Status of Hawaii's Coastal Fisheries in the New Millennium

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The American Fisheries Society (AFS) was founded in 1870. It is the oldest and largest professional society representing fisheries scientists in the U. S. AFS promotes scientific research and enlightened management of resources for optimum use and enjoyment by the public. It also encourages a comprehensive education for fisheries scientists and continuing on-the-job training.

The Hawaii Chapter (AFS-HI) was founded in 1982, and currently has about thirty members. AFS-HI has quarterly meetings of its membership, and occasionally sponsors special sessions at technical conferences that are held locally. Communication with its membership is primarily through the minutes of its quarterly meetings. The chapter occasionally testifies before the State legislature with the objective of contributing a sound, unbiased technical context to fisheries-related legislation.

The Hawai‘i Audubon Society was founded in 1939 to foster community values that result in protection and restoration of native ecosystems and conservation of natural resources through education, science and advocacy in Hawai‘i and the Pacific. The Society is a member of the Marine Fish Conservation Network.

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The Status of Hawai‘i’s Coastal Fisheries in the New Millennium

The coastal fisheries in Hawai‘i have undergone enormous changes in the past 100 years. A breakdown of the traditional kapu system and the demise of the ahupua‘a (watershed) as a management unit after western contact led to the virtual elimination of traditional Hawaiian fisheries management practices. The early 1900s saw a rapid change from subsistence to a cash economy and large increases in the commercial landing of fish and other marine resources. Following statehood, Hawai‘i saw a rapid growth in tourism, an increasingly urban resident population, and the continued development of shoreline areas for tourism and recreation. These changes resulted in another change in the character of the coastal fisheries as they became dominated by recreational anglers and a greater number of part-time commercial fishers who curtailed their fishing to take advantage of more lucrative economic activities.

The only consistent long-term source of data of Hawai‘i’s coastal fisheries is the commercial landings database maintained by the State Division of Aquatic Resources. The major coastal commercial fishery in Hawai‘i is the net fishery for akule (*Selar crumenopthalmus*) which in 2000 landed nearly 500 metric tons with a value of 1.5 million dollars. Akule, along with opelu (*Decapterus* spp.) account for nearly 80% of the entire coastal catch by weight. The remainder of the catch consists of various reef species including surgeonfishes, goatfishes, squirrelfishes, and parrotfishes, respectively, which are taken with a wide variety of gear types.

Fisheries catch statistics alone are unreliable owing to under-reporting by commercial fishers and a large resident recreational and subsistence fishing catch that goes unreported. Hawai‘i is one of the few coastal states that do not require a saltwater recreational fishing license and this harvest therefore goes undocumented. The nearshore recreational and subsistence catch is probably equal to or greater than the nearshore commercial fisheries catch, and recreational and subsistence fishers take more species using a wider range of fishing gear. Intensive fishing pressure on highly prized and vulnerable species has led to substantial declines in catch as well as size and has raised concerns from fishers and resource managers alike about the long-term sustainability of these stocks. The lack of marine-focused enforcement and minimal fines for those few cases that have been prosecuted contribute to a lack of incentive by the population to abide by fisheries management regulations.

In addition to commercial, recreational, and subsistence fisheries, most of the marine ornamental fish and invertebrates originating from U.S. waters are collected in Hawai‘i, which is known for its high quality animals and rare endemics of high value. This fishery ranks second only to akule in terms of total dollar value for coastal fisheries and the true dollar value is thought to be substantially higher than the one million dollars reported in FY 2002. There are no regulations limiting the size, number, and collecting season for most species, and the full impacts of this fishery may not be felt yet. Conflict over competing uses and widespread reports of declining reef fish populations prompted the creation of nine marine reserves, termed Fish Replenishment Areas (FRA), where aquarium collecting is prohibited.

Owing to the poor state of Hawai‘i’s coastal fisheries, the Hawai‘i Department of Land and Natural Resources, Division of Aquatic Resources, has undertaken a number of measures to improve the management of these resources. A few of these measures include changes in minimum size limits for certain resource species, initiation of marine recreational fisheries surveys, and changes to commercial reporting forms. Other management measures have included the use of stock enhancement based on aquaculture for a few highly prized species, marine protected areas, and artificial reefs to improve the catch of some coastal fisheries species in a few select locations.

There are a variety of marine areas in Hawai‘i that have some type of protected status.. The goals of these protected areas vary greatly but areas with good habitat quality and protection from fishing have been shown to substantially increase fish abundance and size within their boundaries. A number of communities throughout the state are currently strengthening local influence and accountability for the health and long-term sustainability of their marine resources through revitalization of local traditions and resource knowledge. The State of Hawai‘i has been encouraging community-based management of subsistence fishing areas since legislation was enacted 1994, and a number of community-managed areas are now being established. Despite the fact that no-take marine reserves and areas under community-based management have proven to be successful fisheries management strategies, less than 1% of the coastal areas in Hawai‘i are managed in these ways.

On November 1, 2001, scientists and resource managers from throughout the state attended a symposium at the Univesity of Hawai‘i entitled “Hawai‘i’s Coastal Fisheries in the New Millennium”. The purpose of this symposium was to document the current status of Hawai‘i’s coastal fisheries and to identify strategies for the effective management of these resources. The major current challenge is to rebuild sustainable fisheries while conserving marine resources and providing non-consumptive benefits to all Hawai‘i’s residents and visitors.

Alan M. Friedlander

Past-president
American Fisheries Society, Hawai‘i Chapter
October 14, 2003

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A Historical Perspective of Hawai‘i’s Marine Resources, Fisheries, and Management Issues over the Past 100 Years

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Introduction

Given the objectives of this symposium, I thought it would be appropriate to review what has happened to Hawai‘i’s fishery resources, fisheries, and management issues over some time framework. In the mid-1980s I prepared a paper “Hawai‘i’s fisheries, past and present;” and today’s presentation will be a follow-up to that paper.

The time period that I will be discussing is 100 years. I would like to highlight three periods: 1900, 1950, and 2000. While I will focus on these three periods, I will also be commenting on what has happened to fisheries here in Hawai‘i as well as fisheries worldwide. I will comment on (1) the size of populations of residents and visitors, (2) fisheries, (3) introduction of species, and (4) management issues.

Table 1: Population size, fishery landings, and fishery product values for the years 1900, 1950, and 2000.

	1900	1950	2000
Population			
Resident	150,000	499,000	1.2 million
Tourist		686,000	6.9 million
Fish Catch (pounds)	6.2 million	16.1 million	23.4 million
Value	$1.1 million	$3.6 million	$59.0 million

1900

Let us begin with the year 1900. I would urge those interested in fisheries of Hawai‘i in 1900 to look up two papers prepared and published in 1902. One is entitled “Preliminary Report on the Investigation of Fish and Fisheries of the Hawaiian Islands” by Jordan and Everman; the other is “Commercial Fisheries of the Hawaiian Islands” by John M. Cobb. These papers were written by scientists whom the U.S. Government sent to look into the fisheries of the Hawaiian Islands after the annexation of the Territory of Hawai‘i to the U.S. They are extremely interesting and exceptional papers depicting people and fisheries under artisanal conditions.

In 1900, the resident population of Hawai‘i was about 150,000 individuals and the number of tourists and visitors to Hawai‘i was negligible. Most of the residents were native Hawaiians; others included other nationalities, primarily Chinese and Japanese. It is interesting to note that prior to the migration of non-Hawaiians from other areas, the population of native Hawaiians was reported to be close to one million individuals. The marked decline was due primarily to mortality attributed to various diseases introduced to the Hawaiian Islands.

In terms of fisheries, the 1900 commercial catch was 6.2 million pounds valued at $1.1 million. One of the most important commercial species was the flying fish (malolo in the Hawaiian language). It is hard to believe, but Cobb reported that in 1900 over 500,000 pounds of flying fish were sold in the markets. I do not think anyone has seen flying fish in the markets over the past 75 years.

I believe that the total amount of fish landed in Hawaiʻi in 1900 was substantially higher than the reported commercial catch of 6.2 million pounds. I say this because in 1900 the population of the Hawaiian Islands was scattered and transportation between communities was very limited. By law the commercial catch had to be sold through a centralized, official market system that consisted of seven centers. There were four of these market centers on Maui and one on Oahu. On Oahu commercial fishery products were handled and sold in central Honolulu. Since people lived in small communities scattered throughout the Hawaiian Islands, the lack of easy access to the centralized markets undoubtedly meant that a considerable amount of localized fishing for home consumption was carried out.

I was interested to find out in Cobb's report that several species had been introduced into the Hawaiian waters prior to 1900. While these were primarily freshwater species, their introduction did indicate the thinking at that time. The fish species introduced at that time included trout and salmon; only the trout has managed to become established on Kauai. Oysters were successfully introduced here. Cobb gave a number of suggestions as to what other species might be considered for introduction here.

A number of management measures or regulations were on the books for the Territory of Hawaiʻi in 1900. Most of these measures dealt with minimum size and presumably related to size at first spawning. My guess is that a number of these regulations were carryovers from the days of the kingdom. Jordan and Everman's account of management practices during the kingdom indicates that fishery management was highly structured and enforcement was extremely good. In fact, the enforcement was so good that the highest level of penalty was death.

1950

In 1950 the resident population of Hawaiʻi was 499,000; the tourist or visitor population was 686,000. Please keep in mind that the 686,000 visitors did not reside in Hawaiʻi throughout the year. In the 1900 the fisheries in Hawaiʻi operated in near-shore waters using vessels that were non-motorized. Although the fisheries operating in Hawaiian waters in 1950 were still considered small-scale fisheries, most of the commercial and recreational vessels were motorized. During the intervening period from 1900 to 1950 several new fisheries developed. One was the pole-and-line fishery for skipjack, another was the longline fishery for larger tunas and billfishes. Both fisheries utilized vessels adapted from fisheries that were developed in Japan. Interestingly, a small-scale purse seine fishery developed in the mid-1950s to fish for schools of big-eyed scad (akule in the Hawaiian language) located in near-shore waters, especially waters outside of embayments. In addition to the fisheries that were localized in the main Hawaiian Islands, there were several forays to the Northwestern Hawaiian Island for bottom fish.

The catch in 1950 was 16.1 million pounds valued at $3.6 million. This was a substantial increase in catch and value from 1900. Most of the increase was attributed to the successful pole-and-line fishery and the longline fishery.

I noted earlier that the commercial fishery products in 1900 were sold through a centralized marketing system operated by the government. As noted in the paper by Cobb, the data collected through the distribution centers were very good. By 1950 my guess is that the quality of data had deteriorated, partly because of the system established after annexation. In 1900 the system was highly structured with all sales having to pass through a centralized market system, and the government was careful about collecting the statistics from these centers. In subsequent decades the centralized system broke down to more of an open sales and marketing system. The result was a deterioration of the data collected from the various fisheries.

In the mid-1940s the Territory of Hawaiʻi hired Vernon Brock from the Oregon Fish Commission to become the director of Hawaiʻi's Division of Fish and Game. Brock initiated a data collection system for the commercial fisheries based on the pink ticket system that was being used in Oregon and California. Several old documents I came across suggest that at the time a system was being developed there were discussions to also collect recreational fishery data. I recall from one report that the likelihood of passing such legislation was good; however, this did not happen and to this day the only data collected regularly and under law have been from the commercial fisheries.

It was during the 1950s and 1960s that introduction of species from outside Hawaiʻi was the highest. Before you throw stones at the individuals who were involved with these introductions, please understand that the rationale behind this effort was, in my opinion, sensible. At that time, those in positions to make these decisions noted that Hawaiʻi was at the edge of the range of the Indo-Pacific marine fauna, and therefore a number of important marine species were missing from the Hawaiian Islands region. The niches that these missing species would have occupied in the Hawaiian marine fauna were reportedly filled by lesser-desired species such as eels. This general belief in the paucity of taxa desirable to fishermen led to the introduction of a number of species from other parts of the Indo-Pacific region. Introductions included the taʻape and several species of groupers.

There was also a move to introduce non-food fish such as baitfish for the then-important aku fishery. Introduced species included tilapia, Marquesan sardines, and threadfin shad.

There was a marked increase in commercial and recreational fishing in the 1950s. Much of this increase related to changes in materials and equipment used in fishing. Prior to World War II, nearly all of the fishing vessels in Hawaiʻi were wooden-hulled. By the 1950s the development of synthetic fibers made it possible to construct fishing vessels from synthetic materials. Mass-produced "off-the-shelf" synthetic hulls cost less and recreational fishers could haul out these boats rather than maintain them at added cost in a slip or anchorage.

In addition to the introduction of synthetic hulls, there was a tremendous improvement in fishing gear and navigational equipment. The world of synthetics led to synthetic ropes, netting, floats, and fishing poles. In the 1950s the modification of LORAN for use on small boats allowed fishing vessels to traverse great distances and to locate fishing grounds with precision. In addition to improvements in navigation, fishing efficiency increased with the introduction of fish finders or depth indicators.

