the start of a shift, 1200 hr, 1400 hr, 1600 hr, and at the end of a shift. Digital report counts are available daily from January 2009. Access to all raw, digital data was provided on June 7th, 2015 from the County of Hawai'i. Daily figures in 2014 were used to estimate average amounts of surfers and beachgoers at Honoli‘i, and counts taken at 1400 hr from 2009 to 2014 were used to estimate trends of beachgoers. A linear trend analysis was used to see if there has been a change in the number of surfers between 2009 and 2015.

4.4 Results

4.4.1 Socio-demographic profile

One-hundred two surfers were surveyed, with 98 completing the entire survey (Table 2; Appendix B). Survey respondents were predominantly male (75%), ranging in age from 18 and 70 (Mean = 36 ±13). Most respondents lived in a household of 3 people (±1.4) and have lived in Hilo for most of their lives (Mean = 22 years ±15). Respondents generally surfed year-round (89%) with an average 2.9 days per week (±1.7). I surveyed a normally distributed population of surf types and skills with means of 3.2 and 3.03 respectively on a scale of 1 to 5. Because no previous research has assessed the general population of surfers, I assume this is a representative, random sample. As the survey implementation continued through week 4, a saturation seemed to be reached where most of the surfers above age 18 had been sampled.

4.4.2 Research Question 1 - Recreation specialization & substitutability

All surfers associated strongly with Honoli‘i and with surfing (Table 4.3; Figure 4.4). Surfers mean responses stated that surfing was an important part of their lives (4.41), that surfing allows them to be themselves (4.06), that Honoli‘i is very special to them (4.32), and that surfing offers them relaxation when life’s pressure builds up (4.46). All specialization indices categories had Cronbach alphas between 0.7 and 0.9 except for place dependence indices which was 0.6075. When all categories were calculated together, Cronbach alphas for the behavior category were less than specialization metrics without, indicating that behavior metrics contributed to information loss. The surfer specialization index created from summing the scores from each category resulted in a possible range of scores from 26 -125. The actual range of scores were normally distributed with a range of 39 -105 with a mean of 80 ± 13.

Table 4.2 Demographics of surfers surveyed at Honoli‘i Hawai‘i between December 2014 and February 2015.

Question	Responses		N	SD
Gender	Female	25	100	
	Male	75		
Age	Mean	36	94	12.8
	Range	18-70		
Household Size	Mean	3	100	1.4
	Range	0-7		
Years in Hilo	Mean	22	98	15
	Range	0-64		
Years surfed Honoli‘i	Mean	15.42	98	12.3
	Range	0-50		
Days a week surf	Mean	2.9	95	1.69
	Range	0-7		

Almost half of all surfers responded that if they were not surfing they would be participating in another water activity (Table 4.4). Almost half of surfers responded that no other activity gives them the same satisfaction of surfing. Activities listed as alternates for surfing include ocean activities, other nature, sports, and other (n = 23). Surfers were active in the past year in an average of 6 different ocean activities along with surfing.

Table 4.3 Specialization of Surfers on a scale of 1 to 5 from strongly disagree to strongly agree.

Type	#	Question	N	Mean	SD	α	α
Centrality	a	If I stopped surfing, an important part of my life would be missing.	99	4.41	1.02	.7083	
Centrality	b	Most of my friends are in some way connected with surfing.	99	3.80	1.03		
Centrality	c	I find a lot of my life is organized around surfing.	99	3.63	1.02		
Centrality	d	Most other recreation activities do not interest me as much as surfing.	99	3.39	1.08		
Self-Expression	a	When I surf I can really be myself.	99	4.06	1.02	.8174	
Self-Expression	b	Surfing says a lot about who I am.	99	3.58	1.05		
Self-Expression	c	I am often recognized as a surfer.	98	3.60	1.10		
Self-Expression	d	You can tell a lot about a person by seeing them surf.	99	3.22	1.06		
Place Identity	a	I identify strongly with the surfing community at Honoli‘i.	99	3.86	1.05	.8017	
Place Identity	b	I enjoy surfing at Honoli‘i more than any other surf spot.	99	3.80	1.00		
Place Identity	c	I am familiar with Honoli‘i.	99	4.53	0.73		
Place Dependence	a	Honoli‘i means a lot to me.	98	4.32	0.81	.6075	
Place Dependence	b	I would enjoy surfing at Honoli‘i just as much at a similar spot.	99	3.57	1.07		
Place Dependence	c	I would prefer to spend more time at Honoli‘i if I could.	99	4.12	0.94		
Place Dependence	d	I feel Honoli‘i is very special to me.	99	4.32	0.86		
Attraction	a	Surfing is very important to me.	97	4.30	0.93	.828	
Attraction	b	Surfing offers me relaxation when life's pressure builds up.	99	4.46	0.80		
Behavior		Proportion of life surfed at Honoli‘i.	97	15.80	12.54		
Behavior		Skill (Novice, Intermediate, Proficient, Advanced, Expert)	98	3.03	1.06		.6101
Behavior		Amount of money spent yearly on surf travel or equipment	99	$927			.6320
Behavior		How many days a week do you surf?	95	2.98	1.69		.6674
Behavior		Surf Type (Beginner, Casual, Active, Dedicated, Committed)	96	3.26	1.02		.7580
Overall		Behavior, Centrality, Self-Expression, Place Identity, Place Dependence, Attraction					.9061
Overall		Centrality, Self-Expression, Place Identity, Place Dependence, Attraction					.9205

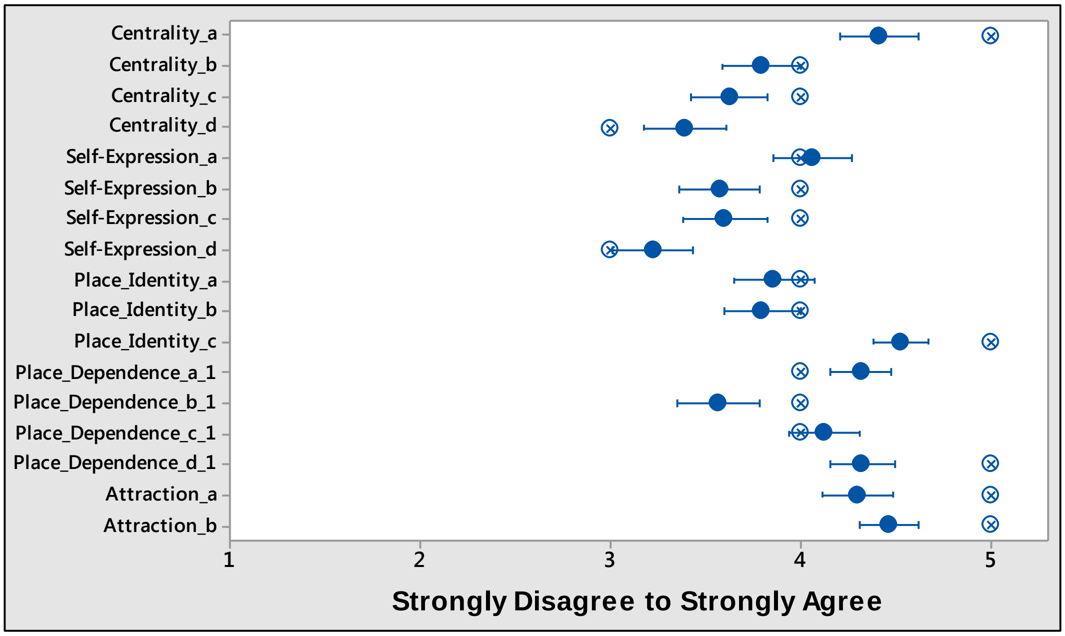


Figure 4.4 Recreational specialization of surfing index. Solid blue dots and lines represent mean and standard deviation. Clear dots represent the mode (n = 98).

Table 4.4. Substitutability of surfing with another outdoor activity and satisfaction rating in comparison to surfing (n = 98).

Does it give you the same satisfaction as surfing?	No	Yes
Ocean Activities; fishing, diving, paddling, swimming, lying on the beach	14%	30%
Other Nature; camping, farming, hiking, hunting, horseback riding	11%	13%
Sports; baseball, basketball, bike, crossfit, golf, dirtbike, running, skateboarding, soccer, softball, tennis, volleyball	15%	11%
Other; spending time with family, sleeping, not specified	3%	1%
Total	43%	55%

4.4.3 Research Question 2 - Ideal physical and social surf quality at Honoli'i

Surfers described little variation in surf direction (90% preferred NNE – ENE; Figure 4.5a) and wind direction/speed (88% preferred offshore winds of 0-10mph; Figure 4.5b) as preferred conditions. Survey results from best river flow and tide conditions reflected slightly more variation. A majority of surfers preferred the changing tides (61%) or mid-tide (24%) with a height measured in Hawaiian faces from 2-6 (78%). Most surfers preferred surfing in the morning hours (81%; dawn to 10am). Surfer's preference for surf conditions were not differentiated based on recreational specialization, surfing skill or surfer type.

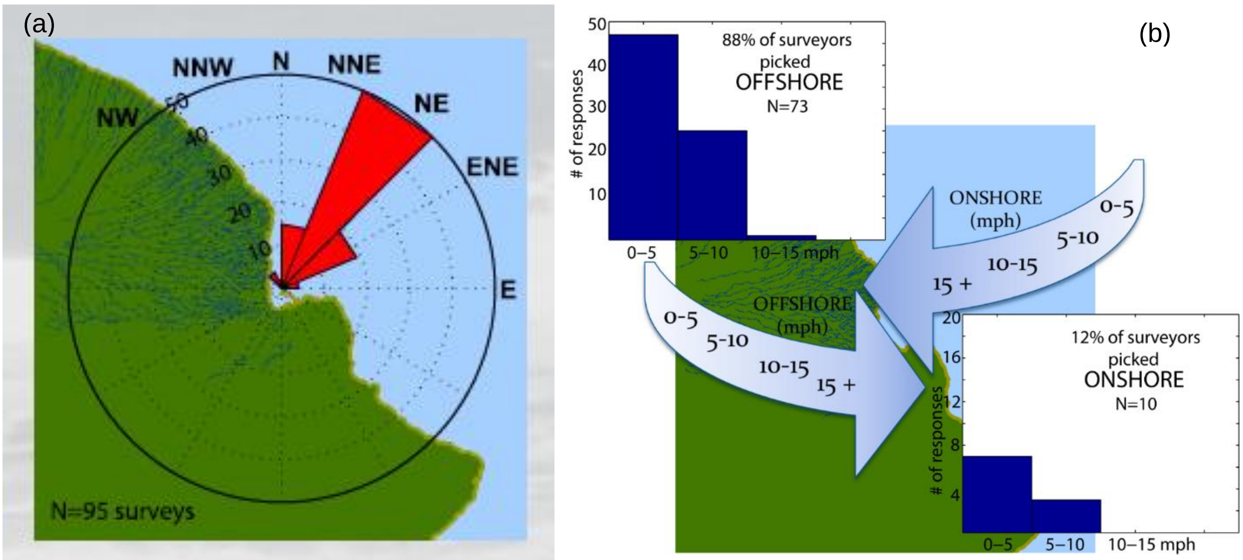


Figure 4.5 (a) Preferred swell direction as selected in surveys (n = 94). (b) Preferred wind direction and speed as selected in surveys (n = 94).

Qualitatively, surfers describe their ideal surf conditions to include the above conditions, as well as environmental conditions such as the type of wave and "*A beautiful day*", "*Glassy, Clean water*", or "*A light rain*". Other social/cultural qualities include the behaviors and actions of those around them, such as "*People following the rules (not dropping in, sharing waves)*", "*Friendly, old timer crowd*", "*Everyone smiling makes it even better*", "*Friends*". The ideal amount of surfers in the water ranged from 1 to 50 with a mean of 9.3 and a mode of 5 (Table 4.5).

Table 4.5 Surf forecast responses based on the surf specialization index.