Probably because more people were able to afford the cost of fishing, commercial and recreational fishing markedly increased. The ability to develop reasonable fishing capabilities without years of actual fishing experience also helped expand fishing in Hawaiʻi.

Before moving on to more recent times, I would like to comment on several points relating to fishery resources in general. Up until the early 1900s, there was a belief that the sea contained unlimited resources and mankind could not over fish it. This belief was immediately proven to be wrong in the early 1900s with the collapse of fisheries in the North Sea. These collapses were instrumental in the development of population dynamics in fisheries. Among the leaders in the development of fish population dynamics during the first half-century were Baranov, Beverton, Holt, Ricker, and Gulland.

The world marine fisheries catch increased substantially in the immediate post World War II years to about 20 million metric tons. The increase continued into the 1950s and 1960s. The FAO recognized that some fisheries had collapsed and that the world fishery resources were probably limited. So in the 1950s and 1960s the FAO began studies to understand these changes and to attempt estimates of the potential fishery yields for the various oceans. During the course of these studies, one estimate by knowledgeable fishery scientists was that the world's oceans could probably provide about 200 million metric tons annually; judging by recent total world catches this did not come to pass. In recent years the annual total catch of marine fishery resources has been around 100 million metric tons.

2000

In the year 2000 the resident population in Hawaiʻi was about 1.2 million individuals and the number of visitors about 6.9 million. You can see that there has been a dramatic change in population size over the one-hundred-year period. This change can only mean that there has been considerable human impact on the nearby ocean waters, and this increase is much more dramatic than the population increase suggests. In 1900 human-induced discharge into the ocean contained very few chemicals and pollutants. By 1950, even with a population of nearly one half million people, there was not much concern with human-induced discharge. As I recall, in 1950 the amount of sewage that was discharged directly into the ocean was fairly small. Most households operated on waste treatment by cesspools. Today, most homes and businesses are connected to centralized waste treatment centers, and as a result treated water is being discharged into the ocean.

While in 1950 the fisheries in Hawaiʻi were small-scale, by the year 2000 there was an influx of large fishing vessels capable of reaching distant waters and able to fish for several months at a time. As a result, the catch in 2000 went up to 23.4 million pounds and its value went up to

$59.0 million. Of the major fisheries, only the skipjack fishery showed a reduction in catch. This reduction was not due to a lack of skipjack in island waters but was dictated by economic conditions: the cannery in Hawaiʻi closed in 1984, and the only demand was for a limited amount of fresh skipjack by the local markets.

After the 1950s and into 2000 recreational fisheries grew rapidly. As I indicated earlier, the use of synthetic hulls and the availability of better navigational and depth sounding equipment led to the dramatic growth of both recreational and commercial fisheries. By 2000 the availability of the GPS navigational system provided fishers with an even more impressive system than the Loran did in the 1950s. The GPS system, which depends upon use of satellites, made it possible for fishers to determine the accuracy of positions to within meters.

The most interesting aspect of fisheries during the second half of the 20^{th} century has been the series of new legislation that involved the federal government in fisheries regulations. The new laws included the Marine Mammal Protection Act of 1972, the Endangered Species Act of 1973, and the Fishery Conservation and Management Act of 1976. These initiatives indicated that the federal government thought not only the state governments, but it, too, needed to be involved in monitoring and managing these resources. The states now had to work with the federal government in implementing these regulations. During the second half of the century, a lot more official and unofficial groups have become involved or interested in the management of fishery resources. This has been true not only in Hawaiʻi, but throughout our nation and throughout the world. In Hawaiʻi in 1900 the only people who were really interested in fisheries were the fishermen, the buyers, and to some extent the territorial government. By the 1950s we had not only the commercial fishermen but an increasingly important recreational fishing community and the beginning of the environmental interests in the ocean areas and its resources.

By the year 2000 there was considerable activity and involvement by various interests in fisheries management, in where fisheries is going, and in allocation problems. You have large-scale and small-scale commercial fishers, recreational fishers, and more recently individuals catching reef fishes for the aquarium trade. You have fishing effort directed to marketable species from near-shore reef areas as well as from the deep waters offshore. You have the local buyers who are interested in any legislation dealing with fish – those who are interested in filling the needs of the local market, those who are interested in meeting national markets, and those who are interested in the international trade. Then you have the consumers, including those who are only interested in recreational observations of the marine fauna. Then you have the various environmental groups and the general public, the latter ranging from those who have a passing interest to those who have an intense concern with our fisheries and the marine resources. Finally, you have the legal groups, the lawyers and the judicial system, which have in recent years become deeply involved with fisheries and resource issues. This mix of people has brought on a lot of interesting times.

To summarize, I would like to look at what we know and what we don't know about the coastal resources in Hawaiʻi. We know a little about the life histories and population dynamics of some of the species in coastal waters. But we really don't know much about the dynamics of many of the important commercial and recreational species. We have a good database of commercial catch statistics, but we have very few recreational catch and effort statistics. As noted earlier, recreational fishing in Hawai‘i has shown a remarkable increase in recent decades.

We do not know much about the interaction among and within species in coastal waters. What happens if one were to reduce the population or biomass of a species by 50 percent? What would be the impact of this reduction on other species? We don’t know. How about interaction of various species with the environment? A good example is the Japanese sardine fishery. Prior to World War II, the total catch of sardines in Japan was around 50,000 metric tons. The Japanese do not have size restrictions on the capture of sardines, and to this date they target the post-larval stages of sardines and anchovies. By the 1970s and 1980s, the annual catch of sardines in Japan had gone up to 3 to 4 million metric tons. Just think, despite intensive fishing, the annual catch of sardine increased more than sixty fold. This increase was not due to good management by the Japanese but it apparently was due to environmental changes conducive to a tremendous increase in spawning success. We still know very little about the dynamics of coastal and offshore ecosystems.

Now let us assume that we had as many fisheries biologists and quantitative specialists as we wanted, we had all the money needed to carry out research, and the scientists in Hawai‘i understood the population dynamics of the important as well as the unimportant species. I am confident that my colleagues in stock assessment and modeling would come up with outstanding models and a good understanding of the resources of the Hawaiian Islands. Does this mean we would end up with good management practices? The older I get the more conservative and pessimistic I become. At this point, I think that even given all of this knowledge we would still end up with what we have today. Each vested interest group puts a different value on what the scientists come up with. The scientists cannot come up with precise figures, so they will define the lower and upper bounds of their results. Each interested group will pick and choose the value it wants, it will buy the best lawyers it can find, and it will go to the courts to fight the case. The final outcome in the courts may not be in the best interest of the people or of the resources. Hopefully, I will be proven wrong on this point.

The Status of Inshore Fisheries Ecosystems in the Main Hawaiian Islands at the Dawn of the Millennium: Cultural Impacts, Fisheries Trends and Management Challenges

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Auhea ke kala
kala loloa, kala
kala loloa o ka kai, kala
kala māewa ana i kai,
kai pīkai, kala ē
e kala ka hewa kua
e kalakala ka hewa alo
a kala loa ka hewa a kanaka ē
i ola lo-a kanaka
a pua-aneane
'o ka'u pule kala nō ia
ua lele a'ela nei pule

[Where is the kala seaweed
the long kala, forgive
the long kala of the ocean, forgive
the kala swaying in the sea,
the salty water of purification, forgive
forgive the wrongdoing of yesteryear
forgive fully the wrongdoing of the present
forgive wholly the wrongdoing of man
so man may experience life
until breathing is but a faint sound
this is my prayer for forgiveness
my prayer has taken flight]

- Edith Kanaka'ole Foundation 1995a)[1]

[1] *Pule Kala* (Prayer for Forgiveness). Note: *kala* is both the name of a *limu* ("seaweed") and of a group of interesting and edible inshore fishes (the unicorn surgeonfishes) favored by commercial, recreational and subsistence fishers alike.

Abstract

An overview of the status of inshore fisheries in the main Hawaiian Islands (MHI) is presented, with emphasis on the impacts of cultural and economic changes in the past century on fishing and conservation practices, subsistence yields, and coastal ecology. The effects of changing customs and values are illustrated via a geographic overview of inshore fisheries in the eight MHI, from the Kaua‘i-Ni‘ihau-Ka‘ula group to the Island of Hawai‘i (the Big Island), with examples of how tourism, urbanization, runoff, pollution, localized over fishing, and the gradual commercialization and privatization of the shoreline impact inshore fisheries directly and indirectly. A 360-degree scan of shoreline fishing on the Big Island shows how differences in geography, climate, accessibility, urbanization, prevailing cultural practices, and inshore habitat affect fishing gears and methods, catch per unit effort, size structure, and species composition of the catch. Resolving limited access and/or crowding issues, and mitigating conflicts between inshore tourism (“commercial recreation”) and fishing are increasingly important determinants of spatial and temporal fisheries use patterns and management initiatives as Hawai‘i breaches into the new millennium. Community-based efforts and the renaissance of native culture offer new hope of restoring inshore habitats upon which fisheries rely and of revitalizing inshore stocks through the observance of enlightened old customs, such as caring for stocks in one’s own fishing area, allowing time for resources to renew themselves, integrating watershed management, and exercising restraint in the volume and frequency of fishing.

Introduction and Background Information

> *A harmonious relation to land is more intricate, and of more consequence to civilization, than the historians of its progress seem to realize. Civilization is not, as they often assume, the enslavement of a stable and constant earth. It is a state of mutual and interdependent cooperation between human animals, other animals, plants, and soils, which may be disrupted at any moment by the failure of any of them.*
>
> \- Aldo Leopold 1933[2]

> *In amnesiac revery it is also easy to overlook the services that ecosystems provide humanity. They enrich the soil and create the very air we breathe. Without these amenities, the remaining tenure of the human race would be nasty and brief.*
>
> \- E. O. Wilson 1999

Fishing and ocean recreation have been a way of life for Hawai‘i's people for centuries (Malo 1835-1838, Kamakau 1839, Hoffman and Yamauchi 1973, Anderson and Miura 1990). In this regard, little has changed over the past few hundred years in this unique, geographically isolated archipelago. However, a great deal has changed politically and demographically in a few centuries. Hawai‘i has gone from a series of kingdoms (or chiefdoms) to a united monarchy (Pogue 1858, Cahill 1999), from a monarchy to a U.S. territory (Liliuokalani 1898, Potter et al.1983, Wong and Rayson 1987, Reeves 1992, Dougherty 1992), and from a U.S. territory to a U.S. state (Mellen 1958, Allen 1982, Reeves 1992, Budnick 1992, Hawaiian Patriotic League and Nā Maka o ka Āina 1998, Barnes 1999). Sweeping changes in culture and demography have

[2] “The Conservation Ethic” In: Flader and Callicott 1991

driven changes in government, water rights, land use, and land ownership (Hutchins 1946, Simonds 1949, Tate 1968, Twigg-Smith 1921, Horwitz and Meller 1966, Kelly 1956, *n.d.*, Stannard 1994, Barnes 1999, Chinen 2002), producing a dramatic transformation of Hawaiian land and seascapes (Hobbs 1935, Pratt 1944 1965, Bosselman and Callies 1971, Ferguson Wood and Johannes 1975, Meyers 1976, Devaney et al. 1982, Kelly 1984, Ramil 1984). The concept of land tenure throughout Hawaiʻi and other Pacific island nations has traditionally included inshore estuarine and marine fisheries (Lundsgaarde 1974, Kelly 1980, Acquaye and Crocombe 1984, Crocombe 1987a, Johannes 1978 and 1986, Costa Pierce 1987, Smith and Pai 1992, Adams et al. 1995, Graham 1995). Because of this, and since land use practices affect inshore habitat (via dredging, erosion, runoff, groundwater impacts, etc.), it is not surprising that changes in culture and land dominion have brought changes in the status of Hawaiʻi's inshore fisheries and the ecosystems that sustain them (Bosselman and Callies 1971, Brower 1974 and 1989, Johannes 1978 and 1997, Pooley 1987, Harman and Katekaru 1988, Lowe 1995).

Cause and effect are hard to separate throughout the successive waves of immigration and upheaval that have completely reshaped Hawaiʻi's demography and culture within a few generations (Bishop, 1888, Liliuokalani, 1898, Hoffman 1916, Twigg-Smith 1921, Pratt 1944, Mellen 1958, Tabrah 1980, Hooper 1980, Bell 1984, Budnick 1992, Barnes 1999, Cahill 1999, Grant et al. 2000). Once a unified culture with a self-sustaining economy based on sharing, agriculture, subsistence fishing and gathering (Malo, 1835-1838, Kamakau 1839, Kelly 1980 and 1984, Stannard 1994, Diamond 1997), Hawaiʻi is now a multi-ethnic society with an economy dependent upon the tourist industry and the importation of food, energy, and basic supplies (Smith and Pratt 1992, Modavi 1992, DBED&T 1968-2001). The shifting cultural makeup of Hawaiʻi's population and government has driven fundamental changes in land use practices (Hobbs 1935, Pratt 1944, Bosselman and Callies 1971, Meyers 1976, Creighton 1978, Ramil 1984, Costa Pierce 1987, Modavi 1992, Smith and Pai 1992), redefined and redistributed wealth and power (Tate 1905 and 1968, Kelly, n.d.), and altered perceptions of and uses for natural resources amongst its people (Mellen 1949 1952, and 1956, Pratt 1965, Mullins 1976 and 1977, Tabrah 1980). The effects of Hawaiʻi's changing culture are reflected in the abundance, diversity, and size structure of coastal fish stocks today, as well as in the water quality, health, and integrity of the terrestrial, freshwater, estuarine and marine habitats that sustain them (Jordan and Evermann 1905, Norton et al. 1978, Timbol and Maciolek 1978, Devaney et al. 1982, Shomura 1987, Lowe 1995, Yamamoto and Tagawa, 2000, Friedlander and DeMartini, 2002).

When foreign settlers came to Hawaiʻi in the late 1770s, they found healthy forests, streams, and inshore ecosystems, pristine coastal waters, and a flourishing culture that could feed itself by fishing and gathering diverse and abundant coastal resources (Beckley, 1883, Kahaulelio 1902, Kaʻelemakule 1928-1930, Jordan and Evermann 1905, Craighill Handy et al. 1972, Acquaye and Crocombe 1984, Dieudonne, 2002). In a few generations, changing land use practices have disrupted the connections between rainfall, forests, streams, soils, and groundwater (Hutchins 1946, Creighton 1978, Kameʻeleihiwa 1992, Mueller-Dombois 1996a, Cahill 1999, Dieudonne, 2002, HBWS 2002). Equally problematic, cultural change has produced a new breed of fishers with deficient conservation and resource management skills, as well as societal values and economic constraints that conflict with the need to sustain the fisheries they rely upon for food and income (Johannes 1978, Kelly 1984, Anderson and Miura 1990, Hui Mālama o Moʻomomi 1996). In an isolated archipelago like Hawaiʻi, comprised of relatively small islands with limited inshore shelf area, it would be naïve to think coastal fisheries ecosystems could be managed without regard for land management issues. But a combination of ignorance and arrogance has allowed two-and-a-quarter centuries of immigrants to overlook the *mauka-makai* (land-to-sea) connections understood and managed responsibly by Hawai‘i’s early civilizations for approximately seven centuries prior to “western”[3] contact.

As a result, Hawai‘i now sustains some of the United States’ most threatened forest and wetland ecosystems (Stone and Scott 1984, Williams and Nowak 1986, Stone and Stone 1992, Brower 1974 and 1989, King et al. 1989, National Geographic Society and Hawai‘i Public Television 1993, Mueller-Dombois 1996b, Liittschwager and Middleton, 2001) and inshore fisheries are impacted by habitat destruction, loss of spawning and nursery habitat, and regional overfishing (OCZM and DPED 1978, Devaney et al. 1982, Shomura 1987, KBMPTF 1992, Lowe 1995 and 1996, Friedlander and DeMartini, 2002). Inshore ecosystems that rely on watersheds to gather rainfall, sustain soils, maintain water quality, filter runoff, and moderate primary and secondary productivity are adversely affected in many ways (Banner 1974, OCZM and DPED 1978, Hunter and Evans 1995, Klein 1979, Hunter et al. 1979, Kinsey 1988, Rogers 1990, USACE 1981 1991, Araki Wyban 1992, KBMPTF 1992, Nakasone 1995, Laws and Allen 1996, Mueller-Dombois 1996a and b, HBWS, 2002). Fifty percent or more of water from streams statewide has been diverted for irrigation and other purposes, markedly changing the characteristics of inshore ecosystems (Hutchins 1946, Ramil 1984, Araki Wyban 1992, HSRS 1996, Nakasone 1995, CWRM 1995, Wilcox 1996, Puhipau and Lander, 2003). In some areas, particularly on Maui, the mere presence of water in streams is an issue on all but a few days of the year (Hau 1996).

In addition to affecting habitat quality, cultural change has reshaped fishing practices, perceptions of acceptable levels of abundance, and views of appropriate management. The effects are clearly recognizable in the status of inshore fisheries (Grigg and Pfund 1980, Grigg and Tanoue 1984, Kelly 1984, Pooley 1987, Harman and Katekaru 1988, Iversen et al. 1990a and b, Friedlander and DeMartini, 2002), bringing *Hawai'i nei* (beloved Hawai‘i) to a crossroads where the future of inshore fisheries and the ecosystems that sustain them hangs in the balance (Shomura 1987, Anderson and Miura 1990, Smith 1993, Lowe 1995). The abundance of marine fishes, invertebrates and *limu* (algae) represent one of nature’s barometers, signaling fluctuations in ocean climate, water quality, coastal activities, and impacts of humans and other predators. Groups that are more sensitive to environmental variation, including endemic fishes and invertebrates, wetland species, and even corals found in other regions of the Pacific, represent Hawai‘i’s “canaries in the coal mine.” Broad scale and localized impacts these populations are experiencing now may signal challenges that even the most resilient and widespread organisms will face eventually. Therefore, a glance at the status of Hawai‘i’s fisheries resources and habitats at the dawn of the millennium is a useful “reality-check,” charting where we are today and indicating our prospects and needs to ensure a sustainable future.

Modern ocean activities differ from ancient practices in ways too numerous to mention, but Hawai‘i’s people still feed themselves from the sea and enjoy relaxing along her shoreline.

[3] First contact was with Europeans, then U.S. mainlanders, more accurately “easterners” from a Hawaii perspective. Later immigrants included Asians and people from the Philippines, Guam, Samoa, Tonga, the Commonwealth of the Northern Marianas, etc., generally south- or northwest of Hawaii. A change of perspective would suit a broader consideration of Pacific fisheries issues, but the inaccurate “western” convention will be maintained herein for the sake of continuity.

Although time has changed a lot, one guiding principle remains in the hearts and minds of most of Hawai‘i's people today. That is a desire to conserve this jewel of the Pacific and her freshwater, estuarine, and marine fisheries as a legacy for future generations (Meyers 1976, Tabrah 1980, Anderson and Miura 1990, DBED&T 1991, DAR, 2002). The challenges of the new millennium will be explored in light of this motivating goal as we examine the effects of socio-economic change on inshore fisheries in the main Hawaiian Islands.

The Main Hawaiian Islands

The eight southernmost islands of the Hawaiian Archipelago and their associated rocky structures are known as the main Hawaiian Islands (MHI, Figure 1). The MHI accommodate over 99 percent of the State's 1.3 million residents (Table 1). In addition, over 6 million tourists visit Hawai‘i each year (DBED&T, 2001). The large number of residents and visitors who inhabit the state on a daily basis place land and inshore marine resources in the MHI under extraordinary ecological stress, particularly on the island of Oahu, where 70-80 percent of the state's population is concentrated, yet which represents only 9.3 percent of the landmass in the MHI (Table 1).

Cultural, Economic, and Demographic Changes Affecting Hawai‘i's Inshore Fisheries

The Old Ways: An Economy of Responsibility, Aloha, and Respect

They are not dead, they are but sleeping,
the gods of old Hawai‘i.
I have heard them in the still of the night
whispering of huge portent in the seething surf,
they are more than winds in palm trees,
more than surging seas.

I have heard the undertones of power,
of fierceness and of strength,
I have heard the minor tones of nostalgia,
of sadness and of dreams.
No, they are not dead, they are but sleeping,
the gods of old Hawai‘i

- Anonymous[4]

The philosophy of the native people who once ruled the Hawaiian Islands was expressed succinctly by King Kauikeaouli Kamehameha III, upon the event of his reinstatement after one of the various military overthrows that define Hawai‘i's history as a U.S. state (Lili‘uokalani 1898, Allen 1982, Budnick 1992, Dougherty 1992, Cachola 1995, Reeves 1992, Buck 1993, Trask 1993, Hawaiian Patriotic League and Nā Maka o ka Āina 1998). The essence of Hawaiian heart and government is demonstrated in his words, spoken at a time of critical import to the

[4] In: Mellen 1963.

Table 1: Main Hawaiian Islands Geography and Resident Population[1] (1950-2000)

Island	1950	1960	1970	1980	1990	2000	Area (sq.mi.)[2]
Ni‘ihau	222	254	237	226	230	160	69.46
Ka‘ula Rock	-	-	-	-	-	-	0.25
Kaua‘i	29,683	27,922	29,524	38,856	50,947	58,303	552.32
O’ahu [3]	353,006	500,394	630,497	762,534	836,231	876,151	597.11
Moloka'i	5,280	5,023	5,261	6,049	6,717	7,404	260.04
Lanai	3,136	2,115	2,204	2,119	2,426	3,193	140.54
Maui	40,103	35,717	38,691	62,823	91,361	117,644	727.30
Molokini	0	0	0	0	0	0	0.04
Kaho‘olawe	0	0	0	0	0	0	44.60
Hawai’i	68,350	61,332	63,468	92,053	120,317	148,677	4,028.24
All MHI	499,780	632,757	769,882	964,660	1,108,229	1,211,532	6,419.89
Percentage (%) of Whole State Population							**% Land Area**
Ni‘ihau	0.04	0.04	0.03	0.02	0.02	0.01	1.08
Ka‘ula Rock	-	-	-	-	-	-	0.004
Kaua‘i	5.94	4.41	3.83	4.03	4.60	4.81	8.60
O’ahu	70.63	79.08	81.89	79.04	75.46	72.32	9.30
Moloka'i	1.06	0.79	0.68	0.63	0.61	0.61	4.05
Lanai	0.63	0.33	0.29	0.22	0.22	0.26	2.19
Maui	8.02	5.64	5.03	6.51	8.24	9.71	11.33
Molokini	-	-	-	-	-	-	-
Kaho‘olawe	-	-	-	-	-	-	-
Hawai’i	13.68	9.69	8.24	9.54	10.86	12.27	62.75
Whole State [4]	499,794	632,772	769,913	964,691	1,108,229	1,221,537	

Number of Visitors by Island Platform Group: 2000 Only [5]

Island Platform Group	Numberof Tourists/Year
Ni‘ihau, Kaua‘i (most visitors come to Kaua‘i, not Ni‘ihau)	992,780
O'ahu	5,002,530
Maui, Kaho‘olawe, Lanai and Moloka'i (Molokini not specifically included)	2,376,330
Hawai‘i	1,255,480
Northwestern Hawaiian Islands	5,000

Table Legend

[1] **Population Data Source:** Hawai‘i Online 2001 (www.Hawaii.gov), U.S. Bur. Census decennial bull.(1940-90) 1990 printouts/tapes, Census 2000 Redistr. Data (P.L.94-171) Summary 1990 census printouts and tapes, and Census 2000.

[2] **Land Area Source:** DBED&T 1997 (Table 5.08) Estimated in 1990

[3] **Oahu Lands and Population Including:** Sand Island, Mokauea Island, Ford Island and Moku o Loe

[4] **Whole State Population** includes a small number of residents of the Northwestern Hawaiian Islands.