Variable	P-value	R squared
49. Wave Heights	0.77	5.92%
48. Wind Consistency	0.91	4.93%
51. Dry Days	0.78	7.64%
47. Streamflow	0.72	8.83%
50. Same Weather	0.21	13.57%
52. Sea Level Rise	0.53	10.05%
53. Extreme Events	0.74	7.69%

4.4.4 Research Question 3 - Hindcast of physical and social surf quality

Recollections of past surf conditions did not reveal significant patterns in surf conditions over time. Surfers responded that there were no change in surf quality over the last 5, 10 or 20 years (P = 0.363; Figure 4.6), with a mean of 5.7 on a scale of 1 to 10. Reasons attributed to a negative trend in surf quality through time stated better surf conditions in the past, more storms and better surf at the break called "Points", and more consistent trade wind swells. Reasons attributed to no change in surf quality instead focused on the constant change at the surf site, and how large geological events such as erosion and a shifting sandbar create ever changing surf quality. There are always "*Too many to remembe*r" or "*Always fun to jump in no matter what*". A third of surfers have spent more than twenty years at Honoli'i, and only a few of these explained the reason for their assessment.

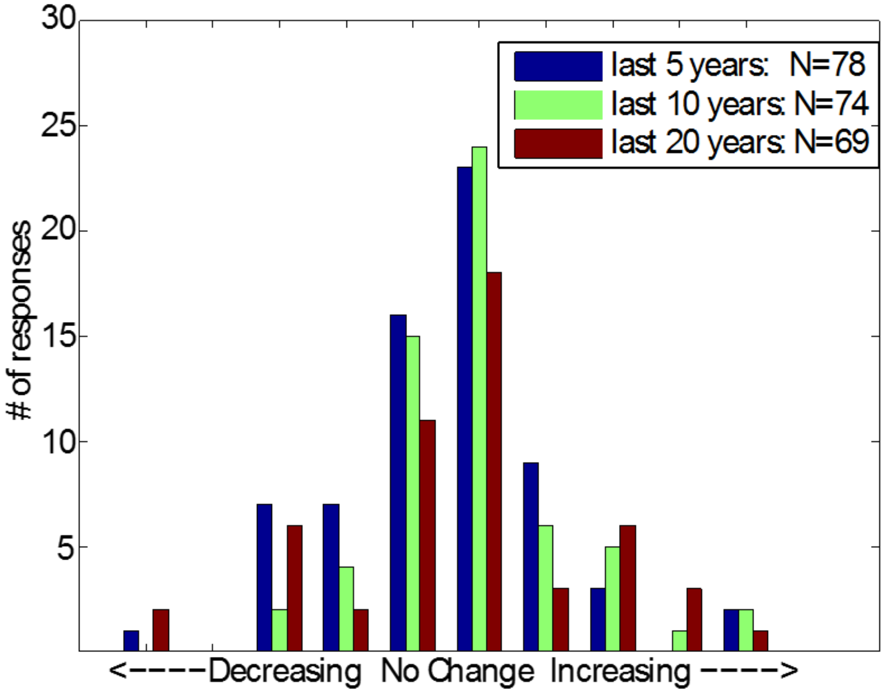


Figure 4.6 Surf Quality over the last 5 (blue), 10 (green), and 20 (red) years.

Surf quality assessment of particular surfing periods in the recent past (within the past 6 months of the survey), such as after large weather and swell events, resulted in mixed responses unrelated to recreational specialty, surfer type or skill (Appendix B, page 5 and 6). Surfers did not recollect a swell/weather event in the same way, assigning a broad range of surf quality rankings for each question. Questions that were more specific, asking how particular swell directions influence surf quality, resulted in clearer responses. Surfers responded that swells from the northeast and east northeast created Good to Epic surf conditions, while surf from the west northwest did not create good surf conditions, and surf from the east was generally fair to good (Figure 4.7).

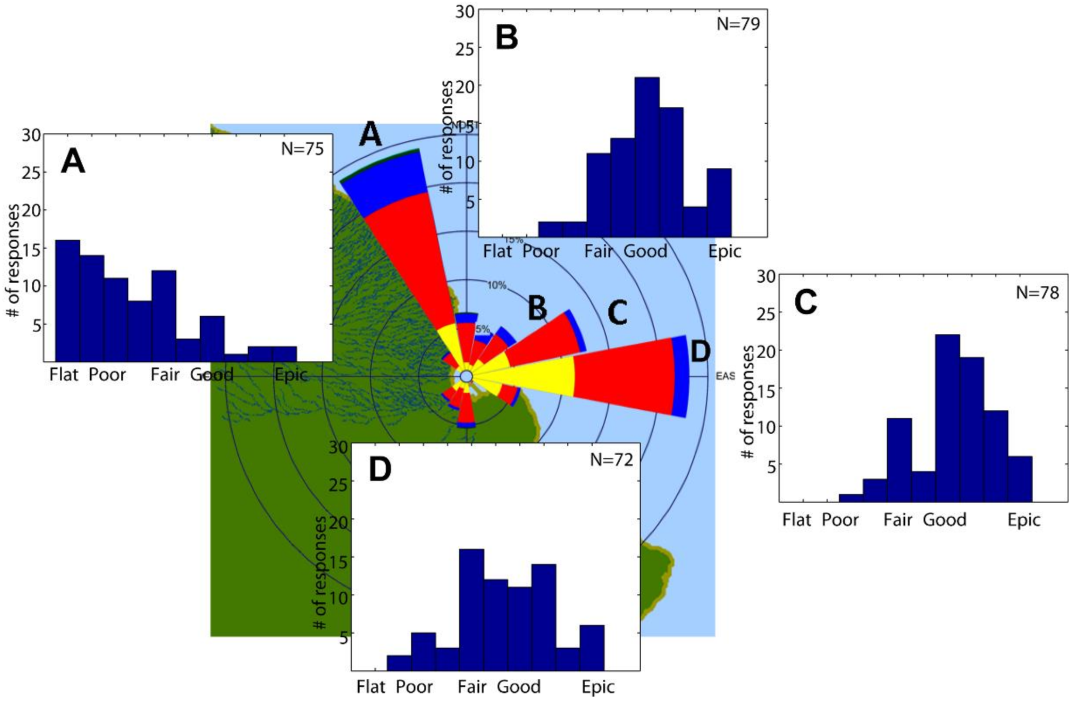


Figure 4.7 Wave Quality on a scale from Flat to Epic when surf originates from the direction of A) WNW (n = 74) B) NE (n = 78) C) ENE (n = 77) and D) E (n = 71).

A few surfers did comment on decreasing surf quality because of the increase of surfers in the water. Similarly, they reflected that the amount of surfers at Honoli‘i has significantly increased over all time periods (p = 0.759), with the largest increase in the last 5 years. On a scale of one to five, with five being “significantly increased”, surfers had a mean response of 4.48, 4.35, and 4.39 respectively for each time period. The maximum amount of surfers observed in the water at one time showed a mean of 64.76, with a total of 82.9 on the beach. The typical amount of surfers observed at one time was 30.15 (Table 4.6).

4.4.5 Research Question 4 - Predictions of physical and social surf quality

When presented with forecasts of a range of weather and climate predictions, surfers generally expect no change in surf quality due to decreasing stream flow, sea level rise, likelihood of dryer days, and the possibility of similar weather patterns to the current regime (Figure 4.8). Complex climate conditions such as these affect surfers in different ways as noted in their qualitative responses - “*Heat or windy dry? Means different effects*” and a few that reflected “*The surf is better with rain/wind storms*”. Responses regarding decreasing streamflow ranged from “*Even with changing streamflow, I think Honoli‘i is a stable surf spot and won't be affected too much that soon*” to “*Might affect the sandbar but not the surf*” and “*Decreased streamflow decreases the steepness of the waves*.” Surfers had a range of responses for each question, but means were not significantly different from “no change” ($p > 0.05$). A decrease in surf quality was forecasted due to decreasing trade wind days and strength ($p = 0.00$), and decreased wave heights ($p = 0.00$). An increase in surf quality is expected as the frequency of extreme events (rainfall, wave heights, and intense hurricanes) may increase (Figure 4.8; $p = 0.00$).

Table 4.6 Crowding recollections, preferences, and empirical observations at Honoli‘i.

Question	N	Mean	SD	Mode
Ideal amount of people in the water	96	9.33	10.24	5
Typical amount of people in the water	91	30.15	14.71	30
Typical amount of surfers is ok? (scale of 1 to 5)	95	3.89	0.88	4
Maximum amount of people observed	93	82.90	106.90	60
Maximum amount of surfers observed in the water	95	64.76	36.22	50
Future amount of surfers expected (scale of 1 to 5)	93	4.6	.60	5
Maximum numbers of surfers you would accept	80	64.44	83.25	50
County of Hawai‘i Lifeguard Statistics				
2014 average count of surfers (5 counts/per day)	1796	38.50	25.46	35
2014 daily average of surfers at Honoli‘i	359	155.55	79.51	145
2014 daily average of total attendance	364	296.58	133.41	275

Using the surf specialization index to compare responses to the forecast of varying surf conditions resulted in no significant patterns. Surfers with higher specialization to Honoli‘i and surfing did not respond in any obvious pattern in comparison to surfers with a lower specialization index score (Table 4.5).

The only social condition I asked them to comment on pertained to the amount of surfers and beachgoers at Honoli‘i. Regardless of physical surf conditions, the amount of surfers is expected to increase in the future, with a mean response of 4.6 on a 5-point Likert scale of decrease to increase. Sixty-six percent of surfers said that the opportunity to escape crowds at Honoli‘i was slightly or moderately important, and 27% said it was extremely important.

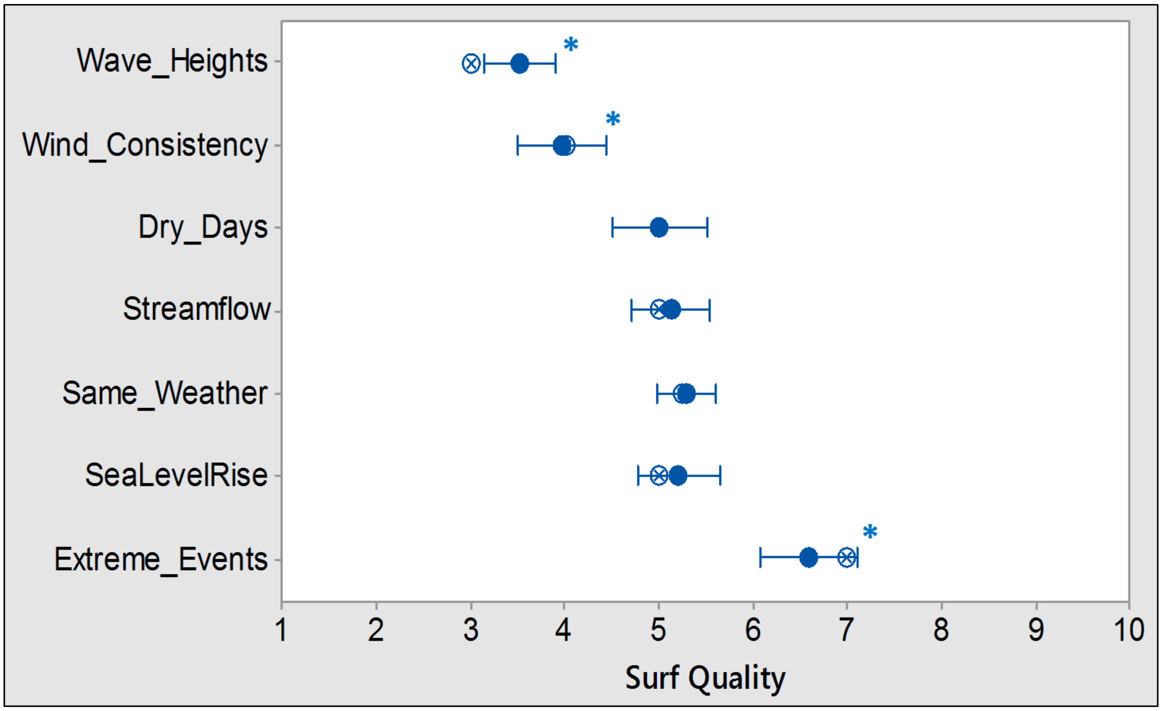


Figure 4.8 Forecast of future surf quality at Honoli‘i based on seven predictions (n = 77-89). Surf quality was ranked from 1 (decreasing surf quality) to 10 (increasing surf quality). * values denote p values significantly different from a no change value of 5.5. Solid circles represent the median value and crossed circles represent the mode.

4.4.6 Empirical physical and social surf quality

Trade winds, and swell direction and strength are the primary indicators of physical surf quality at Honoli‘i. Garza et al. (2012) showed that Hilo does not have a dominant wind direction and is instead affected by orographic and katabatic winds. Yet, regardless of the direction, wind intensity has shown a significant decrease in strength in Hilo (Figure 1a) as has wave height. The decrease in streamflow intensity is also significant in the last 30 years, and this trend is expected to hold into the future (Elison Timm et al. 2015).

Crowding concerns at Honoli‘i were examined by comparing visual counts by County of Hawai‘i lifeguards with surfer’s estimates. Lifeguard statistics do not show a significant trend in surfers since 2009, rather they show a constant of about 39 surfers at a time (Figure 4.9), a little higher than surfers estimate (Table 4.6).

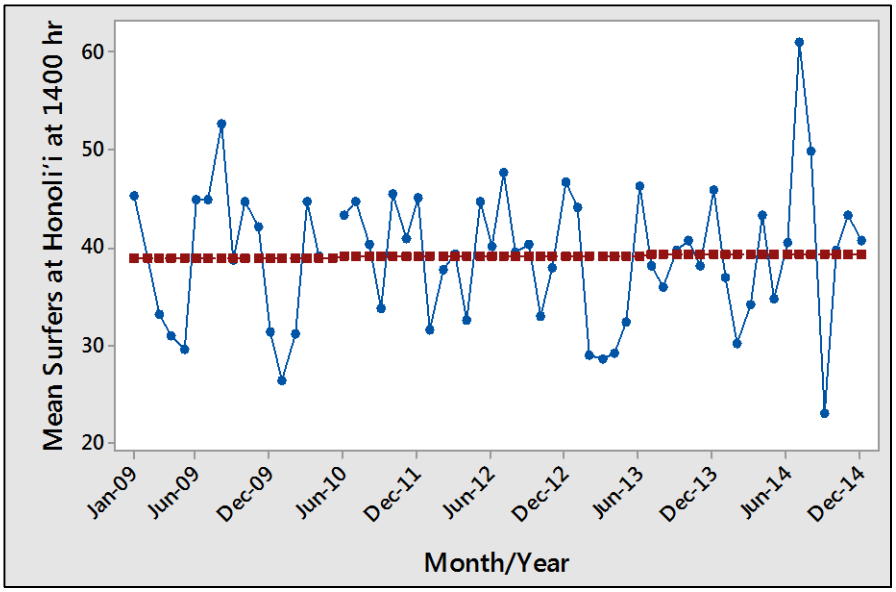


Figure 4.9 A linear trend analysis for average daily surfer counts per month at Honoli‘i Jan ‘09 - Dec ‘14, showed a constant average of 39 surfers per day at 2:00pm.

4.5 Discussion

4.5.1 Research Question 1- Recreational Specialization

Surfers at Honoli‘i include a heterogeneous range of ages, household sizes, surfing experience and commitment to surfing. Yet classifying surfers based on traditional recreational specialization indices did not benefit this analysis since all surfers tended to have high centrality to surfing and identity associated with Honoli‘i. Recreational specialization literature has recognized the difficulty in classifying recreationist along a spectrum, especially those committed to outdoor recreation (Scott 2012), such as I see here with surfers at Honoli‘i. As the survey was directed at surfers at this surf spot and there is limited opportunity to surf elsewhere in Hilo, the affinity to Honoli‘i was somewhat expected. Yet I did expect to see some separation in responses in their predictions or reflections of surf due to their experience, age, or percentage of life surfed at Honoli‘i. However, the limited separation by specialization categories, and the self-classification of experience may not be good indicators of a surfer being able to accurately understand the conditions that make quality surf conditions at Honoli‘i.

Surfing is often recognized as a religion, as in the phrase “soul surfer”, and with the practice of any religion, the attendance and visits to particular places are part of the culture (Taylor 2007). The affinity of beginner and casual surfers to Honoli‘i showed no difference than that of dedicated and expert surfers. This affinity to site by all surfers may be the result of the pride the local community has as caretakers of the property and in training the youth, hosting surf competitions, and organizing beach clean-ups (Walker 2011). Honoliʻi, the place, seems to be as much tied to surfers' identity as is the act of surfing. When asked, 'Why do you surf at Honoliʻi", many surfers commented on the fact that Honoliʻi was their "*home*" spot or where they first learned to surf.

4.5.2 Research Question 2 - Surf quality (a) physically and (b) socially at Honoliʻi

Surf quality, both the social and physical components of surfing, are evaluated as a component of the surf culture of a place (Lazarow et al. 2007). The quality of the physical wave is only part of the overall surfing experience; people will continue to surf in mediocre wave conditions. A surfer's analysis of the surf quality of a particular session may intermingle the social and physical conditions together, while other surfers are able to separate these conditions and comment solely on the waves characteristics. This complexity of defining surf quality, because of the dependence on social conditions that differ among surfers, makes it difficult for a group of surfers to define a particular surf session along a scale of 1 to 10. As shown in the recreational specialization index, surfing as an act of relaxation and identity is important to all surfers, regardless of surf conditions.

4.5.3 Research Question 3 - Surfer's hindcast of surf quality (a) physically and (b) socially at Honoliʻi

When surfers assessed historical surf quality, their recollections included not only the physical conditions, but the social conditions they remembered. In their remembrances of high quality surf sessions, many times it included the presence of their best friends, a time when they were "*all together*", or when they had the surf break to themselves. These social conditions of past surf events are as important to surf quality as the physical conditions of a wave breaking. Affinity to place, friends, and the enjoyment of surfing are social components that influence surf quality, and therefore the culture of surfing. Some social conditions at Honoliʻi have improved over the last 10 years, with decreased drug usage, better access, and a landscaped park along the coastline. Yet other social conditions, such as perceived crowding and unknown surfers may decrease the experience.

Surfers at Honoliʻi had a particular preference for surf quality based on swell direction, wind strength and direction, and height. Although each of these stated preferred conditions have been decreasing in frequency over time, surfers did not seem to assess this decrease in surf quality equally (although I did not ask surfers to specifically recollect these past physical conditions). Although qualitatively and informally, some surfers commented that physically, surf was better in the past, statistics of the overall population of surfers did not support this. Assessing surf quality hindcasts by surfer's age, skill, or proportion of life surfed at Honoliʻi also did not show any significant patterns. Since buoys and wind gauges measure physical conditions independently, to truly know if physical surf quality has been declining, a model would need to concurrently assess the frequency and consistency of surf conditions.

4.5.4 Research Question 4 - Surfer's forecasts of surf quality (a) physically and (b) socially at Honoliʻi

Similarly, when I attempted to understand surf quality forecasts, the responses include the influence of both the potential social and physical aspects of surfing. A simple climate forecast for East Hawaiʻi based on rain and trade wind patterns is the likelihood of increased "Dry days". Surfer's responses to the influence on surf quality in the future based on this scenario showed increasing surf quality because of social conditions (e.g., nice beach weather), and varying responses of decreasing and increasing surf quality due to physical conditions (cleaner water without run-off from the river, less waves due to the lack of trade winds, etc.). This highlights the complexity of the mental model within and among surfers.

Each surfer's mental model of surf quality included a range of variables due to changing physical and social conditions. I expected surf specialization, or a surfer's devotion to surfing, and the proportion of time spent surfing at Honoliʻi, to influence surfers' hindcast and forecast models of surf quality. However I found no differentiation in their responses. As one surfer responded "*It feels like there are (and have always been) good days and bad days at Honoliʻi - just depends!*"

4.5.5 Surf resilience

Surfers at Honoliʻi have taken advantage of the resources (surf quality) available, and their commitment to place have persisted "*It's changed, not better or worse. Each spot is always changing*". Although the physical conditions at Honoliʻi show a decreasing trend, trends are hard for humans to assess, and instead surfers probably feel the peaks (Hulme et al. 2009). Wave heights and wind strength are modeled at large-scales, while surfers individually interact with surf conditions on a small scale. This mis-match in perception and the dynamic conditions of surfing may result in continued enjoyment by surfers. Communities with high place identity may not perceive gradual environmental change, even as it affects their lifestyle, since their social identity is tied to place and activity, and not particularly to the resource abundance (Saenz-Arroyo et al. 2005). A high place dependence for a surfing community may lead to a more socially resilient community even as resource declines persist.

I can further assess surfer's mental models of past surf quality by 1) conducting semi-structured interview and 2) more precisely modeling the occurrence and frequency of historical and predicted ocean conditions. Wind-swell surf at Honoliʻi is created through constant trade winds blowing out of the northeast offshore. Large swell events are created by storms offshore in the north to southeast direction. I can refine understanding of physical surf quality at Honoliʻi by identifying past wind and swell conditions to correlate with wave buoy height data to understand the location and timing of good quality wave conditions at Honoliʻi. Coupling this assessment with past recollections from surfers, as well as modeling the expected future occurrences of these conditions, will give us a more precise understanding of past and future physical surf quality.

I may also understand the social conditions of surf quality by more precisely mapping out the changing conditions at Honoliʻi. Demographics regarding the rise in female surfers, and younger children were noted, as were the rise in stand-up paddleboards. These changes may already be a response to changing social and physical conditions of easier access, weaker currents, and smaller swells ideal for long boards. If these conditions persist, the increase in the amount of surfers may not be evident because of changing demographics. Comparisons of the amount of surfers and preference for surfing at Honoliʻi must also be compared with surfers at other surf spots near Hilo, it was noted that although Honoliʻi is the most consistent spot presently, in the past other breaks were given greater preference. These differences in perception and consistency need to be better understood before further conclusions can be made regarding the changes of surf quality at Honoliʻi.

The range of surf quality mental models by surfers highlight the complexity of predicting future surf conditions, even for a particular surf spot. Climate forecasts show increasing dry, hot days for Hilo, a gradual change from historical experiences of constant winds, frequent rainfall events, and larger wave heights. Although I predicted this to have a negative impact on surf quality, this may not be the case. Future climate conditions may make it more likely that surfing, and other coastal ocean sports and activities that enjoy these conditions will be increasing along

Hilo's coastlines. Coastal resource managers, especially in the face of climate change and a growing population, will have to respond or act pro-actively to manage the potential increased access, crowding, and user conflicts along the shoreline. However, as we've also shown, defining the preferred social qualities of an ocean recreational site can be complicated. Activity and site specific studies to understand ideal social qualities of coastal recreational areas will be needed in order for managers to effectively and pro-actively manage these complex seascapes.

4.6 Conclusion

Honoli'i surfers were interested in learning about Hilo's climate history and predictions of climate change for the future. Surfers asked questions, were engaged with the study, and completed the entire 20 minute survey. The integration of instrumented data along with human recollection and observations show us the limitation of basing conclusions solely on one source of data. The results from the survey showed that although surf quality may appear be decreasing in the future due to potential physical and social changes, the perception, and therefore the reality, of surf quality may not indeed decrease. The gradual decline in surf quality may be too slow to observe or internalize within a surfers mental model and the epic times that do bring good surf will satisfy and fuel their commitment to surfing. As coastal managers begin to integrate the potential effects of climate change on ocean recreationist and coastal resources, research such as this can help illuminate the complexity and resiliency of communities.

Acknowledgements

I would like to acknowledge the assistance of Ayesha Genz, Craig Severance, and Aloha Kapono in the preparation, administration, and analysis of the surveys. They were instrumental in creating a survey that could easily capture the knowledge of the surf community and were my staunch supporters throughout. Cherie Kauahi was also instrumental in conducting the initial testing of physical surf quality parameters. Thanks also go to all the surfers who allowed us to interrupt their precious surfing session.