[5] **Number of Tourists by Island** from Gulko et al. (2000)

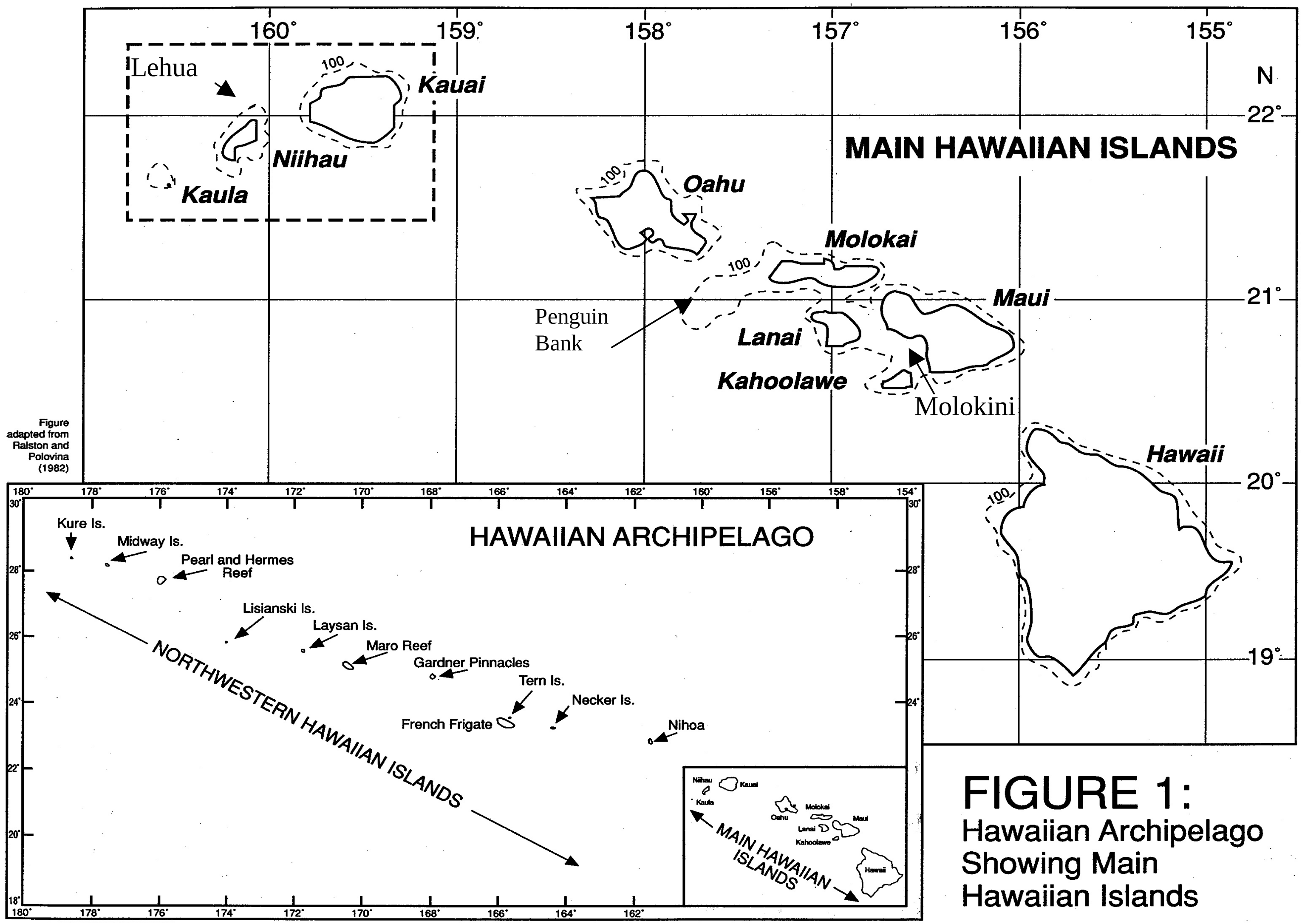

FIGURE 1:
Hawaiian Archipelago Showing Main Hawaiian Islands

Kingdom (Castro and Yost 1972) and in a place sacred to the Hawaiian people (Ka-wai-a-Haʻo Church). His statement, ”*Ua mau ke ea o ka ’āina i ka pono*”, has been interpreted as “the life of the land is perpetuated in righteousness” [5]. Native Hawaiians were able to perpetuate healthy and abundant aquatic and terrestrial ecosystems for centuries through their adherence to righteous cultural practices, such as carefully tending crops, forests, and fisheries with an eye toward sustaining them for future generations, maintaining the integrity of upland and coastal watersheds, not just harvesting, but also giving back to fish stocks (feeding them a portion of crops, letting some of the fish raised in ponds go free, etc.), sharing nature’s bounty with neighbors, and shunning actions of greed and waste (such as overfishing).

The native people of Hawaiʻi (*na kanaka maoli*) have a deep spiritual connection to the land, sea, sky and other elements of the natural world (Bingham 1849, Liliuokalani 1897, Beckwith 1951, Barrère 1969, Araki Wyban 1992, Kameʻeleihiwa 1992, Kanakaʻole Foundation 1995a and b, Dames & Moore et al. 1997). This relationship, which includes Hawaiʻi’s marine, brackish, and freshwater habitats and all their living and non-living elements (Liliʻuokalani, 1897, Beckwith 1951, Johnson 1981, Araki Wyban 1992), has brought *aloha*[6] to the art of fishing since ancient times. In some cases, it has even allowed native fishermen to enlist help from ocean creatures in herding schools of fish and/or gathering their catch (Kahaulelio 1902, Hoala na Pua 1996).

In addition to showing appreciation for nature’s gifts through offerings and prayers, *kanaka maoli* throughout history have acknowledged a responsibility to actively *mālama* (“take care of”)[7] shorelines, streams, reefs, inshore fisheries and other natural resources (Malo, 1835-1838, Titcomb 1952, Craighill Handy et al.1972, Araki Wyban 1992, Dieudonne, 2002, Poepoe et al., 2003). The definition of *kuleana*, a family parcel to which one belonged through heritage, included both a right to partake in the use of its natural resources and a responsibility to take care of, manage, and share them with others (Beckley, 1883, I’i 1959, Kamakau, 1839, 1842-1868, Malo, 1835-1838, Kahaulelio 1902, Kihe 1914-1930, Ka’elemakule 1928-1930, Araki Wyban 1992, Chinen, 2002, Maly and Pomroy-Maly, *in prep*.). This right and responsibility to *mālama* the land and share its gifts extended to inshore and offshore areas surrounding the Hawaiian Archipelago.

Like successful indigenous cultures across many continents and centuries (Elliot and Gare 1983, Reeves 1992, Tucker and Grim 1993, Callicott 1994, McDaniel and Gowdy, 2000), *kanaka maoli* recognized and taught the principle of caring for the life of the land and sea as part of learning how to be a responsible human being (Titcomb 1952, Craighill Handy et al. 1972, Creighton 1978, Pukui 1983, Kelly 1980 and 1984, Johannes 1978 and 1997, Araki Wyban 1992, Hoala na Pua 1996, Farber 1997, Dieudonne 2002, Friedlander et al. 2002a). These principles are valid regardless of one’s ancestry but are not universally recognized or practiced

[5] These words have endured to become Hawaii’s state motto.
[6] Pukui and Elbert (1986) describe some of the depth of meaning of the word *aloha*, including:“love, charity, mercy, kindness, compassion…” The importance of this spirit to sustainable fishing should be clear to fishermen and fisheries managers alike, as opposed to the spirit that invokes the “tragedy of the commons” so often described in “Western style” management (Baden and Noonan 1998).
[7] Pukui & Elbert (1986) list important included meanings: “to take care of, tend, attend, care for, preserve… honor, etc.”

by all cultures[8]. Logically, the importance of this philosophy to the survival of island people increases with increasing distance from other communities and places. Perhaps in part for this reason, and because of the size and topography of the Hawaiian Archipelago, *kanaka maoli* societies throughout the islands had mastered the arts of governing, administering, sharing, nurturing, and conserving natural resources for centuries before *haole* (foreign) intervention in the late 1700s (Craighill Handy et al. 1972, DB&F 1979, Diamond 1997, Kirch 1985, U.S. Congress and Senate 1993).

Traditional fishing, upland, wetland, and sea farming methods of *na kanaka maoli* incorporated a wide range of conservation, cooperation and sustainable management practices (Craighill Handy et al. 1972, Kirch and Dye 1979, Kirch 1982 1985, Costa Pierce 1987, Meller and Horwitz 1987, Araki Wyban 1992, Smith and Pai 1992, Kamehameha Schools Bernice Pauahi Bishop Estate 1994, Miller and Bay 1995, Johannes 1997, Farber 1997, Trask 1999, McDaniel and Gowdy, 2000, Pacific American Foundation and Hui Mālama o Moʻomomi, 2001, Dieudonne, 2002, Poepoe et al., 2003). Offerings of vegetables and fruits that accompanied prayers and chants to the sea before and/or after fishing, building, or harvesting fishponds may have also served to fertilize, enhance and/or feed stocks, of which only a portion was harvested when the time was right (Malo, 1835-1838, Kamakau, 1839, Titcomb 1952, Pukui 1983, Iversen et al. 1990b, Stokes and Dye 1991, Araki Wyban 1992, Hoala na Pua 1996, Dieudonne, 2002). Strict *kapu*[9] protected various fishery elements (stocks, species, age/size/sex-classes, areas, seasons, lunar phases, etc.), managing the impacts of fishing according to *manaʻo*[10] inherited from the ancients (Malo 1835-1838, Kamakau 1839, Kirch and Dye 1979, Araki Wyban 1992, Kanakaʻole Foundation 1995a, Taylor 1995, Pacific American Foundation and Hui Mālama o Moʻomomi, 2001, Friedlander et al., 2002a). The *kapu* system included periods when inshore fishing was not allowed. During these times (and others), fishermen foraged miles offshore of populated and unpopulated islands, to depths over 2400 feet (Hawaiian Laws 1840, Beckley 1883, Kahauelelio 1902, Thurston 1904, Kirch and Dye 1979).

These practices helped ensure that a relatively high abundance of flora and fauna could be found close to shore, allowing people to feed their families even through times when weather or other circumstances made it difficult to go out to sea. The maintenance of subsistence fishing and gathering resources, to ensure the well being of the common people, was of high priority to *kanaka maoli* societies. Management to this end was implemented via government and community policies, traditional practices, and finally by laws in place until the overthrow of the Hawaiian Kingdom. Rules and protocols for fishing and gathering were respected by all. The penalty for breaking the *kapu* in ancient times was death, or in lesser cases a loss of status and the disdain of the village and its *kupuna* (elders). Even when extreme penalties were warranted, there was a process for showing remorse and seeking forgiveness (Hazlett 1986, Bryan and Emory 1986, Soehren and Tuohy 1987, Barrère 1994). A system of regulations with significant fines remained in place into the early 1900s.

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[8] Moreover, as the world's ancient cultures adapt to socio-economic changes forced upon them in recent centuries, cultural practices are also changing (often tragically). Culture is not a static characteristic of any people, including *na kanaka maoli*.

[9] Restrictions or sacred rules, governing fishing and other aspects of life.

[10] The meaning of the word *"manaʻo"* encompasses perspective, theory, insight, belief, recommendation, hope, and more (Pukui and Elbert 1986). It can be translated roughly as "living knowledge", adapting in response to new observations.

The archaeological record substantiates oral histories, showing that *kanaka maoli* possessed a knowledge of the marine world surpassing that of modern marine biologists (Malo 1835-1838, Kahaulelio 1902, Kihe 1914-1930, Ka'elemakule 1928-1930, Green and Kelly 1970, Kirch 1982 and 1985, Araki Wyban 1992, Dieudonne, 2002, Maly and Pomroy-Maly, *in prep*). Fishing was an important source of food for ancient Hawaiians and was as much a way of life for fishermen and their families then as it is today (Bishop 1916, Green and Kelly 1970, Kirch and Dye 1979, Kirch 1982, Taylor 1995, Meyer 1998, Dieudonne, 2002). Fishermen then (and now) developed a complex understanding of the life history and behavior of fish stocks and their food, based upon trial and error, longterm observations, and information passed on through generations (Johannes 1981a and b, Araki Wyban 1992, Pacific American Foundation and Hui Mālama o Moʻomomi 2001, Dieudonne 2002, Poepoe et al. 2003). This "fishermen's science" encompassed an understanding of weather and climate, oceanography, ecology, and other important determinants of abundance, fishing conditions, harvest rates, and appropriate short- and longterm fishing strategies.

The *manaʻo* of master fishermen was recognized in Hawaiʻi's past and given a level of authority. Because of his skill and knowledge, the status of a master fisherman in ancient Hawaiian communities was one of great importance and respect. His ability to predict long-term changes in climate affecting crops and fisheries, provide food to sustain villages through periods of drought and famine, and forewarn coastal communities of impending hurricanes and other dangerous storms made the master fisherman a sentinel, overseeing the health of resources and the environment (Beckley 1883, Kaʻelemakule 1928-1930, Hui Mālama o Moʻomomi 1996).

An important category of master fishermen equivalent to a high chief, the *konohiki* were masters of certain fishing areas and adjoining lands (Kosaki 1954, Araki Wyban 1992, Dieudonne, 2002). As the headman under a chief, the *konohiki* had chiefly responsibilities and knowledge. Responsible for inshore fishponds, *koʻa*[11] and other fishing areas, the *konohiki* had the power and wisdom to implement open and closed seasons, allow or limit the catch of species, sexes, growth stages, and areas, and respond to variations in resource abundance with appropriate *kapu* measures (Kikuchi 1973, Apple and Kikuchi 1975). In addition to variable *kapu*, which *konohiki* could implement or rescind as needed, a series of longterm *kapu* were essentially always in effect, governing what types of fishing, gathering, planting, prayers, and other activities should be done, according to the days of the lunar calendar (Malo 1835-1838, Kamakau 1839, Thurston 1904, Kosaki 1954, Taylor 1995, Farber 1997, Dieudonne, 2002).

The cultural traditions of *kanaka maoli* and the ways they were transferred to each new generation ensured the continued existence of plentiful food from the sea and healthy inshore ecosystems. *Kamaliʻi* (children) were taught how to keep life going through practice and example. They learned respect, understanding, and appreciation for the resources that sustain Hawaiʻi's fisheries directly from their *kupuna*, *konohiki* and other skilled fishermen (Tava and Keale 1989, Hoala na Pua 1996, Hui Mālama o Moʻomomi 1996, Johannes 1978, Kanakaʻole Foundation 1995a and b, Barnes 1999). Women, responsible for shoreline gathering, were shown how to collect *limu* and invertebrates by *kupuna wahine* (female *kupuna*) experienced in

[11] Sacred locations along the coast where fish breeding, feeding, and growth were nurtured, tended, and honored, and where limited harvest was allowed at appropriate times [sometimes in a ritualized manner], followed by sharing with neighbors.

these arts. Young boys and girls accompanying their mothers and older sisters began their learning process at a tender age. As native sons and daughters learned how to walk, they learned to step carefully over reefs and rocky shorelines. Gradually wading a little deeper, they were taught to harvest only the tops of *limu*, leaving the roots and holdfasts to regenerate, to leave behind large egg-bearing shellfish, so they could produce the next generation, to let small things grow before they were harvested, and never to turn their back on the ocean, either literally or figuratively. Amongst knowledge passed on to young people blissfully at play on Hawaiʻi's shorelines was the understanding that one should take only what was needed and never leave a place barren for the next person (Titcomb 1952, Hui Mālama o Moʻomomi 1996, Friedlander et al., 2002a).

Traditional Watershed Management

Equally important to fisheries conservation in old Hawaiʻi was the *moku* and *ahupua'a* system, which integrated communities into self-sustaining geographic groups, oriented from the mountainside (*mauka*) to the seaward (*makai*) edge of the reef (Hobbs 1935, Hutchins 1946, Kelly 1956 and 1980, Chinen 1958, Craighill Handy et al.1972, Meller and Horwitz 1987, Kamehameha Schools Bernice Pauahi Bishop Estate 1994, Stannard 1994). These districts were governed by and loyal to a hierarchy of chiefs and *konohiki*, united both within and between each other through bonds of *kōkua* (cooperation) and shared responsibility for cultivation, tribute, harvest and management of agriculture and fisheries in their region (Hobbs 1935, Green and Kelly 1970, Craighill Handy et al. 1972, Costa Pierce 1987, Smith and Pai 1992, Araki Wyban 1992, Diamond 1997, Dieudonne 2002, Puhipau and Lander 2003). Not only did this system provide for all the basic needs of the people living in a given *ahupua'a* (fish, farm crops, woods of all types, game animals, etc.), but it also placed residents living *mauka* of a given shoreline area in a direct line of management of and responsibility for their own coastal impacts, such as stream diversion, wetland alteration, sediment runoff, construction, agriculture and fishing (Kelly 1956, Chinen 1958, Lowe 1995, Miller and Bay 1995).

The importance of water to *kanaka maoli* societies must be recognized in understanding traditional management of watersheds, riparian and inshore habitats (Hutchins 1946, Nā Maka o ka 'Āina and Native Hawaiian Advisory Council 1995, Puhipau and Lander 2003). Besides fish, *kalo* (taro) was the staple in the Hawaiian diet. More than a dietary staple, *kalo* was the root from which land and eventually all life forms arose in Hawaiian creation legends (Liliuʻokalani 1897, Beckwith 1951, Barrère 1969). The life and productivity of *kalo* and inshore fishes both depend heavily upon a clean and reliable source of water. Therefore, maintenance of an abundant and healthy water supply was an essential function of *kanaka maoli* societies. Their success in this regard was both a measure of prosperity and an element of survival (DB&F 1979, Stannard 1994)[12].

[12] The importance of water to *na kanaka maoli* is symbolized in a simple etymological sequence. *Wai* is the word for water, *waiwai* (literally "water-water") means wealth, assets, prosperity, etc., and *kānāwai* is the word for law. Pukui and Elbert (1986) dispute whether the derivation of *kānāwai* actually relates to water or not, but regardless of its exact derivation, the responsible, orderly, sustainable management of water and watersheds was a high priority for *kanaka maoli* societies.

The land and marine tenure system of *na kanaka maoli* was another element of successful fisheries and water resource management in ancient Hawai‘i. This system did not recognize the concept of ownership of natural resources (Hutchins 1946, Johannes 1978, 1986 and 1997, Acquaye and Crocombe 1984, Crocombe 1987a). Instead of believing they could own land, water, etc., *kanaka maoli* culture acknowledged these life giving resources as flowing to them through the divine providence of gods such as *Kane-i-ka-wai-ala* (Procreator-in-the-water-of-life)[13] and *Lono-makua* (the Rain-provider)[13]. “Property” was not an issue, nor could there be “rights” without *aloha*, hard work, and responsibility. So the modern meaning of the word “rights” provides only a shallow interpretation of what was (and still is) understood in Hawaiian culture and language in relation to natural resources. Although high chiefs and monarchs had ultimate political dominion over land, water, fisheries, and natural resources in general, in the same way commoners received rights (or blessings) along with responsibilities to take care of their *kuleana*, *ali‘i* (high ranking individuals) had even greater responsibilities to *mālama*, manage, and share resources entrusted to them through their ancestral lineage, experience, insight, and training. The *kanaka maoli* social system, including the way warriors, teachers, spiritual leaders, etc. became nobles, rulers, and even monarchs, was designed to develop wise, fair, compassionate, and judicious leadership, which in turn would ensure the maintenance of the prosperity and life of the land and waters of *Hawai‘i nei* (Malo 1835-1838, DB&F 1979).

With such intimate understanding of and relationship with watersheds and inshore ecosystems, it is not surprising that *kanaka maoli* societies also developed an intricate system of *lo‘i* (flooded farms) and inshore fishponds, with ‘*auwai* (water conduits, ditches, and canals) and *mākāhā* (sluice gates), all of which had multiple functions in maintaining inshore water quality and managing, producing, and harvesting wetland crops and fisheries (USEPA 1998, 2003). These integrated agro-ecosystems were managed cooperatively with neighbors to farm freshwater, wetland, estuarine and marine flora and fauna (including domestic crops), produce and recycle nutrients, manage land runoff, and maintain a source of fresh fish and *poi*[14] close to home (Summers 1964, Craighill Handy et al. 1972, Apple and Kikuchi 1975, Devaney et al. 1982, Costa Pierce 1987, DHM Inc. et al. 1990a and b, Araki Wyban 1992, Kamehameha Schools Bernice Pauahi Bishop Estate 1994, Stannard 1994, Farber 1997, Dieudonne, 2002, Puhipau and Lander, 2003). The fishponds worked as part of area- and stock-specific programs, designed to sustain inshore fish abundance, including fish farming (production for direct harvest), stock enhancement (selective and non-selective breeding, nursery, grow-out, and release), community building and education, seasonal *kapu* and other conservation activities. In addition to their authority and responsibility to manage coastal fisheries, the *konohiki* had clear dominion in and around the fishponds, a topic to be discussed further in relation to modern management jurisdictions.

Diverse forms of fishponds[15] were developed and adapted to unique inland and coastal features throughout the MHI (Summers 1964, Kikuchi and Belshe 1971, Kikuchi 1973 1987, Apple and Kikuchi 1975, Araki Wyban 1992, Farber 1997, Dieudonne, 2002), becoming underwater

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[13] As expressed by DB&F (1979), these definitions are not translations, but describe the function of these gods.

[14] Staple food made from *kalo*

[15] An extension of the land and *lo‘i*, the fishponds (*loko i‘a*) came in many freshwater, brackish, saltwater and anchialine forms, and included natural and manmade pools with and without spring water or tidal influences and/or above-ground connections to the ocean or nearby streams (see references cited).

extensions of the mountains, valleys and ridges that define upland watersheds once generated from the Earth’s crust and the ocean floor. The *kanaka maoli* management and belief system did not merely look down on the coastal zone from the mountains, it acknowledged the life of the land as arising from the sea. This perspective was multi-dimensional and far-reaching, encompassing diverse geological, astral and oceanographic aspects, such as the moon, stars and planets, superficial and deep ocean currents, submerged spawning and nursery areas, prominent points and peaks of the islands, groundwater reservoirs created by these features, and changing seasonal and supra-annual cycles of productivity (Malo, 1835-1838, Kihe 1914-1930, Kahaulelio 1902, Ka‘elemakule 1928-1930, Titcomb 1952, Taylor 1995, Hui Mālama o Mo‘omomi 1996, Dieudonne 2002).

With all these cultural assets, *kanaka maoli* societies sustained and were sustained by their fisheries for generations prior to “western” intervention. Even after the ancient *kapu* system was abolished, many cultural practices endured, so that a conservation ethic prevailed and fisheries remained abundant for generations after *haole* contact (Beckley 1883, Jordan and Evermann 1905, Hobbs 1935, Titcomb 1952, Meller and Horwitz 1987, Dieudonne, 2002). However, in time this system was eroded, inshore ecosystems began to deteriorate and Hawai‘i’s fisheries and other natural resources to decline (Jordan and Evermann 1905, Shomura 1987).

<u>Modern Ways: An Economy of Dollars</u>

all those 5 gallon
toilets flushing
away tourist waste
into our waters

Waikīkī home
of ali‘i[16]
sewer center
of Hawai’i

8 billion dollar
beach secret
rendezvous for
pimps

Hong Kong hoodlums
Japanese capitalists
haole punkers

condo units
of disease
drug traffic
child porn

AIDS herpes
old fashioned
syphilis
gangland murder

gifts of industrial
culture for primitive
island people
in need

of uplift discipline
complexity sense
of a larger world
beyond

their careful taro
gardens chiefly
politics, lowly
gods

Waikīkī: exemplar
of Western ingenuity
standing guard against

the sex life
of savages

the onslaught of barbarians

\- Haunani-Kay Trask (1999)

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[16] Now a congested Mecca of tourism, Waikīkī, O‘ahu, was once the home of some of Hawaii’s most prominent rulers (Liliu‘okalani, 1898, Dieudonne, 2002). Its name, which means “spouting waters” (Pukui et al. 1989), refers to a time when the area was known for its clean natural springs, carefully tended *lo‘i* and extensive fishponds (Pratt 1944).

With respect to sustaining inshore fisheries, a more responsive, responsible and effective management system than the *konohiki* of an *ahupuaʻa* with insight and oversight for local resources has yet to be created in modern times. The authority to manage Hawaiʻi's fisheries ecosystems was seized by the United States of America and delegated to various State and Federal agencies with the overthrow of the Hawaiian Kingdom (Liliuʻokalani 1898, Allen 1982, Dougherty 1992, U.S. Congress and Senate 1993, Hawaiian Patriotic League and Nā Maka o ka Āina 1998). Unfortunately, this responsibility was assumed without the benefit of learning from native practitioners how these resources were to be cared for, monitored and maintained (Kamakau 1842-1868, Kanakaʻole Foundation 1995a, Hui Mālama o Moʻomomi 1996, Pacific American Foundation and Hui Mālama o Moʻomomi, 2001).

While recognition of traditional fisheries management practices was thwarted by the loss of sovereignty, the teachings of old Hawaiʻi were diluted by immigration, mortality, language suppression, and the cultural amnesia resulting from these and other factors (Bingham 1849, Bishop 1888 and 1916, Pratt 1944, Malo, Haleʻole and Kamakau in Chun 1993, Kelly 1984, Iverson et al. 1990a and b, Buck 1993, Trask 1993, Barnes 1999, Wood 1999). Like most native populations in the modern world, numbers of *kanaka maoli* declined dramatically after colonization due to epidemics and other complex cultural impacts (Bishop 1888, Hoffman 1916, USCCRHAC 1980 and 1991, Stannard 1994, Diamond 1997). Some cultural memory was lost, because use of the Hawaiian language was inhibited in various ways (Bingham 1849, Bishop 1888 and 1916, Kamakau in Chun 1993, Iverson et al. 1990a and b, Buck 1993, Trask 1993, Wood 1999). Immigrants and their children were actively discouraged from learning the language and ways of native people by missionaries who believed these customs to be ignorant and sinful (Bishop 1888 and 1916, Allen 1982, Kame'eleihiwa 1992, Buck 1993). Moreover, respect for traditional teachings was even undermined amongst *kanaka maoli* (Liliu"okalani, 1898, Kamakau in Chun 1993). In the meantime, large numbers of immigrants were continuously arriving from North America, China, Japan, and other places in the Pacific (Bishop 1888, Pratt 1944, Meyers 1976, Tabrah 1980, Ramil 1984, Wood 1999, Grant et al. 2000).