APPENDIX A. SURF QUALITY SURVEY

Int: ________ Place: ________ Date: ________

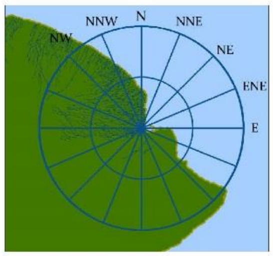
Think about a single session when Honoli'i had the perfect surfing conditions for you.

*Choose **one** option from each of the choices below.*

The Best Surfing at Honolii for me is...

1. Swells from _______ direction.

(Fill in the blank)



2. Tides

A) Rising
B) High
C) Dropping
D) Mid-tide
E) Low

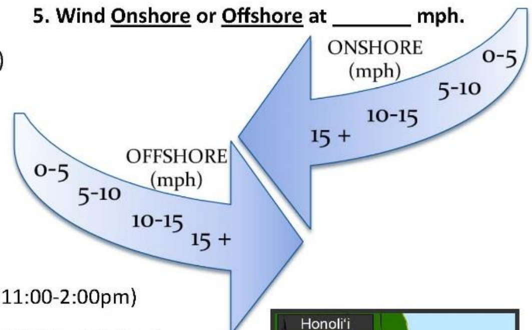
3. Wave Heights of

A) < 2'
B) 2' – 4'
C) 4 - 6'
D) 6 - 8'
E) 8' +

4. River flow

A) Flowing Fast (Days after Anna or a big storm)
B) Flowing Normal (This past July)
C) Flowing Slightly (This past June)
D) No River Movement

5. Wind Onshore or Offshore at _______ mph.



6. Time of Day

A) Dawn (Before 6:30am)
B) Early Morning (6:30-8:30am)
C) Morning (8:30-11:00am)
D) Mid-day (11:00-2:00pm)
E) Afternoon (2:00 - 5]:00pm)
F) Early Evening (After 5:00pm)

7. Surf Break

A) Sandbar present.
B) Sandbar not present.

8. What creates that perfect sandbar? Where is it? ____

____

____

9. Favorite Surf Break at Honoli'i: A) Points B) Mids C) Channels D) Privates E) Tombstone

10. How many is the ideal amount of people in the water? __________

11. Anything else that makes the wave quality perfect?____________________________________

____

____

1

Honolii, Surfing, and Me

12. What year were you born? __________

13. How long have you lived in Hilo? _________

14. Zip code? __________

15. Gender? __________

16. How many years have you surfed at Honoli'i? _________

17. How many days a week do you surf? _______

18. When do you usually surf? *(Select all that apply)*

A) I surf all year round.

B) I surf mostly in the summer.

C) I surf mostly in the winter.

D) I surf mostly on the weekends.

19. How many people are in your household? __________

21. Your Ethnicity (ies) *(Select all that apply)*

A) Hawaiian

B) Filipino

C) Other Pacific Islander

D) Asian

E) White

F) Black/African American

G) Hispanic/Latino

H) Native American

I) Other

20. Please rank on a scale from 1 to 5 how much you agree with the following statements.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I enjoy surfing at Honoli'i more than any other surf spot.					
If I stopped surfing, an important part of my life would be missing.					
Most of my friends are in some way connected with surfing.					
I find a lot of my life is organized around surfing.					
Surfing says a lot about who I am.					
Most other recreation activities do not interest me as much as surfing.					
I feel Honoli'i is very special to me.					
When I surf I can really be myself.					
I identify strongly with the surfing community at Honoli'i.					
You can tell a lot about a person by seeing them surf.					
Surfing is very important to me.					
Surfing offers me relaxation when life's pressure builds up.					
Honoli'i means a lot to me.					
I am often recognized as a surfer.					
I would prefer to spend more time at Honoli'i if I could.					
I would enjoy surfing at Honoli'i just as much at a similar spot.					
I am familiar with Honoli'i.					

2

Honoli'i, Surfing, and Me

22. There are many types of surfers. Which of the five surfer descriptions below is most similar to yourself today? Select the description that generally describes you the best.

	Commitment		Social Life	Behavior
A) Committed Surfer	• Central focus of life	• Devote all your free time	• Revolves around surfing	• Travel to places just to surf
B) Dedicated Surfer	• Most important leisure activity	• Devote a lot of your free time	• Circle of friends includes surfers	• May sometimes travel just to surf
C) Active Surfer	• One leisure activity among many	• Surf regularly	• Occasionally go surf with friends	• May travel for good swells
D) Casual Surfer	• Not an important leisure activity	• Surf occasionally	• May not involve surfing	• Selects convenient places and times
E) Beginner Surfer	• Not an important leisure activity	• Surfed a few times	• Does not involve surfing	• Surf at one or two sites

23. I know about _____ (how many) people that surf at Honoli'i.

24. My favorite type of board to use at Honoli'i. (Circle One)

A) Short B) Long C) SUP D) Body board E) Other _____________

25. I would rate my skill level in surfing as: (Circle one)

A) Novice B) Intermediate C) Proficient D) Advanced E) Expert

26. About how often have you (on a scale from 0 to 5)…

		Never	Rarely		Sometimes		Usually
Checked the surf report?	IDK	0	1	2	3	4	5
Go surf based on the surf report?	IDK	0	1	2	3	4	5
Agreed with the surf report?	IDK	0	1	2	3	4	5

27. Which surf reports do you like or check the most?____

____

28. What one outdoor activity would you likely do instead of surfing? ___________________________

29. Is this activity a substitute that would give you the same level of satisfaction or benefit that you get from surfing? Yes or No

30. Which of these other ocean activities have you done in the past year? (*Select all that apply*)

A) Surf B) Swim C) Paddleboard D) Canoe paddle E) Shoreline Fish
F) Free or Spear Dive G) Fish from Boats H) Throw Net I) Jet Ski J) SCUBA
K) Lifeguard L) Hang out at the Beach M) Observe / Kilo

Honoliʻi, Surfing, and Me

31. How much money do you spend a year on surfing related travel or equipment? _________

32. What is the maximum number of people you've seen on the <u>beach</u> at Honoliʻi? _______

33. What is the maximum number of people you've seen on the <u>water</u> at Honoliʻi? _______

34. Has the amount of surfers at Honoliʻi changed on a scale of 1-5?

IDK for I Don't Know and 1 = decreased, 3 = no change, 5 = increased

	Number of Surfers					
5 Years ago (2010-'14)	IDK	1	2	3	4	5
10 Years ago (2000-'10)	IDK	1	2	3	4	5
20 Years ago (1990-'00)	IDK	1	2	3	4	5

35. How many surfers are in the water on a typical day? ________

36. Is this amount of surfers?

1 2 3 4 5

Too Little OK Too Much

37. How you think the amount of surfers will change in the future? Is there always more surfers when the waves are good? Y or No

1 2 3 4 5

Decrease No Change Increase

38. What is the maximum number of other people you would accept seeing at any one time at Honoliʻi?

0 5 10 20 35 50 75 100 200 350 500

OR ☐ The number of people doesn't matter to me ☐ It matters to me, but I can't specify a number

39. How important is it that you have the opportunity to escape crowds of people at Honoliʻi?

☐ Not at all Important ☐ Slightly Important ☐ Moderately Important ☐ Extremely Important

40. In general, how would you rank the SURF QUALITY at Honoliʻi this past year?

☐ 1 2 3 4 5 6 7 8 9 10

Flat Poor Fair Good Epic

41. Has the <u>population</u> of the following animals changed at Honoliʻi on a scale of 1-5?

IDK for I Don't Know and 1 = decreased, 3 = no change, 5 = increased

	Over the Last 5 Years					
Water Fleas	IDK	1	2	3	4	5
Sharks	IDK	1	2	3	4	5
Turtles	IDK	1	2	3	4	5

42. Why is surfing at Honoliʻi important to you? ____

____

4

How WAS the surf at Honolii?

43. How did the following events affect surf quality on a scale of 1 to 10? If you weren't there or can't recall check this box next to each event. ☐

A) 1st Week of December (North Swell) ☐
1 2 3 4 5 6 7 8 9 10
Flat Poor Fair Good Epic

B) After Tropical Storm Anna (Oct) ☐
1 2 3 4 5 6 7 8 9 10
Flat Poor Fair Good Epic

C) Hot & Dry September (w/ variables) ☐
1 2 3 4 5 6 7 8 9 10
Flat Poor Fair Good Epic

D) After Tropical Storm Iselle (Aug) ☐
1 2 3 4 5 6 7 8 9 10
Flat Poor Fair Good Epic

E) Heavy rain & Strong Trade winds in July ☐
1 2 3 4 5 6 7 8 9 10
Flat Poor Fair Good Epic

44. Do you remember any specific times in the past when the surf quality was best? Please describe the surf *and* the surf community (# of surfers, conditions) Think back to these times.

5 Years ago? (2010-'14) ______________________________

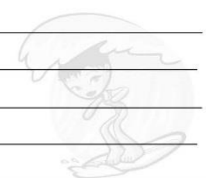
____

10 Years ago?(2000-'10) ______________________________

____

20 Years ago? (1990-'00) ______________________________

____



45. Have you seen any changes in Surf Quality in the last… (check the box if you can't remember)

5 Years? ☐
1 2 3 4 5 6 7 8 9 10
Decreasing Surf Quality No Change Increasing Surf Quality

10 Years? ☐
1 2 3 4 5 6 7 8 9 10
Decreasing Surf Quality No Change Increasing Surf Quality

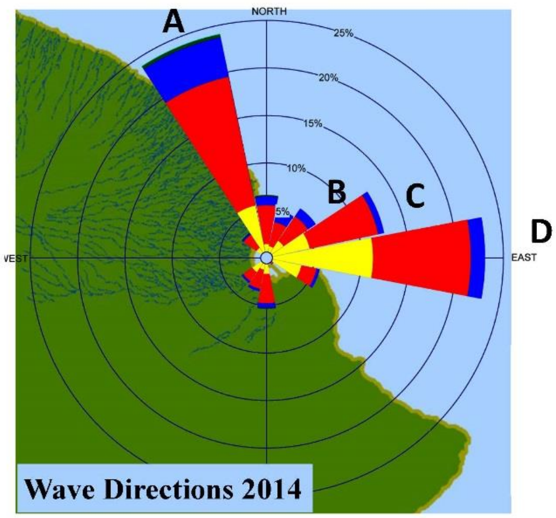
20 Years? ☐
1 2 3 4 5 6 7 8 9 10
Decreasing Surf Quality No Change Increasing Surf Quality

Can you explain? ______________________________

____

How WAS the surf at Honolii?

46. How is Surf Quality when the waves approach from these directions? For E, choose an unmarked direction. If you don't know, check this box next to each event. ☐



SIGNIFICANT WAVE HEIGHT (FT)

- >= 15.0
- 12.0 - 15.0
- 9.0 - 12.0
- 6.0 - 9.0
- 3.0 - 6.0
- 0.1 - 3.0

A) ☐ 1 2 3 4 5 6 7 8 9 10
Flat Poor Fair Good Epic

Why? ____

B) ☐ 1 2 3 4 5 6 7 8 9 10
Flat Poor Fair Good Epic

Why? ____

C) ☐ 1 2 3 4 5 6 7 8 9 10
Flat Poor Fair Good Epic

Why? ____

D) ☐ 1 2 3 4 5 6 7 8 9 10
Flat Poor Fair Good Epic

Why? ____

E) ☐ 1 2 3 4 5 6 7 8 9 10
Flat Poor Fair Good Epic

Why? ____

Please take the time to think about the conditions for good surfing at Honoli'i. Based on the trends that you see, how do you think the surf will be in 10 years from now?

What is your FUTURE SURF FORECAST for Honolii?

47. Streamflow at Honoli'i has been decreasing for 30 years. How do you think SURF QUALITY will be affected at Honoli'i in the next 10 YEARS…

1	2	3	4	5	6	7	8	9	10

☐ Decreasing Surf Quality — No Change — Increasing Surf Quality

Why? ____

48. If we have less Trade winds, do you think SURF QUALITY in 10 YEARS will have…

1	2	3	4	5	6	7	8	9	10

☐ Decreasing Surf Quality — No Change — Increasing Surf Quality

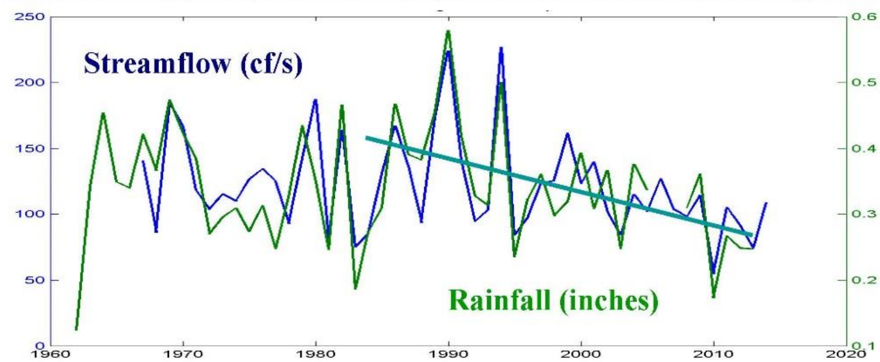
Why? ____

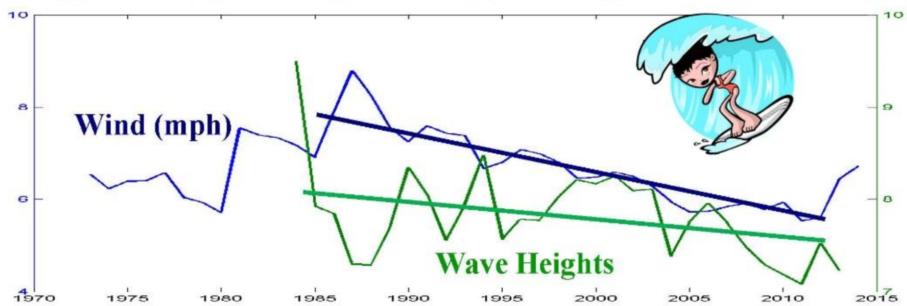
49. If we have smaller Wave Heights, do you think SURF QUALITY at Honoli'i in 10 YEARS will be...

1	2	3	4	5	6	7	8	9	10

☐ Decreasing Surf Quality — No Change — Increasing Surf Quality

Why? ____





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What is your FUTURE SURF FORECAST for Honolii?

50. If scientists predict that weather patterns at Honoli‘i will remain the same in the future, how will this affect the Surf Quality at Honoli‘i in 10 YEARS?

1 2 3 4 5 6 7 8 9 10

Decreasing Surf Quality — No Change — Increasing Surf Quality

Why? ____

51. Scientists predict that there will be an increase in <u>DRY</u> days in the future. How do you think this forecast is likely to affect Surf Quality at Honoli‘i in 10 YEARS?

1 2 3 4 5 6 7 8 9 10

Decreasing Surf Quality — No Change — Increasing Surf Quality

Why? ____

52. Sea Level is rising at about 3 mm/year in Hilo (1 ft./century). How do you think this will affect Surf Quality in 10 YEARS?

1 2 3 4 5 6 7 8 9 10

Decreasing Surf Quality — No Change — Increasing Surf Quality

Why? ____

53. Scientist predict that we'll have more extreme rain events and tropical storms/hurricanes in the future. How do you think this forecast is likely to affect Surf Quality at Honoli‘i in 10 YEARS?

1 2 3 4 5 6 7 8 9 10

Decreasing Surf Quality — No Change — Increasing Surf Quality

Why? ____

54. What other conditions might change the Surf Quality at Honoli‘i?

____

____

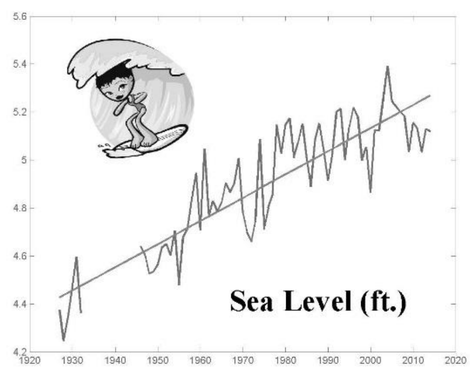
____

55. At what point would you stop surfing regularly at Honoli‘i? Why?

____

____

____



MAHALO

APPENDIX B. SURF QUALITY SURVEY RESULTS

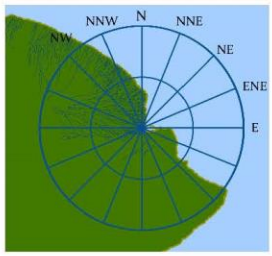
Int: ________ Place: ________ Date: ________

Think about a single session when Honoli'i had the perfect surfing conditions for you.
*Choose **one** option from each of the choices below.*

The Best Surfing at Honolii for me is...

1. **Swells from _______ direction.**

NW - 2%
NNW - 2%
N - 2%
NNE - 16%
NE - 54%
ENE - 20%
E - 3%
ESE - 1%



2. Tides

38% Rising
7% High
23% Dropping
24% Mid-tide
8% Low

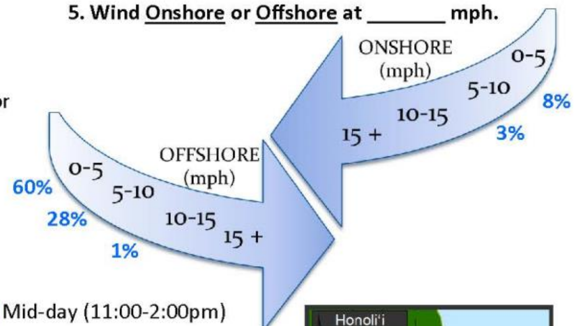
3. Wave Heights of

6% < 2'
30% 2' – 4'
48% 4 - 6'
14% 6 - 8'
2% 8' +

4. River flow

8% Flowing Fast (Days after Anna or a big stor
28% Flowing Normal (This past July)
40% Flowing Slightly (This past June)
24% No River Movement

5. Wind Onshore or Offshore at _______ mph.



6. Time of Day

24% Dawn (Before 6:30am)
34% Early Morning
23% Morning (8:30-11:00am)
10% Mid-day (11:00-2:00pm)
7% Afternoon (2:00 - 5:00pm)
2% Early Evening (After 5:00pm)

7. Surf Break

62% Sandbar present.
38% Sandbar not present.

8. What creates that perfect sandbar? Where is it? ________________________________

____

____

9. Favorite Surf Break at Honoli'i: 14% Points 33% Mids 2% Channels 46% Privates 4% Tombstone

10. How many is the ideal amount of people in the water? Mean = 9.33 SD = 10.24

11. Anything else that makes the wave quality perfect?________________________________

1

Honolii, Surfing, and Me

12. What year were you born? Mean = 1977 SD = 12.8 yrs
13. How long have you lived in Hilo? Mean = 22.73 SD = 15.06
14. Zip code?
15. Gender? N = 102, 25 = female, 77 = male
16. How many years have you surfed at Honoli'i? Mean = 15.8 SD = 12.54
17. How many days a week do you surf? Mean = 2.98 SD = 1.69
18. When do you usually surf? *(Select all that apply)*
    - 88% I surf all year round.
    - 2% I surf mostly in the summer.
    - 1% I surf mostly in the winter.
    - 8% I surf mostly on the weekends.
19. How many people are in your household? Mean = 3.07 SD = 1.40
20. Please rank on a scale from 1 to 5 how much you agree with the following statements.
    (Re-arranged from original survey too group category data together.)

	Strongly Dis	Disagree	Neutral	Agree	Strongly Agr
Centrality					
Most other recreation activities do not interest me as much as surfing.	4%	16%	33%	29%	17%
If I stopped surfing, an important part of my life would be missing.	4%	3%	6%	21%	66%
Most of my friends are in some way connected with surfing.	4%	8%	16%	47%	24%
I find a lot of my life is organized around surfing.	2%	11%	31%	33%	22%
Self-Expression					
Surfing says a lot about who I am.	2%	13%	33%	28%	23%
I am often recognized as a surfer.	3%	13%	30%	29%	26%
You can tell a lot about a person by seeing them surf.	4%	21%	36%	25%	13%
When I surf I can really be myself.	3%	3%	21%	30%	42%
Place Identity					
I enjoy surfing at Honoli'i more than any other surf spot.	3%	4%	31%	33%	28%
I identify strongly with the surfing community at Honoli'i.	3%	9%	17%	40%	30%
I am familiar with Honoli'i.	2%	0%	2%	35%	61%
Place Dependence					
I would enjoy surfing at Honoli'i just as much at a similar spot.	4%	18%	27%	30%	23%
Honoli'i means a lot to me.	1%	1%	12%	37%	49%
I feel Honoli'i is very special to me.	2%	1%	10%	36%	51%
I would prefer to spend more time at Honoli'i if I could.	1%	5%	17%	34%	42%
Attraction					
Surfing is very important to me.	3%	2%	7%	37%	51%
Surfing offers me relaxation when life's pressure builds up.	1%	2%	7%	29%	61%

21. Your Ethnicity (ies)
    - 46% Hawaiian
    - 22% Filipino
    - 3% Other Pacific Islander
    - 41% Asian
    - 55% White
    - 0% African American
    - 7% Hispanic/Latino
    - 3% Native American
    - 9% Other

Honolii, Surfing, and Me

22. There are many types of surfers. Which of the five surfer descriptions below is most similar to yourself today? Select the description that generally describes you the best.

	Commitment		Social Life	Behavior
11% Committed Surfer	• Central focus of life	• Devote all your free time	• Revolves around surfing	• Travel to places just to surf
29% Dedicated Surfer	• Most important leisure activity	• Devote a lot of your free time	• Circle of friends includes surfers	• May sometimes travel just to surf
33% Active Surfer	• One leisure activity among many	• Surf regularly	• Occasionally go surf with friends	• May travel for good swells
20% Casual Surfer	• Not an important leisure activity	• Surf occasionally	• May not involve surfing	• Selects convenient places and times
3% Beginner Surfer	• Not an important leisure activity	• Surfed a few times	• Does not involve surfing	• Surf at one or two sites

23. I know about Mean = 59.31 (SD = 74.08) (how many) people that surf at Honoli'i.

24. My favorite type of board to use at Honoli'i. (Circle One)

38% Short **26%** Long **2%** SUP **13%** Body board **11%** Other: Alaea, multiple, hybrid

25. I would rate my skill level in surfing as: (Circle one)

8% Novice **22%** Intermediate **34%** Proficient **27%** Advanced **7%** Expert

26. About how often have you (on a scale from 0 to 5)…

	Never	Rarely		Sometimes	Usually	
Checked the surf report?	9%	5%	4%	19%	19%	43%
Go surf based on the surf report?	13%	9%	7%	27%	16%	25%
Agreed with the surf report?	7%	12%	12%	37%	21%	6%

27. Which surf reports do you like or check the most?_Surfline, Swellwatch, Magic Seaweed, Surf News Network, NOAA...

28. What one outdoor activity would you likely do instead of surfing? See Table 3

29. Is this activity a substitute that would give you the same level of satisfaction or benefit that you get from surfing? 57% Yes or **43% No**

30. Which of these other ocean activities have you done in the past year? (*Select all that apply*)

99% Surf **91%** Swim **55%** Paddleboard **41%** Canoe paddle **60%** Shoreline Fish
58% Free or Spear Dive **36%** Fish from Boats **24%** Throw Net **16%** Jet Ski **18%** SCUBA
15% Lifeguard **89%** Hang out at the Beach **36%** Observe / Kilo

Honolii, Surfing, and Me

31. How much money do you spend a year on surfing related travel or equipment? **Mean = $926, SD = $1,944**

32. What is the maximum number of people you've seen on the <u>beach</u> at Honoli‘i? **Mean = 82.1, SD = 106.6**

33. What is the maximum number of people you've seen on the <u>water</u> at Honoli‘i? **Mean = 64.3, SD = 36.26**

34. Has the amount of surfers at Honoli‘i changed on a scale of 1-5?

IDK for I Don't Know and 1 = decreased, 3 = no change, 5 = increased

	Number of Surfers					
5 Years ago (2010-'14)	IDK	1%	3%	12%	16%	69%
10 Years ago (2000-'10)	IDK	2%	2%	17%	21%	59%
20 Years ago (1990-'00)	IDK	4%	6%	6%	16%	69%

35. How many surfers are in the water on a typical day? **Mean = 30.15 SD = 14.71**

36. Is this amount of surfers?

0% 2% 37% 27% 30%

Too Little OK Too Much

37. How you think the amount of surfers will change in the future? Is there always more surfers when the waves are good? Y **(81%)** or No **(19%)**

0% 1% 3% 26% 64%

Decrease No Change Increase

38. What is the maximum number of other people you would accept seeing at any one time at Honoli‘i?

Average = 64.44 (SD = 83.25)

OR **6%** The number of people doesn't matter to me **9%** It matters to me, but I can’t specify a number

39. How important is it that you have the opportunity to escape crowds of people at Honoli‘i?

7% Not at all Important **26%** Slightly Important **40%** Moderately Important **27%** Extremely Important

40. In general, how would you rank the SURF QUALITY at Honoli‘i this past year?

0% 1% 4% 6% 23% 11% 39% 13% 1% 2%

Flat Poor Fair Good Epic

41. Has the <u>population</u> of the following animals changed at Honoli‘i on a scale of 1-5?

IDK for I Don't Know and 1 = decreased, 3 = no change, 5 = increased

	Over the Last 5 Years					
Water Fleas	**IDK**	**15%**	**11%**	**58%**	**9%**	**8%**
Sharks	**IDK**	**10%**	**12%**	**69%**	**5%**	**3%**
Turtles	**IDK**	**3%**	**3%**	**26%**	**32%**	**37%**

42. Why is surfing at Honoli‘i important to you? ____

____

4

How WAS the surf at Honolii?