Through the loss of cultural dominance and political sovereignty, the knowledge and expertise to take care of Hawaiʻi for future generations was misinterpreted, forgotten, inhibited and undermined in many ways (Hobbs 1935, Brower 1974 and 1989, Kelly 1984, Anderson and Miura 1990, Kameʻeleihiwa 1992, Budnick 1992, Miller and Bay 1995, Farber 1997, Wood 1999). As a result, less and less intact conservation practices were handed from one generation to the next, while various immigrant cultures taught their own traditions or interpretations of what they had learned in Hawaiʻi (Creighton 1978, Kelly 1984, Araki Wyban 1992, Buck 1993, Hui Mālama o Moʻomomi 1996). Although many of the new cultures that arrived in Hawaiʻi brought skills that included complex agricultural and fishing arts, most of these were not specifically adapted to remote Pacific islands, much less to *Hawaʻi nei*.

Under new cultural influences, Hawaiʻi's coastal ecosystems were transformed beyond recognition. Forested slopes were denuded in many areas, increasing erosion and runoff (OCZM and DPED 1978, HCZMP 1995, Smith and Kukert 1995, Calhoun and Fletcher 1996, DOH 1990, 2000, USGS 1999, Field et al. 2000 and 2003, Rooney and Fletcher 2001, Loope 2003). Alien trees, brought in to fill a perceived lack of diversity in Hawaiian forests, displaced native species adapted to Hawaiian soils, climates, and habitats (Mueller-Dombois 1996b). This is not to imply that *kanaka maoli* had not already made introductions and adversely impacted native ecosystems (Olson and James 1982, Kirch 1985, Roberts 2001, Loope 2003), but the process accelerated and expanded at a phenomenal rate after "western" contact (Hobbs 1935, Creighton 1978, Stone and Scott 1984, Williams and Nowak 1986, Stone and Stone 1992, Liittschwager and Middleton 2001, Loope 2003). Agriculture, including cattle farming, produced additional loss of groundcover and degradation of the delicately balanced lining of forests and watersheds (Smith and Kukert 1995, Fletcher and Calhoun 1995, Calhoun and Fletcher 1996 and *in press*, Tummons 1999, DOH 1990 and 2000, Field et al. 2000 and 2003, Roberts 2001, Loope 2003). Hillsides were bulldozed and streams diverted for sugarcane, pineapple, and other mono-crop farming (Bingham 1849, Bishop 1888, Hobbs 1935, Pratt 1944, Creighton 1978, Ramil 1984, CWRM 1995, Chong 1996, Wilcox 1996, Puhipau and Lander 2003). Second-growth forests quickly took over areas where regrowth was allowed, increasing the spread of opportunistic species (aliens and natives) and further increasing erosion and runoff (Hobbs 1935, Mueller-Dombois 1996b, Loope 2003). The combination of all these factors affecting groundwater replenishment, coupled with increasing demands on island water resources, brought about serious groundwater depletion by the mid 1920s (Hutchins 1946).

More recently, streets have been paved and skyscrapers raised, increasing land runoff (direct to the sea via storm drains) and water consumption in urban areas (DOH 1978, 1990, and 2000; HCZMP 1995; Gulko et al. 2000). Reefs, *lo'i* and fishponds have been replaced with urban and industrial development, using dynamited reef rubble, dredged materials, urban and industrial waste as landfill (Kelly 1956, Summers 1964, Apple and Kikuchi 1975, Devaney et al. 1982, DHM Inc. et al. 1990a and b, HSRS 1996, Belt Collins 1998, USEPA 1998 and 2003, Envirowatch 1999 and 2000). Shoreline alteration and urbanization have contributed to beach erosion, causing a chain reaction of sand loss along and across Hawai'i's beaches (Fletcher and Hwang 1994, Coyne et al. 1996 and 1999, Fletcher 1997, Fletcher et al. 1997, Mullane and Suzuki 1997, Mullane et al. 1997, Fletcher 1999, USGS 1999, Fletcher et al. 2002, Fletcher and Lemmo in press)[17]. Runoff, effluents, and debris from sewage, storm drains, and urban, agricultural, and industrial development have been (and still are) discharged directly or indirectly into streams, inland ponds and coastal waters (Welsh 1949, Banner and Bailey 1970, Bather 1972, Banner 1974, DOH 1978, 1990 and 2000, Smith et al. 1981, Anderson and Miura 1990, Freeman 1993, Fujioka et al. 1993, Krock and Sundararaghavan 1993, Ahuna and Fujioka 1993, Grigg 1994, Shimabuku 1999, Envirowatch 1999, 2000 and 2003). Urban, agricultural and industrial pollutants (including metals, pesticides, and hydrocarbons), largely ignored in coastal water quality monitoring efforts, are a common feature of coastal waters and sediments that may comprise a long-term threat to Hawaiian inshore ecosystems (Hunter et al. 1979, Schmitt and Brumbaugh 1990, Schmitt et al. 1990, KBMPTF 1992, Spencer et al. 1995, 2000 and *in press*, DeCarlo and Spencer 1997, OP 1998, DeCarlo et al. in press, Spencer and DeCarlo, *ms.*). Where environmental concerns regarding direct discharge have been raised, contaminants are routinely pumped into the ground via injection wells, with potential adverse impacts to groundwater and coastal ecosystems located *makai* of the injection zones (Modavi 1992, HCZMP 1995, HBWS, 2002, DOH 1990, 2003). This is of concern to beach, wetland, and shoreline fisheries, since in Hawai'i's relatively young volcanic environment, fresh and brackish water movement through lava tubes, springs, sediments, and groundwater is an important element of coastal ecology.

[17] The extent to which sand loss may also be attributable to decreased numbers of sand generating species (such as parrot-fishes) is as yet undetermined, but (odd as it sounds) may be a contributing factor.

Unlike old Hawai‘i, which was largely self-sufficient (Hobbs 1935, Heyerdahl 1979, U.S. Congress and Senate 1993, Diamond 1997), modern residents and visitors are dependent upon imported goods, increasing the intensity of human impacts on inshore ecosystems. Today shipping, travel, and ocean freight, essential activities that degrade the inshore environment, comprise Hawai‘i’s largest marine industry (MacDonald and Deese 1987 and 1988),[18] driven by our family, tourist, and military ties to the American, Asian, and Australian continents and Pacific islands and our reliance on imported foods, fuels, and supplies. Even efforts to overcome these dependencies threaten coastal ecosystems. Examples include everything from fisheries development to land and seabed mining, “thermal energy conversion,”[19] desalinization,[20] “carbon sequestration,”[21] and other creative coastal experiments.

Adding insult to injury of Hawai‘i’s inshore ecosystems, the state’s beaches, river mouths, and other inshore spawning and nursery areas have been stocked with an endless supply of well-oiled tourists, motorized, wind- and wave-driven water toys, fishing gears (nets, traps, poles, etc.), and small and large shipping, military, and cruise/tour vessels (OCZM and DPED 1978, Pooley 1987, Aotani and Associates 1988, DAR 1988, DBED&T 1991, Reynolds 1991, KBMPTF 1992, Wilson Okamoto and Associates 1992, Everson 1994, DLNR 1995, Mamala Bay Study Commission 1996, OP 1998). Many inshore impacts are intensified by tourism, including shoreline construction (hotels, golf courses, parks, etc.), pollution (sewage runoff, herbicides, pesticides, sediments, and fertilizers), reef trampling, and boat traffic (jetskis, water toys, shipping, and pleasure boats). It was estimated in the late 1970s that by 1990, the demand for Hawai‘i’s launching and mooring facilities would exceed capacity by 10-50 percent and the demand for beach camping areas[22] would be more than 50 percent beyond capacity (OCZM and DPED 1978). In addition to compounding other urban impacts, tourism affects fisheries by increasing congestion and transiting of spawning and nursery areas. In some cases, this is actually the purpose of commercial tours, since some visitors seek to observe fishes, turtles, birds, and marine mammals in their feeding, basking, and nursery areas. In other instances, shallow sandbars, reefs, and beaches are merely safe, convenient places for people to fish and recreate. Congestion of these areas, where fishing is popular and in some cases traditional, can easily become a source of contention when both fishers and tour groups assert their right to be there (KBMPTF 1992, OP 1998).

Overfishing of inshore areas, a clear impact in some regions, is attributable more to residents than visitors; however, its impacts on fish viewing by tourists creates additional “user conflicts”. The cultural (or educational) problem of fishers not understanding how much is too much or in some cases not even considering their own impact, is compounded in recent decades by changes in fishing practices and increases in gear- or vessel-specific fishing power (Kelly 1984, Pooley

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[18] MacDonald and Deese (1988) projected marine mining would quickly replace these as Hawaii’s first industry (Table 2).

[19] A scheme to harvest thermodynamic energy and produce electricity by exploiting the temperature differential between cold (deep-sea) and warm (tropical ocean surface) waters (The Traverse Group, Inc. 1985, MCM Planning 1987).

[20] Experiments using a refrigerant to extract the salt from seawater (McCormack and Niblock 1998) have killed flora and fauna in tidepools along the shoreline at Keāhole, Kona (Envirowatch 1998).

[21] Experimental deep-sea injection of cold CO_2 to reduce the volume of this waste product in the atmosphere (USDOE, 2001).

[22] Beach camping and fishing go hand in hand in Hawaii.

1987, Harman and Katekaru 1988, KBMPTF 1992, Smith 1992, Gulko et al. 2000). When overcrowding is added to the picture, all activities in inshore areas can easy become destructive and create conflict. Keeping in mind all these inshore activities and impacts, what remains of coastal ecosystems is the nursery, spawning grounds, and essential life support system for Hawai‘i’s inshore fisheries.

In short, the old system of *mālama i ka ‘äina, mālama i ke kai, a mālama i kou kino* (“take care of the land, take care of the sea, [as you would] take care of your own body”) has evolved into a system of “ocean users” and “resource stakeholders” vying for Hawai‘i’s freshwater, marine, and estuarine resources and habitats (Kelly 1984, DBED&T 1991, Kame‘eleihiwa 1992, Smith 1992, OP 1998a). Modern *kanaka maoli*, who now represent about 20 percent of the population (DBED&T, 2001), sum this up succinctly as a culture of greed.

Hawai‘i’s Modern Ocean Users

> *Ua hala nā kūpuna, a he 'ike kōli'uli'u wale nō kō keia lā, i nā mea i ke au i hope lilo, iō kikilo.*
> [The ancestors have passed on, today’s people see but dimly times long gone and far behind]
> - Hawaiian proverb in Pukui et al. (1989)

Changes in cultural practices and perspectives of Hawai‘i’s people have impacted inshore fisheries in many ways (Johannes 1978 and 1997, OCZM and DPED 1978, Kelly 1980 and 1984, Anderson and Miura 1990, Kame‘eleihiwa 1992, Modavi 1992, Araki Wyban 1992, Kanaka‘ole Foundation 1995a, Dames & Moore et al. 1997, Friedlander and DeMartini, 2002). Most Hawai‘i residents today appreciate ocean resources in one way or another, but many are satisfied to demonstrate this solely by partaking of nature’s bounty via commercial and non-commercial fishing, scuba diving, snorkeling, skiing, wind and water surfing, etc. (Hoffman and Yamauchi 1973, Harman and Katekaru 1988, Anderson and Miura 1990, DBED&T 1991, DBED&T 1968-2001[23], Kame‘eleihiwa 1992, USFWS/USBC 1993 1998). Residents and tourists alike consider fishing, seafood, and water sports as important aspects of life in Hawai‘i (Hoffman and Yamauchi 1973, MacDonald and Deese 1987 1988, Anderson and Miura 1990, DBED&T 1991, KBMPTF 1992, OP 1998a and b, Hawai‘i Visitors and Convention Bureau, 2003).

Fishing and eating fish are important today, as they were in old Hawai‘i, but rates of consumption per capita are greater and inshore fisheries feed a much larger population than the land supports. Residents eat almost twice the national average of seafood (Iversen et al. 1990b), tourists enjoy a wide selection of the most desirable and highest quality inshore, pelagic, and demersal marine species (HVCB, 2003), and the majority of fish caught in Hawaiian waters is exported to the U.S. Mainland and world markets (MacDonald and Deese 1987, Borreca 1997a and b, Ambrose 1997). Although problems with statistical reporting confound the issue, generally less than 20 percent of seafood sold via local retail markets is caught in Hawai‘i (MacDonald and Deese 1987). In keeping with trends in other Pacific island nations where traditional fisheries management has been replaced by systems dominated by modern investment

[23] Sections on Recreation and Travel, Transportation, Forests, Fisheries and Mining, and Prices (for seafood).

capitalism, Hawai‘i is no longer able to feed her people from local fisheries resources (Johannes 1978, 1986, and 1997, Johannes et al. 1993, Ledua 1995, Tonga Ministry of Fisheries 1995). Local seafood consumption is supplemented with products cultured in the few remaining functional inshore fishponds (Apple and Kikuchi 1975) and a wide variety of modern aquaculture systems (DBED&T 2001 and 2003), yet today Hawai‘i remains unable to satisfy its seafood needs from local production.

As a result, inshore fish stocks once conserved for subsistence have become depleted in most accessible regions of Hawai‘i's shoreline (Jordan and Evermann 1905, Thurston 1936a, Johannes 1978, Kelly 1984, Pooley 1987, Shomura 1987, Hui Mālama o Mo‘omomi 1996, Grigg 1997, Meyer 1998, Pacific American Foundation and Hui Mālama o Mo‘omomi, 2001, Friedlander and DeMartini, 2002). While examples of other human impacts to inshore ecosystems abound throughout the Pacific, inshore fisheries are protectively held in trust for subsistence use by current and future generations in most other Pacific island nations (Sullivan 1977, Johannes 1978 and 1986, Beeby 1989, Reeves 1992, Johannes et al. 1993, Hampton et al. 1995, Jarchau et al. 1995, Ledua 1995, SERP 1995, Dalzell et al. 1996, Mungkaje 1999, Dieudonne 2002, Pacific Fisheries Case Study Writing Project, 2003). Although foreign governments have supplanted indigenous sovereignty throughout the Pacific, there are many examples of efforts to meld traditional and modern systems into a workable hybrid that respects both traditional and modern fisheries management concepts and conserves inshore fisheries for local residents (Johannes et al. 1993, Belhadjali 1995, Bertram and Newnham 1995, STMMPM 1995, Pacific Fisheries Case Study Writing Project 2003). But in areas like Hawai‘i, where subsistence fishing interests have been given only incidental standing by government (DBED&T 1991, Smith 1992, Barrett 1997, Haia 1996 c and d, Pacific American Foundation and Hui Mālama o Mo‘omomi, 2001), the decline of inshore subsistence fisheries has come on the heels of the development of commercial fisheries (Johannes 1978, Uchida and Uchiyama 1986, Shomura 1987, Kimura and Fa‘anunu 1995, Ledua 1995, Tonga Ministry of Fisheries 1995, Tuilagi and Green 1995, Udagawa et al. 1995, Pacific American Foundation and Hui Mālama o Mo‘omomi, 2001). Far from the example of sustainable development Hawai‘i should be, our state provides excellent examples of what can be lost through the failure to incorporate traditional knowledge into modern fisheries management. In recent years, efforts to rectify this situation have been initiated through the initiative of forward-thinking communities (Hui Mālama o Mo‘omomi 1995 and 1996, Pacific American Foundation and Hui Mālama o Mo‘omomi 2001, Friedlander et al. 2002a, Poepoe et al., 2003).

Both subsistence and recreational fishing are tremendously important to Hawai‘i residents, but their economic importance and impacts on fish stocks are poorly documented, loosely managed, and rarely enforced (Hoffman and Yamauchi 1973, Grigg 1997, Pooley 1987, Everson 1994, Kahiapo and Smith 1994, Friedlander et al. 1997, Grigg 1997, Glazier 1999). Because of the value to the U.S. economy of fish caught in Hawaiian waters, when statistical monitoring began in the late 1940s, only commercial fish catches and their sale price were officially registered (DAR 2003). Monitoring of recreational/subsistence fisheries has been conducted sporadically at selected sites but has never been done comprehensively on a statewide basis (Smith 1992, Everson 1994, Lowe 1995, Friedlander et al. 1997, Glazier 1999, Everson and Friedlander 2003). As such, an opportunity was lost to capture baseline information during an important growth period for Hawai‘i's inshore fisheries. Based on estimates of 202,000-260,000 recreational/subsistence fishers (USFWS 1993, 1998) and records of 3000-3500 licensed commercial fishers (DAR 2002[24]), recreational/subsistence fishers outnumber commercial fishers by at least 71:1[25]. Although most non-commercial fishers are lumped into the "recreational" category, most of Hawaiʻi's inshore fishers who are residents eat all or part of their catch and/or share it with neighbors. Thus, an extensive subsistence and recreational fishery endures in Hawaiʻi today, providing food and relaxation for the majority of our state's fishing public (Hoffman and Yamauchi 1973, Everson 1994, Kahiapo and Smith 1994, Hui Mālama o Moʻomomi 1995 1996, Pacific American Foundation and Hui Mālama o Moʻomomi 2001, Friedlander et al, 2002a).

Hawaiʻi's Land and Natural Resource Management Structure and Funding to Sustain Inshore Fisheries Ecosystems

Funding, Focus, and Programmatic Support

> *"From the point of view of human needs, a resource stock is simply a particular form of capital that can either be consumed or conserved. What distinguishes a biological resource from a stock of traditional capital … is the mechanism of growth: biological resources grow 'by the gift of nature', traditional capital can only increase through human effort."* [26]
>
> \- Colin W. Clark (1990a)

The values that motivate both public and private decisions affecting Hawaiʻi's fisheries today are strongly allied to the interests and outcomes of capital investment (Bosselman and Callies 1971, DBED&T 1991, Modavi 1992, Buck 1993). Decisions at the State and County levels regarding coastal development, resource allocation, and how to care for ocean resources are driven by the balance of costs versus revenues from tourism and other economic ventures (fish sales, ocean sports, etc.). Because Hawaiʻi's economy relies so heavily on the visitor industry, many state and country programs become paralyzed or actually move backwards during years when tourism declines. Projects, staff, and funding are cut in direct proportion to the prosperity of the tourism industry. Because the economy of dollars is the priority value system in Hawaiʻi today, sustaining the life of Hawaiʻi's fisheries is placed at the end of a long list of essential societal functions that government finances and staff will remain unable to fulfill in this lifetime without a radical paradigm shift.

If money is the measure of value in today's culture, Hawaiʻi residents place a relatively low importance on protecting natural resources from the threats that affect fisheries. This is demonstrated by the disproportionate share of the state's budget allocated to this activity by the Legislative and Executive Branches of Government. Hawaiʻi spends millions annually to promote and monitor tourism, yet limited funding is allocated to monitor and manage its impacts or to maintain a healthy environment. With the fourth longest coastline, eleventh-largest state

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[24] Ref: Commercial Fish Catch Statistics Unit Data, Division Aquatic Resources, Hawaiʻi State Dept. Land & Natural Resources.

[25] The midpoint between each range was used in calculation of this ratio. Both the numbers of recreational/subsistence and commercial fishers are believed to be underestimated.

[26] This practical modern economic perspective directly contradicts the old Hawaiian perspective and system, whereby natural resources increased through both "the gift of nature" <u>and</u> the righteous and dedicated work of human beings.

forest, 376 perennial streams, and 80 percent of U.S. coral reefs, Hawaiʻi ranks 47th in the nation in state fish and wildlife funding (DLNR 1996). Given that Hawaiʻi's visitor industry relies on beautiful ocean and coastal ecosystems, it is difficult to explain the miniscule investment in sustaining the resource base that supports the state's economy. Since elected officials answer to voting residents, these allocations and management decisions represent the predominant cultural priorities, ecological concepts, and values.

The focus, priority, or programmatic funding necessary to address issues affecting the health of Hawaiʻi's fisheries ecosystems simply does not exist at the State level. State agencies charged with protecting the life of the land and sea face a plethora of obligations and needs with limited financial resources, while funding is allocated in ample proportion to maintain human health, promote tourism, and stimulate the growth of other economic activities. Together with the Governor and State Legislature, the Department of Business, Economic Development and Tourism (DBED&T) is responsible for managing Hawaiʻi's economic development. Both its name and annual operating budget of $278.8 million[27] reveal the importance of the visitor industry to Hawaiʻi residents. Over 36 percent of this budget is dedicated strictly to tourism, 12 percent to other commerce and industry related programs, and less than 0.2 percent to assist in statewide land use management (Hawaiʻi State Legislature, 2000). In addition to protecting human health, the Department of Health (DOH) is responsible for maintaining air and water quality, including streams, groundwater, and coastal waters to a distance of three miles. Inshore coastal waters are to be maintained in "pristine" condition, despite a variety of impacts from sewage, storm runoff, and point and "non-point-source" pollution, all of which affect inshore fisheries. DOH receives about $757 million annually, but the use of this enormous budget is limited by its programmatic emphasis on human health. Over 95 percent of DOH programs, funding, and policies relate to hospitals and health care, controlling vectors of human disease, managing poisons and toxic waste affecting humans, caring for children and the elderly, managing mental health, etc., with the remainder judiciously applied to other aspects of the environment.

With an annual operating budget of less than $80 million, the Department of Land and Natural Resources (DLNR) is responsible for maintaining healthy terrestrial, freshwater, and marine ecosystems; conserving and protecting land, forests, fisheries, and wildlife; and permitting and managing the impacts of construction, water diversion, tourism, fisheries, agriculture, and other activities that affect these resources. Of DLNR's operating budget, approximately $7 million (8.7 percent) is devoted to aspects vital to healthy fisheries. Some of these programs are housed in different DLNR divisions (see the following section). With an operating budget of less than $5.3 million, the Division of Aquatic Resources (DAR) is responsible for maintaining and managing the living component of aquatic ecosystems. Under the Division of Water Resource Management (DOWRM), an additional $1.6 million is allocated to protecting the water itself. Under the Division of Forestry and Wildlife (DOFAW), an additional $4.2 million (5.2 percent of DLNR's budget) is devoted to environmental protection of forests and wildlife, which contributes in various ways to maintaining the health and productivity of watersheds and thus indirectly freshwater and inshore ecosystems (DLNR 1998, DOFAW 1999, 2003).

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[27] All annual funding amounts are mean annual Program Appropriations for the 1999-2000 Fiscal Biennium (Hawaii State Legislature, 2000), including all means of funding (State, Federal, Bonds, Trusts, Special and Revolving Funds, etc.).

Fisheries ecosystem management at the federal (and international) level is even more strongly linked to commerce and industry (Cropper et al. 1979, Gulland 1971 and 1981, Amacher and Sweeney 1976, May et al. 1978, Anderson 1986, Lluch-Belda et. al. 1989, Cropper 1988, Paul et al. 1996, Baden and Noonan 1998, Caddy and Griffiths 1995, Munro 1998, Paul 1999, CFRs, 2002). Functioning under the Department of Commerce (DOC), the National Marine Fisheries Service (NMFS) has historically based marine fisheries management on the concept of exploiting stocks to their maximum sustainable [economic] yield (Sweeney 1975, Clark 1990a, Laevastu and Larkins 1981, USWPRFMC 1983, Pauly 1994). Although estimates of single stock biological production are incorporated into these models, under conditions of high interest and inflation (chronic in Hawaiʻi, the U. S., and world markets), economic optimization is easily reached at the expense of renewable resources (Smith 1968; Clark 1973 and 1990a; Clark and Munro 1975; Clark et al. 1979; Cropper 1988; Caddy and Griffiths 1995; Lande et al. 1995, 1998, and 2003; McKelvey 1997; Brown 2000; Laukkanen 2001, 2003). Examples of lasting harm to "managed" commercial fisheries abound in the literature (Gould 1972, McKelvey 1987, Hilborn and Walters 1992, Ludwig et al. 1993, Grafton et al. 1996, Hannesson 1996, Wetherall et al. 1995, Dinardo and Haight 1996, Dinardo et al. 1998, Dinardo and Marshall 2001, Munro 1998, Laukkanen, 2001, Peña-Torres 2002, Peña-Torres et al, 2003). In fact, this is the expected outcome when the commercial industry dominates management decision-making (Clark 1973 and 1990a, Caddy and Griffiths 1995, McKelvey 1997, Brown, 2000). Webster's primary definition of "commerce" includes "social intercourse: interchange of ideas, opinions or sentiments" (Mish et al. 1990), but use of the word by federal agencies (CFRs 2002) encompasses only elements of Webster's secondary definition, "the exchange or buying and selling of commodities on a large scale, involving transportation from place to place." The Magnuson-Stevens Act (USNMFS 1996) refers to conservation and management measures to *"prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry"* [28] and proceeds to describe various ways of carving up fisheries as single species stocks and fisheries property. There are no federal guidelines that provide for sustaining the life of the land and sea, let alone the exchange of ideas about the beauty, color, and enjoyment of nature. Although optimizing biological productivity of selected species or gear-related species groups is a major consideration of federal fisheries management publications, economic optimization is the primary subject of discussion and debate in the various fisheries management councils established to interface at a regional level within the U. S. Exclusive Economic Zone (Alverson 1972, USWPRFMC 1983, Schug 1991, Paul et al. 1996, USNMFS 1996).