43. How did the following events affect surf quality on a scale of 1 to 10? If you weren't there or can't recall check this box next to each event. ☐

Event	☐	Flat		Poor		Fair		Good			Epic
A) 1st Week of December (North Swell)	☐	2%	0%	2%	5%	21%	14%	29%	16%	9%	3%
B) After Tropical Storm Anna (Oct)	☐	2%	0%	0%	9%	10%	14%	31%	16%	9%	10%
C) Hot & Dry September (w/ variables)	☐	3%	2%	15%	11%	30%	11%	16%	10%	2%	0%
D) After Tropical Storm Iselle (Aug)	☐	0%	0%	5%	3%	13%	16%	23%	15%	16%	10%
E) Heavy rain & Strong Trade winds in July	☐	2%	2%	23%	14%	28%	8%	6%	8%	11%	0%

44. Do you remember any <u>specific</u> times in the past when the surf quality was best? Please describe the surf *and* the surf community (# of surfers, conditions) Think back to these times.

5 Years ago? (2010-'14) ______________________________

____

10 Years ago?(2000-'10)______________________________

____

20 Years ago? (1990-'00)______________________________

____

45. Have you seen any changes in Surf Quality in the last… (check the box if you can't remember)

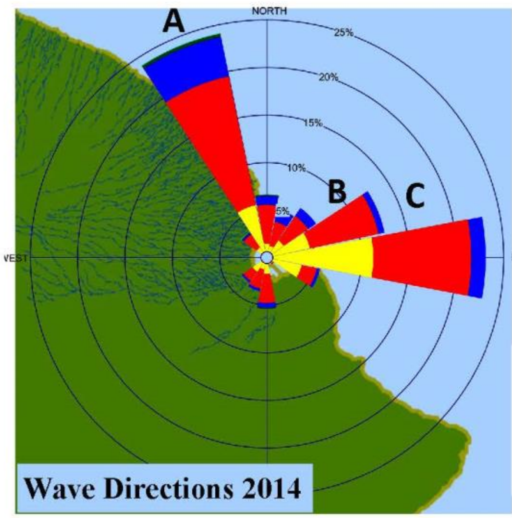
	☐	Decreasing Surf Quality				No Change			Increasing Surf Quality		
5 Years?	☐	1%	0%	10%	10%	24%	33%	13%	6%	0%	3%
10 Years?	☐	0%	0%	3%	7%	27%	40%	10%	8%	2%	3%
20 Years?	☐	4%	0%	11%	4%	23%	34%	6%	11%	6%	2%

Can you explain? ______________________________

____

How WAS the surf at Honolii?

46. How is Surf Quality when the waves approach from these directions? For E, choose an unmarked direction. If you don't know, check this box next to each event. ☐



A) ☐

21%	19%	15%	11%	16%	4%	8%	1%	3%	3%
Flat	Poor			Fair		Good			Epic

Why? ______________________________

B) ☐

0%	0%	3%	3%	14%	16%	27%	22%	5%	11%
Flat	Poor			Fair		Good			Epic

Why? ______________________________

C) ☐

0%	0%	1%	4%	14%	5%	29%	23%	16%	8%
Flat	Poor			Fair		Good			Epic

Why? ______________________________

D) ☐

0%	3%	7%	4%	22%	17%	15%	19%	4%	8%
Flat	Poor			Fair		Good			Epic

Why? ______________________________

E) ☐

1	2	3	4	5	6	7	8	9	10
Flat	Poor			Fair		Good			Epic

Why? ______________________________

6

Please take the time to think about the conditions for good surfing at Honoli'i. Based on the trends that you see, how do you think the surf will be in 10 years from now?

What is your FUTURE SURF FORECAST for Honolii?

47. Streamflow at Honoli'i has been decreasing for 30 years. How do you think SURF QUALITY will be affected at Honoli'i in the next 10 YEARS…

2% 2% 13% 23% 21% 16% 9% 9% 2% 2%

Decreasing Surf Quality — No Change — Increasing Surf Quality

Why? ____

48. If we have less Trade winds, do you think SURF QUALITY in 10 YEARS will have…

13% 14% 21% 20% 6% 12% 7% 4% 1% 2%

Decreasing Surf Quality — No Change — Increasing Surf Quality

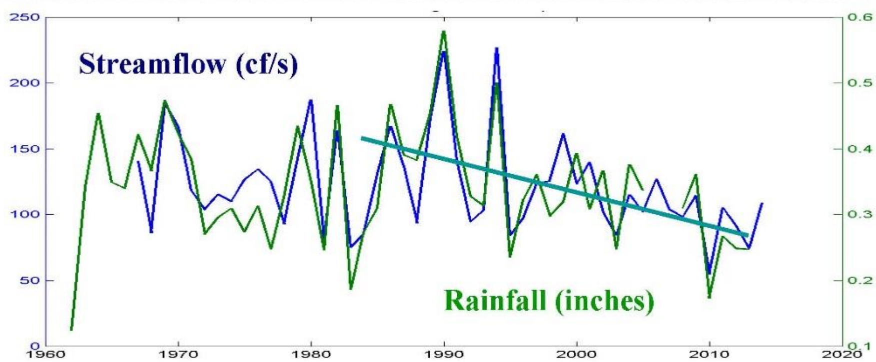
Why? ____

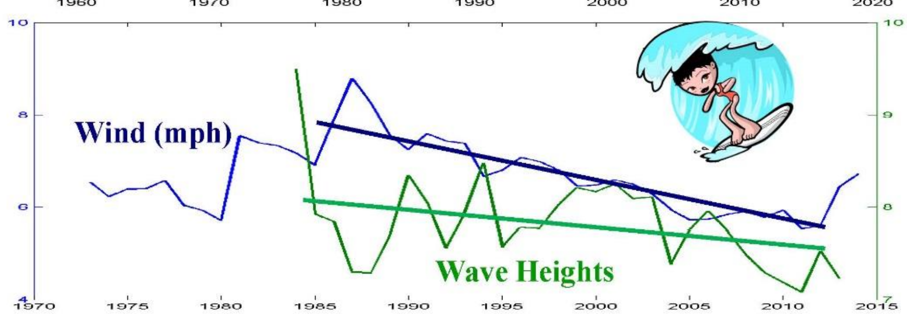
49. If we have smaller Wave Heights, do you think SURF QUALITY at Honoli'i in 10 YEARS will be...

15% 9% 31% 22% 8% 8% 3% 1% 0% 1%

Decreasing Surf Quality — No Change — Increasing Surf Quality

Why? ____





7

What is your FUTURE SURF FORECAST for Honolii?

50. If scientists predict that weather patterns at Honoli‘i will remain the same in the future, how will this affect the Surf Quality at Honoli‘i in 10 YEARS?

2%	3%	8%	6%	31%	37%	7%	4%	0%	1%

Decreasing Surf Quality — No Change — Increasing Surf Quality

Why? ____

51. Scientists predict that there will be an increase in DRY days in the future. How do you think this forecast is likely to affect Surf Quality at Honoli‘i in 10 YEARS?

4%	8%	18%	18%	12%	15%	9%	10%	4%	3%

Decreasing Surf Quality — No Change — Increasing Surf Quality

Why? ____

52. Sea Level is rising at about 3 mm/year in Hilo (1 ft./century). How do you think this will affect Surf Quality in 10 YEARS?

2%	4%	18%	13%	20%	14%	17%	5%	2%	4%

Decreasing Surf Quality — No Change — Increasing Surf Quality

Why? ____

53. Scientist predict that we'll have more extreme rain events and tropical storms/hurricanes in the future. How do you think this forecast is likely to affect Surf Quality at Honoli‘i in 10 YEARS?

2%	5%	7%	9%	5%	9%	16%	29%	12%	6%

Decreasing Surf Quality — No Change — Increasing Surf Quality

Why? ____

54. What other conditions might change the Surf Quality at Honoli‘i?

____

____

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55. At what point would you stop surfing regularly at Honoli‘i? Why?

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____

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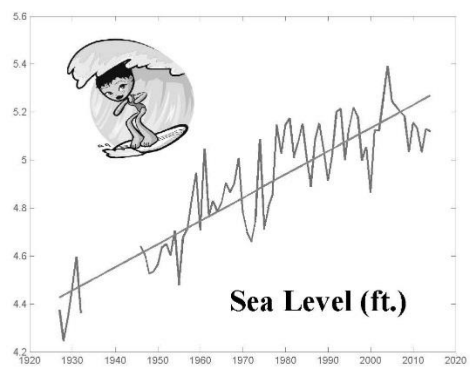

MAHALO

CHAPTER 5. SYNTHESIS, LIMITATIONS, NEXT STEPS

Cultural seascapes are the multiple realities through which people experience and value coastal place and space. Coastal resource managers, especially in the face of climate change and a growing population, will have to pro-actively manage the use of the coastline, acknowledging Hawaii's cultural seascape. Development and recreational interests overlap on Hawaiʼi's coastlines, and the values that we each hold are reflected in our activities. In essence, managers must manage multiple uses, and understand mental models and meanings of the ocean, to be able to manage people and resources more effectively.

5.1 Human observations

Human observations of oceanic conditions can be transformed for integration into resource management. Ocean observers are active on the ocean and document processes at temporal and spatial scales important to their activities. Communicating their knowledge and values of these places and processes can be difficult for some observers, but not all. Although there is room to grow and expand our capabilities for integrating human observations, there are also some observers that easily move between their observational world, and the technical world. As scientists and managers become more adept at listening to these ocean observers, still also we may learn how best to incorporate their knowledge into resource management decisions.

Humans observe their surroundings from a practical spatial scale relevant to their size and activity. Scales of human knowledge are dependent on their human interaction with the ocean. Surfers are observant over a small spatial scale at the intersection of the forming wave and the shoreline. However, as the surfer transitions into a paddler or sailor, his/her mental model will also adjust to the larger scales through which he/she interacts with the seascape. Each of the particular activities which requires the ocean observer to interact with the ocean will be imprinted at a different scale. 'Ike i ke au nui ke au iki - knowledge must be scalable.

We see that cultural seascapes are shaped as much from the social environment as from the physical. The bias in human observations is always present, but understanding the values, scales, relationships, and interactions that shape these biases allow us to accept and use them to further understanding of the seascape. Human bias is present in all observations, be it with the human eye, or a computer model. It's how we receive and recognize this bias in learning that will allow us to grow and expand our knowledge about our seascape.

5.2 Management Implications

A mismatch in scale and/or values can lead managers and ocean users to talking past each other. Without truly hearing or understanding the values and perspectives that another group feels or acts on a seascape, conflict can result. Natural resource management is not all about the "facts" or "science" regarding a topic. It comes down to people's value and the weight we assign to different value systems. Instrumented datasets are important to collect, yet basing management decisions solely on numerical data without acknowledging the potential bias and assumptions that went into collecting and analyzing the data is risky. Managers, and scientists, need to understand how they weigh the value of instrumented data versus human observed data in their management decisions, public outreach and research design. If differing perspectives, mental models, or values are the heart of a conflict over natural resources a technical process cannot lead to a solution, it must be a moral process. People may resist or ignore management strategies if they feel their knowledge system is being ignored.

It's not just about the "system" that collected the data (i.e. western, local, indigenous), but the "system" that decides it use and potential value as a tool in management. When management uses the wrong, or only one type of, tools to manage a resource they are bound to get a reaction or rebuke from user communities. This dissertation chose three different ways to integrate knowledge systems, capitalizing on the many resources within the ocean community. Each scenario allowed us to use a combination of mechanical and human observation to better understand a particular seascape, illustrating the ability and accessibility of new tools for managers.

5.3 Limitations

The most obvious limitation in this research is the narrow (physical and temporal) scale of the data collected. Difficulties in the scaling of research results is always lamented by managers, and to scale up this approach of data gathering to an island or state scale can seam insurmountable. Yet, this mis-match in research and management scales is at the heart of this dissertation. Accepting local knowledge as an important component of natural resource management is easy, but the integration of this knowledge into management tools and processes at a scale that affects management needs to be attempted.

An underlying limitation to the results of my research is in the ability of managers to accept the existence and accuracy of human observations. I state simply the occurrence of human observation systems, and try through this research to convince readers of its reality and applicability. Yet the assumption that all managers and scientists will value this research can be naïve. Correspondingly, human observers need to trust the application and value of their knowledge by researchers. Simply stated, (1) the data needs to be trusted, (2) the process needs to be trusted, and (3) the players need to be trusted. Trust is the most important and foundational virtue upon which all management processes must be built.

Finally, the ability to work within nearshore ocean observer communities was predicated on the trust these individuals have in my ability to represent and protect their perspectives and relationships with the ocean. Although in the writing and analysis of their interviews I present their spatial and temporal observations of the ocean, in reality they shared much, much more. I am grateful and respectful for their sharing of this information with me and yet I am bound by this trust to ensure that the products created accurately portray their stories.

5.4 Next Steps

Subjective meanings of the seascape are the multiple realities through which people experience and value ocean places, ecosystems, and nature. The management of ocean ecosystems by humans is based, sometimes rightfully so, on this subjective bias. By recognizing and identifying our individual and collective bias we can distinguish the choices we make in our research and management actions. I hope to continue my research in understanding the intersection, complement, and disagreement of human and mechanical observation systems in the management of seascapes. Acknowledging the heterogeneous and proud cultural seascapes of Hawai'i will strengthen our resilience as we move into the future.

Pono Science [Management] is driven by ʻIke Pono (knowing what is "right") and Aloha ʻāina (love for the land).

- Ms. Kaleialoha Lum-Ho (2015)

LITERATURE CITED

Alessa, L., Kliskey, A. A., Busey, R., Hinzman, L., and White, D. 2008. Freshwater vulnerabilities and resilience on the Seward Peninsula: integrating multiple dimensions of landscape change. *Global Environmental Change* 18(2):256-270.

Alessa, L., Kliskey, A., Gamble, J., Fidel, M., Beaujean, G., and Gosz, J. 2015. The role of Indigenous science and local knowledge in integrated observing systems: moving toward adaptive capacity indices and early warning systems. *Sustainability Science* (Special Feature):1-12.

Aluli-Meyer, M. 2008. Indigenous and Authentic: Native Hawaiian Epistemology and the Triangulation of Meaning. Pages 217-232; 11 in L. T. Smith, N. Denzin, and Y. Lincoln, editors. *Handbook of Critical and Indigenous Methodologies.* Sage Publishing, Los Angeles.

Aswani, S. 2010. Socioecological approaches for combining ecosystem-based and customary management in Oceania. *Journal of Marine Biology* 2011:13 pages.

Aswani, S. and Lauer, M. 2006. Incorporating fishermen's local knowledge and behavior into geographical information systems (GIS) for designing marine protected areas in Oceania. *Human Organization* 65(1):81-102.

Ball, J. 2002. Towards a methodology for mapping 'regions for sustainability' using PPGIS. *Progress in Planning* 58:81.

Bergquist, D. A. 2007. Sustainability and local people's participation in coastal aquaculture: Regional differences and historical experiences in Sri Lanka and the Philippines. *Environmental Management* 40(5):787-802.

Barnes-Mauthe, M., Arita, S., Allen, S. D., Gray, S. A., and Leung, P. 2013. The influence of ethnic diversity on social network structure in a common-pool resource system: implications for collaborative management. *Ecology and Society* 18(1):23.

Belton, B. and Little, D. 2008. The development of aquaculture in Central Thailand: Domestic demand versus export-led production. *Journal of Agrarian Change* 8(1):123-143.

Berkes, F. 2009. Evolution of co-management: Role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management* 90(5):1692-1702.

Berkes, F. and Berkes, M. K. 2009. Ecological complexity, fuzzy logic, and holism in indigenous knowledge. *Futures* 41(1):6-12.

Bostock, J. 2011. The application of science and technology development in shaping current and future aquaculture production systems. *Journal of Agriculture Science* 149(1):133-141.

Brattland, C. 2013. Sami culture and the mapping of marine biodiversity. *Norsk Geografisk Tidsskrift-Norwegian Journal of Geography* 67(2):87-98.

Bugs, G., Granell, C., Fonts, O., Huerta, J., and Painho, M. 2010. An assessment of Public Participation GIS and Web 2.0 technologies in urban planning practice in Canela, Brazil. *Cities* 27(3):172-181.

Caldwell, P. 2005. Validity of north shore, Oahu, Hawaiian Islands surf observations. *Journal of Coastal Research* 21(6):1127-1138.

Caselle, J. E., Kinlan, B. P., and Warner, R. R. 2010. Temporal and spatial scales of influence on nearshore fish settlement in the Southern California Bight. *Bulletin of Marine Science* 86(2):355-385.

Cesar, H. S. and Van Beukering, P. 2004. Economic valuation of the coral reefs of Hawai'i. *Pacific Science* 58(2):231-242.

Cheng, A. S., Kruger, L. E., and Daniels, S. E. 2003. "Place" as an integrating concept in natural resource politics: Propositions for a social science research agenda. *Society &Natural Resources* 16(2):87-104.

Chu, P., Chen, Y. R., and Schroeder, T. A. 2010. Changes in precipitation extremes in the Hawaiian Islands in a warming climate. *Journal of Climate* 23(18):4881-4900.

Clark, J. R. K. 2011. *Hawaiian surfing: traditions from the past.* University of Hawai‘i Press, Honolulu.

Crowder, L. B., Osherenko, G., Young, O. R., Airamé, S., Norse, E. A., Baron, N., Day, J. C., Douvere, F., Ehler, C. N., and Halpern, B. S. 2006. Resolving mismatches in US ocean governance. *Science-New York then Washington-* 313(5787):617.

D'Arcy, P. 2014. *The people of the sea: Environment, identity and history in Oceania.* University of Hawai'i Press, Honolulu.

Davis, A. and Wagner, J. R. 2003. Who knows? On the importance of identifying “experts” when researching local ecological knowledge. *Human Ecology* 31(3):463-489.

Egenhofer, M. J. and Mark, D. M. 1995. *Naive geography.* Springer.

Eley, T. J. 2001. Mapping local and traditional knowledge: mental maps to GIS. *in 20th International Cartographic Conference* (Beijing, China August 6-10). .

Elison Timm, O., Diaz, H., Giambelluca, T., and Takahashi, M. 2011. Projection of changes in the frequency of heavy rain events over Hawaii based on leading Pacific climate modes. *Journal of Geophysical Research: Atmospheres (1984–2012)* 116(D4).

Elison Timm, O., Giambelluca, T. W., and Diaz, H. F. 2015. Statistical Downscaling of Rainfall Changes in Hawai‘i based on the CMIP5 Global Model Projections. *Journal of Geophysical Research: Atmospheres* 120(1):92.

Endter-Wada, J., Blahna, D., and Krannich, R. 1998. A framework for understanding social science contributions to ecosystem management. 8(3):891.

FAO. 2012. *FAO Statistical Yearbook 2013.* Food and Agricultural Organization of the United Nations, Rome.

FAO Fisheries and Aquaculture Department. 2012. *The State of World Fisheries and Aquaculture.* Food and Agricultural Organization of the United Nations, Rome.

Farina, A. 2000. The cultural landscape as a model for the integration of ecology and economics. *Bioscience* 50(4):313-320.

Feinberg, R., Dymon, U. J., Paiaki, P., Rangituteki, P., Nukuriaki, P., and Rollins, M. 2003. 'Drawing the coral heads': Mental mapping and its physical representation in a Polynesian community. *The Cartographic Journal* 40(3):243-253.

Ferdana, Z. 2002. Approaches to Integrating a Marine GIS into the Nature Conservancy's Ecoregional Planning Process. Pages 153-160 in J. Breman, editor. *Marine geography: GIS for the oceans and seas.* ESRI, Inc., Redlands, California.

Fernandez-Gimenez, M. E., Huntington, H. P., and Frost, K. J. 2006. Integration or co-optation? Traditional knowledge and science in the Alaska Beluga Whale Committee. *Environmental Conservation* 33(04):306-315.

Flament, P., Kennan, S., Lumpkin, R., Sawyer, M., and Stroup, E. 1996. The Ocean Atlas of Hawaii. 2015(May 1 Accessed Online).

Folke, C., Hahn, T., Olsson, P., and Norberg, J. 2005. Adaptive governance of social-ecological systems. *Annu.Rev.Environ.Resour.* 30:441-473.

Food and Water Watch. April 8, 2010. The Empty Promise of Ocean Aquaculture in Hawai`i.

Freundschuh, S., M. and Egenhofer, M. J. 1997. Human Conceptions of Spaces: Implications for Geographic Information Systems. *Transactions in GIS* 2(4):361-375.

Garza, J. A., Chu, P., Norton, C. W., and Schroeder, T. A. 2012. Changes of the prevailing trade winds over the islands of Hawaii and the North Pacific. *Journal of Geophysical Research: Atmospheres (1984–2012)* 117(D11).

Gibbs, J. 1977. *Shipwrecks in Paradise: An Informal Marine History of the Hawaiian Islands.* Superior Publishing Company, Seattle.

Gray, S., Chan, A., Clark, D., and Jordan, R. 2012. Modeling the integration of stakeholder knowledge in social–ecological decision-making: Benefits and limitations to knowledge diversity. *Ecological Modelling* 229:88-96.

Grigorakis, K. and Rigos, G. 2011. Aquaculture effects on environmental and public welfare - The case of Mediterranean mariculture. *Chemosphere* 85(6):899-919.

Gullett, W. 2012. Incorporating Fisheries Interests in National Oceans Policymaking. *Coastal Management* 40(2, SI):222-233.

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., Bruno, J. F., Casey, K. S., Ebert, C., Fox, H. E., Fujita, R., Heinemann, D., Lenihan, H. S., Madin, E. M., Perry, M. T., Selig, E. R., Spalding, M., Steneck, R., and Watson, R. 2008. A global map of human impact on marine ecosystems. *Science (New York, N.Y.)* 319(5865):948-952.

Hau'ofa, E. 2008. *We are the ocean: selected works.* University of Hawaii Press, Honolulu.

Hawai'i Department of Agriculture and Department of Land and Natural Resources. 2010Report to the Twenty-Fifth Legislature State of Hawaii 2010 Regular Session Implementation of Chapter 190d, Hawaii Revised Statutes Ocean And Submerged Lands Leasing. Response to Section 12 of Act 176, Session Laws of Hawaii 1999.

Hawai'i Office of Planning, Coastal Zone Management Program. 2013Hawai'i Ocean Resources Management Plan July 2013. Hawaii State Office of Planning.

Hulme, M., Dessai, S., Lorenzoni, I., and Nelson, D. R. 2009. Unstable climates: Exploring the statistical and social constructions of 'normal'climate. *Geoforum* 40(2):197-206.

Ingersoll, K. E. 2009. Seascape Epistemology: Decolonization Within Hawai'i's Neocolonial Surf Tourism Industry. University of Hawaii at Mānoa Dissertation.

Jarmon, C., Au Bellatti, D., and Mowrey, S. 2004Legal Issues Surrounding the Development of Sustainable Forms of Aquaculture in Hawai'i. University of Hawaii at Mānoa, William S. Richardson School of Law Publication # 2004-3.

Johnson, J. T., Louis, R. P., and Pramono, A. H. 2005. Facing the future: encouraging critical cartographic literacies in indigenous communities. ACME: An International E-Journal for Critical Geographies. 4 (1): 80-98.

Jones, N., Ross, H., Lynam, T., Perez, P., and Leitch, A. 2011. Mental models: an interdisciplinary synthesis of theory and methods. *Ecology and Society* 16(1):46.

Kampion, D. and Brown, B. 2003. *Stoked: A history of surf culture.* Gibbs Smith, Layton, Utah.

Kanahele, P. 2012. *Ka honua ola-'eli'eli kau mai: The living earth descend, deepen the revelation.* Kamehameha publishing, Honolulu.

Kapetsky, J. M. and Aguilar-Manjarrez, J. 2007. *Geographic information systems, remote sensing and mapping for the development and management of marine aquaculture.* Food & Agriculture Org.,

Kaplan, I. M. and McCay, B. J. 2004. Cooperative research, co-management and the social dimension of fisheries science and management. *Marine Policy* 28(3):257-258.

Kelly, J. M. 1973Surf parameters; final report. Part II: social and historical dimensions. *in* Anonymous James K. K. Look Laboratory of Oceanographic Engineering 33.

Klinger, D. and Naylor, R. 2012. Searching for Solutions in Aquaculture: Charting a Sustainable Course. *Annual Review of Environment and Resources* 37:247-76.

Kruk, M. C., Marra, J. J., Ruggiero, P., Atkinson, D., Merrifield, M., Levinson, D., and Lander, M. 2013. Pacific Storms Climatology Products (PSCP): Understanding Extreme Events. *Bulletin of the American Meteorological Society* 94(1):13-18.

Kyle, G., Bricker, K., Graefe, A., and Wickham, T. 2004. An examination of recreationists' relationships with activities and settings. *Leisure Sciences* 26(2):123-142.

Lazarow, N., Miller, M., and Blackwell, B. 2007. Dropping in: A case study approach to understanding the socio-economic impact of recreational surfing and its value to the tourism industry. Pages 448 *in Proceedings of the 5th International Coastal & Marine Tourism Congress: Balancing Marine Tourism, Development and Sustainability* (Auckland, New Zealand.

Lumpkin, R. and Pazos, M. 2005. Measuring Surface Currents with Surface Velocity Program drifters: the instrument, its data, and some recent results. Pages 39 in A. Griffa, A. D. Kirwan, Jr. A.D., A. J. Mariano, T. Özgökmen, and T. Rossby, editors. *Lagrangian Analysis and Prediction of Coastal and Ocean Dynamics.* Cambridge Univ. Press, Cambridge.

Martin, S. 2004. *An Introduction to Ocean Remote Sensing.* Cambridge University Press, Cambridge, United Kingdom.

Maurstad, A. 2004. Cultural seascapes. Preserving local fishermen's knowledge in Northern Norway. *Northern Ethnographic Landscapes: Perspectives from Circumpolar Nations.Contributions to Circumpolar Anthropology* 6:277-297.

Mazur, N. A. and Curtis, A. L. 2008. Understanding community perceptions of aquaculture: lessons from Australia. *Aquaculture International* 16(6):601-621.

McKenna, J., Quinn, R. J., Donnelly, D. J., and Cooper, J. A. G. 2008. Accurate mental maps as an aspect of local ecological knowledge (LEK): a case study from Lough Neagh, Northern Ireland. *Ecology and Society* 13(1):13.

McLain, R., Poe, M., Biedenweg, K., Cerveny, L., Besser, D., and Blahna, D. 2013. Making sense of human ecology mapping: an overview of approaches to integrating socio-spatial data into environmental planning. *Human Ecology* 41(5):651-665.

Menzel, S., Buchecker, M., and Schulz, T. 2013. Forming social capital—Does participatory planning foster trust in institutions? *Journal of Environmental Management* 131:351-362.

Menzies, C. 2006. *Traditional ecological knowledge and natural resource management.* University of Nebraska Press, Lincoln.

Miller, T. R., Baird, T. D., Littlefield, C., Kofinas, G., Chapin, F. S., III, and Redman, C. 2008. Epistemological Pluralism: Reorganizing Interdisciplinary Research. *Ecology and Society* 13(2):46.

Morgan, L. and Etnoyer, P. 2002. The Baja California to Bering Sea Priority Areas Mapping Initiative and the Role of GIS in Protecting Places in the Sea. in J. Breman, editor. *Marine geography: GIS for the oceans and seas.* ESRI Press, Redlands, CA.

Musard, O., Le Dû-Blayo, L., Francour, P., Beurier, J., Feunteun, E., and Talassinos, L. 2014. *Underwater Seascapes: From geographical to ecological perspectives.* Springer Science & Business Media.

Nath, S. S., Bolte, J. P., Ross, L. G., and Aguilar-Manjarrez, J. 2000. Applications of geographical information systems (GIS) for spatial decision support in aquaculture. *Aquacultural Engineering* 23(1):233-278.

Needham, M. D. and Vaske, J. J. 2013. Activity substitutability and degree of specialization among deer and elk hunters in multiple states. *Leisure Sciences* 35(3):235-255.

Nobre, A. M., Robertson-Andersson, D., Neori, A., and Sankar, K. 2010. Ecological-economic assessment of aquaculture options: Comparison between abalone monoculture and integrated multi-trophic aquaculture of abalone and seaweeds. *Aquaculture* 306(1-4):116-126.

Oberding, T. J. 2010. A regional scale site suitability framework for aquaculture in offshore zones. *ProQuest Dissertations and Theses*:161.

Pandian, K. P., Emmanuel, O., Ruscoe, J. P., Side, J. C., Harris, R. E., Kerr, S. A., and Bullen, C. R. 2010. An overview of recent technologies on wave and current measurement in coastal and marine applications. *Journal of Oceanography and Marine Science* 1(1):001-010.

Personal Communication. 2014. Moku O Hawaii Paddlers August 2014.

Poepoe, K., Bartram, P., and Friedlander, A. 2001. The use of traditional Hawaiian knowledge in the contemporary management of marine resources. Pages 328 *in Putting Fishers' Knowledge to Work: Conference Proceedings* Fisheries Centre, UBC Fisheries Centre, UBC.

Pretty, J. 2011. Interdisciplinary progress in approaches to address social-ecological and ecocultural systems. *Environmental Conservation* 38(2, SI):127-139.

Raymond, C. M., Fazey, I., Reed, M. S., Stringer, L. C., Robinson, G. M., and Evely, A. C. 2010. Integrating local and scientific knowledge for environmental management. *Journal of Environmental Management* 91(8):1766-1777.

Rivera-Ferre, M. G. 2009. Can Export-Oriented Aquaculture in Developing Countries be Sustainable and Promote Sustainable Development? The Shrimp Case. *Journal of Agriculture and Environmental Ethics* 22(4):301-321.

Rotarangi, S. and Russell, D. 2009. Social-ecological resilience thinking: can indigenous culture guide environmental management? *Journal of the Royal Society of New Zealand* 39(4):209-213.

Rundstrom, R. A. 1990. A cultural interpretation of Inuit map accuracy. *Geographical Review* 80(2):155-168.

Saenz-Arroyo, A., Roberts, C. M., Torre, J., Carino-Olvera, M., and Enriquez-Andrade, R. R. 2005. Rapidly shifting environmental baselines among fishers of the Gulf of California. *Proceedings Biological sciences / The Royal Society* 272(1575):1957-1962.

Sanchirico, J. N., Lew, D. K., Haynie, A. C., Kling, D. M., and Layton, D. F. 2013. Conservation values in marine ecosystem-based management. *Marine Policy* 38:523-530.

Sanderson, M. 1993. Climate and weather in Hawaii. Pages 12-36 in M. Sanderson, editor. *Prevailing trade winds.* University of Hawaii Press, Honolulu, HI.

Sapkotaa, A., Sapkotaa, A. R., Kucharskib, M., Burkec, J., McKenzie, S., Walker, P., and Lawrence, R. 2008. Aquaculture practices and potential human health risks: Current knowledge and future priorities. *Environment International* 34(8):1215-1215–1226.

Scarfe, B. E., Healy, T. R., and Rennie, H. G. 2009a. Research-based surfing literature for coastal management and the science of surfing-a review. *Journal of Coastal Research* 25(3):539-557.

Scarfe, B. E., Healy, T. R., Rennie, H. G., and Mead, S. T. 2009b. Sustainable management of surfing breaks: Case studies and recommendations. *Journal of Coastal Research* 25(3):684-703.

Schuurman, N. 2009. Critical GIScience in Canada in the new millennium. *Canadian Geographer-Geographe Canadien* 53(2):139-144.

Scott, D. 2012. Serious leisure and recreation specialization: An uneasy marriage. *Leisure Sciences* 34(4):366-371.

Scott, J. C. 1998. Thin simplifications and Practical Knowledge: Metis. Pages 309 in J. C. Scott, editor. *Seeing Like a State and Evading States: How certain schemes to improve the Human Condition have failed.* Yale University, New Haven, Connecticut.

SEAGRANT. 2014Climate Change Impacts in Hawai'i - A Summary of climate change and its impacts to Hawai'i's ecosystems and communities. University of Hawai'i at Mānoa Sea Grant College Program UNIHI-SEAGRANT-TT-12-04.

Shackeroff, J. M. 2011. Social-Ecological Guilds: Putting People into Marine Historical Ecology. *Ecology and Society* 16(1):52.

Shemer, L., Marom, M., and Markman, D. 1993. Estimates of Currents in the Nearshore Ocean Region Using Interferometric Synthetic Aperture Radar. *Journal of Geophysical Research* 98(c4):7001-7010.

Sletto, B. I. 2009. We drew what we imagined. *Current Anthropology* 50(4):443-476.

Strauch, A. M., Mackenzie, R. A., Bruland, G. L., Tingley, R., and Giardina, C. P. 2014. Climate change and land use drivers of fecal bacteria in tropical Hawaiian rivers. *Journal of environmental quality* 43(4):1475-1483.

Suryanata, K. and Umemoto, K. 2005. Beyond environmental impact: articulating the "intangibles" in a resource conflict. *Geoforum* 36(6):750-760.

Suryanata, K. and Umemoto, K. N. 2003. Tension at the nexus of the global and local: culture, property, and marine aquaculture in Hawai`i. *Environment and Planning A* 35:199-213.

Taylor, B. 2007. Surfing into spirituality and a new, aquatic nature religion. *Journal of the American Academy of Religion* 75(4):923-951.

Toupal, R. S. 2003. Cultural Landscapes as a Methodology for Understanding Natural Resource Management Impacts in the Western United States. *Conservation Ecology* 7(1):12.

Walker, I. H. 2011. *Waves of resistance: Surfing and history in twentieth-century Hawaii.* University of Hawai'i Press, Honolulu, HI.

Weller, F. 2009. ``Down-to-Earth'' is Imperative! On the Problems of Landscape-Ecological Regionalisation by Means of Multivariate Statistical Methods. *ERDE* 140(2):113-125.

Wiener, C. S., Manset, G., and Lemus, J. D. 2015. Ocean use in Hawaii as a predictor of marine conservation interests, beliefs, and willingness to participate: an exploratory study. *Journal of Environmental Studies and Sciences* online (tbd):1-12.