Although state and federal priorities had traditionally been geared toward developing underexploited fisheries and optimizing economic growth (DLNR 1979, Grigg and Pfund 1980, Grigg and Tanoue 1984, DAR 1986, Uchida and Uchiyama 1986), in recent decades depletion of inshore fisheries has caused agencies to reevaluate this emphasis and seek measures to conserve and manage inshore and offshore stocks sustainably (HMR 1977, LMR Fisheries Research 1992, Lowe 1995, USNMFS 1996, DAR 2002). However, to secure funding needed to adequately manage Hawaiʻi's fisheries, the state must overcome the economic liability created by the

[28] Hawaii's Ocean Resources Management Plan (DBED&T 1991) contains similar references to encouraging "stewardship", while fostering "economic growth" and "sustainable development", as do state-federally funded plans designed to ensure "uncontrolled exploitation interference" with ocean resources, does not "endanger the environment *and economy* of the state" (Schmitt et al. 1975).

relatively low standing of fisheries in comparison with other "industries." Ranked in terms of economic value, commercial fisheries place fifth among Hawaiʻi's six primary ocean industries (Table 2). Only coastal aquaculture, once at its apex in *Hawaiʻi nei*, ranks lower in economic value among Hawaiʻi's ocean industries today (MacDonald and Deese 1987 and 1988).

The emphasis on dollars versus resource value is upheld by the fact that, despite the relatively low economic value of commercial fisheries versus other ocean industries and the small number of commercial fishers versus recreational/subsistence fishers, for more than 50 years only commercial fisheries have been monitored under Hawaiʻi's only long-term statewide catch and effort government database (USWPRFMC 1983, Smith 1992, Glazier 1999, DAR, 2003). Enhancing recreational fishing opportunities for finned fishes is supported through a tax on the sale of fishing supplies under the Federal Aid in Sport Fish Restoration Program, providing some funding for sporadic monitoring of selected recreational fishing areas (U.S. Federal Aid in Sport Fish Restoration Act 1950, DAR 2002 and 2003, USFWS 2003). In the past decade, other federal agencies have assisted the State's efforts to conduct recreational fishing surveys, generally targeting boat ramps and areas where high-value pelagic fisheries are concentrated (Omnitrack 1991, USNMFS/MRFSS 2003, DAR 2003). The common thread throughout fishing surveys in Hawaiʻi to date is that funding is the limiting factor and an economic priority is what makes it possible to invest in the survey effort. To date, "subsistence fishing" remains officially undefined, unmonitored, and unprotected by either State or Federal programs with rare exceptions (Hui Mālama o Moʻomomi 1995 and 1996, Pacific American Foundation and Hui Mālama o Moʻomomi, 2001), and comprehensive assessment or management of fisheries remains fiscally outside the grasp of any agency operating in Hawaiian waters. While this dilemma remains unresolved, it is increasingly likely that the commercial value of tourism may completely overshadow fisheries management efforts in many areas, making it more feasible (and profitable to tourism) to prohibit fishing rather than manage its impacts.

<u>Management Jurisdictions and Coastal Ecology: Parceling the Great Mahele</u>

> *"A century ago or more ago the land of Hawaiʻi belonged to the king and his various chiefs. This is still in large part true – it is just that the 'king' and the 'chiefs' have become the State and Federal governments and the various trusts and other large private holders."*
>
> - State Representative Tom Gill (1961[29])

As devastating as the lack of funding may be, government compartmentalization of resource management represents an equal threat to fisheries via its impacts on streams, wetlands, estuaries, and other ecosystem components. City, county, state, and federal management agencies alike are comprised of subdivisions that are functionally and geographically incompatible with the realities of coastal ecosystems (OCZM and DPED 1978, KBMPTF 1992, Miller and Bay 1995, Mamala Bay Study Commission 1996, Tiner, 2002, Ahupuaʻa Action Alliance 2003, KNHF 2003). *Ahupuaʻa* boundaries, mapped in the early 1900s and known through generations of oral histories, can be directly related to watershed boundaries determined quantitatively, based on slope, topography, and related hydrological and physiographic features (Mondsarrat 1886, Harvey 1900a and b, Wright et al. 1902, Donn 1906, O'Neal 1915, 'Īao 1929,

[29] <u>In:</u> Horwitz and Meller (1966).

GDSI/EPDPS 1994, Miller and Bay 1995, Lowe 1999, Ahupuaʻa Action Alliance 2003, KBAC, 2003). Modern district boundaries are based on population size, changing annually and bisecting wetlands, streams, ridges, and watersheds (DBED 1988). The creation of transient political entities that conduct independent decision-making on issues with potential coastal ecological impacts (runoff, sedimentation, pollution, stream diversion, changes in public access, etc.) produces another series of obstacles to be surmounted by inshore fish stocks and efforts to restore inshore fisheries (Lowe 1995, 1996, 1999).

Table 2: Revenues and Employment from Hawaiʻi's Ocean Industries*

INDUSTRY	**ADJUSTED REVENUES (millions of dollars)**	**NO. EMPLOYED**
Marine Mining	** 478	** 978
Maritime (ship repair and ocean transportation)	338	1,774
Ocean Recreation	222	2,716
Seafood Marketing	116	2,108
Ocean Research	55	1,342
Recreational{and Subsistence} Fishing ***	46	*** 260,000
Commercial Fishing	**** 24	689
Aquaculture	13	423

Table Legend
- * Most table values adapted from MacDonald and Deese (1988)
- ** Average of values projected by MacDonald and Deese (1988) for an emerging industry, as yet unrealized (DBED&T, 2001)
- *** USFWS (1998), believed to underestimate actual totals. May include some, but not all subsistence fishers. Note: This value represents about 21.3 % of the State's 2000 population (see Table 1)
- **** Commercial Fish Catch Unadjusted Value in 2000 was $59.3 K (DBED&T Data Book Online, data from DAR2000 Commercial Fish Catch Reports)

Although its history is beyond the scope of this discussion, it is important to understand that the first steps in disintegrating the ancient *ahupuaʻa* system[30] were: 1) "unification" of the Hawaiian islands under one rule, and 2) sale or lease of land to foreign agricultural entrepreneurs. By this process, the traditional land, water, and marine tenure system was quickly disrupted (Bingham 1849, Hobbs 1935, Hutchins 1946, Kelly 1956 and 1980, Horwitz and Meller 1966, Lundsgaarde 1974, Acquaye and Crocombe 1984, Johannes 1978 and 1986, Kameʻeleihiwa 1992, Buck 1993,

[30] The term "*ahupuaʻa* system" is used loosely in Hawaii today to refer to the ancient districting system described briefly under the section entitled "The Old Ways," although that system was actually much more complex, including an intricate network of other land divisions known as *mokuʻaiana/mokuʻoloko* (roughly "island districts"), *ahupuaʻa*, *ʻili*, *lele*, *koele* and *kuleana* (Hobbs 1935, Kelly 1956, *Ahupuaʻa* Action Alliance, 2003)

Chinen 2002). Armed with modern weapons following the arrival of *haole* people in the late 1700s, the warrior chief Kamehameha I conquered all the Hawaiian Islands, creating a unified Kingdom by 1795 (Bingham, 1849, Hobbs 1935, Mellen 1949). The second step, known as the Great *Mahele* (Division) of 1848, took place when *haole* residents ("often supported by the commanders of the warships of their homelands…"[31]) convinced King Kamehameha III to sign laws privatizing land and facilitating its purchase by foreigners (Chinen 1958, Kelly 1956, Horwitz and Meller 1966, Meller 1987, Chinen 1958 and 2002, Buck 1993). Within a few decades, most land was neither owned nor managed by *kanaka maoli* (Horwitz and Meller 1966, Chinen 2002). Over the next few decades, Hawaiʻi developed most of the land use characteristics it has today, including its high proportion of mono-crop agriculture and ranching, the destruction or deterioration of many of the fishponds and *loʻi*, land monopoly, and political domination by large land owners (Hutchins 1946, Horwitz and Meller 1966, Apple and Kikuchi 1975, OCZM and DPED 1978, Devaney et al. 1982, Ramil 1984, DHM Inc. et al. 1990a and b, Modavi 1992, Farber 1997).

The oldest modern land categories in Hawaiʻi stem from the *Mahele* but have changed beyond recognition since that time. Prior to the turbulent fifty years from 1848-1898, over which Hawaiʻi was forced into becoming a U.S. territory (Liliuʻokalani 1898, Allen 1982, Dougherty 1992, U. S. Congress and Senate 1993, Hawaiian Patriotic League and Nā Maka o ka Āina 1998), the land and waters of the Hawaiian Kingdom were managed under its *ahupuaʻa* system via laws established by the *aliʻi* for the benefit of society[32] (Hobbs 1935, Hutchins 1946, Kelly 1956 and 1980, Nā Maka o ka ʻĀina and Native Hawaiian Advisory Council 1995, Puhipau and Lander, 2003). These laws were maintained orally until 1840, when the first written Constitution of Hawaiʻi was produced by King Kamehameha III (Thurston 1904). The *Mahele* left three major land categories: Crown Lands (retained, sold, leased, or given away by the King, including to his people), Land Commission Awards (designated to the chiefs and the native people, including fishponds and *loʻi*), and Government Lands (grants, patents, and deeds maintained by the *soon-to-be-overthrown* government). For a short time after the *Mahele*, Crown Lands included submerged land and inshore and deep sea fisheries, from the shoreline to an undefined seaward boundary.[33] But, recognizing the need for fisheries and ocean resources, the King transferred ownership of submerged lands to his people as Government Lands (Kamehameha 1851, Chinen 2002), with the exception of fishponds and other inland and coastal fisheries that had been specifically conveyed to and protected by the *konohiki* (Kosaki 1954, Chinen 1958).

Land in Hawaiʻi today is either privately owned (including by large trusts), or allocated for public purposes under the State or Federal government. In the series of political and military takeovers that followed the *Mahele* (Liliuʻokalani 1898, Thurston 1904 and 1936b, Dole 1958, Mellen 1958, Dougherty 1992, Barnes 1999), the Kingdom and Its Crown and Government Lands were seized by a Provisional Government (1893), transferred to a Republic of Hawaiʻi (1894), then ceded to the United States (1898-1900) as part of a deal to obtain territorial status

[31] Chinen (1958)

[32] After "unification", *Aliʻi* included the King, nobles, representatives and chiefs. Prior to that, the *Aliʻi ʻai Moku* (Island chief) had equivalent standing to a king (Kelly 1956). Regardless, Hawaiian laws prior to 1848 were designed to benefit all classes amongst Hawaiʻi's people, as well as to protect the aina and all its living beings (Thurston 1904).

[33] It is doubtful *na kanaka maoli* would have ever drawn such a line in the sea.

(Hawaiian Patriotic League and and Nā Maka o ka Āina 1998). Hawai'i was a U.S. Territory from 1900-1959, when it was annexed as a U. S. state. At that time, lands ceded in 1898 were conveyed back to the State of Hawai'i, with the exception of lands used by the new Federal Government. Included in lands ceded to the U.S. and conveyed back as State Lands were submerged lands not specifically transferred to *konohiki*, individuals, or trusts. Thus, most inshore fishponds were privately owned, and other submerged inshore lands became Government Lands after the takeover and annexation of Hawai'i (Horwitz and Meller 1966).

The historical and legal intricacies of the takeover of the Hawaiian Kingdom detract in various ways from the integration of fisheries and coastal management. The most obvious direct impact is with respect to the protection of native fishing rights, once clearly understood under the Hawaiian Constitution to include the conservation, health, and utilization of fisheries as a food source (Thurston 1904, Iverson et al. 1990a and b, Haia 1996c and d). The relationship between the disruption of land and water rights and the deterioration of watersheds is also apparent at a glance (Hutchins 1946). But the downstream impacts on fisheries resources are somewhat subtler in their manifestations (Iverson et al. 1990a and b, Kanaka'ole Foundation 1995a, Hui Mālama o Mo'omomi 1995 and 1996). Understanding that land, water and inshore fisheries management cannot function separately on remote Pacific Islands, the impacts and environmental consequences of the *Mahele* extend to the depths of fisheries administration, conservation, and management in Hawai'i today. Beyond human access and other ecological implications, the *Mahele* and overthrow continue to shackle fisheries and coastal resource administration in Hawai'i today in many ways, including via the longterm failure of government to address the facts openly.

Today government lands, including the submerged shoreline, are harbored under various State, City, County, and Federal agencies. Most fishponds have been sold or transferred to government or private interests. In 1921, acknowledging "an obligation to the aboriginal peoples of Hawai'i," the U. S. Congress enacted the Hawaiian Homes Commission Act (HHCA), establishing a land trust of about 200,000 acres "for the use and benefit of Native Hawaiians of 50 percent or more aboriginal blood" and delegated State responsibility for that trust to the Department of Hawaiian Homelands (DHHL), one of several State agencies established via Federal law. Despite its purpose and rhetoric, federal reports document that distribution of lands to *kanaka maoli* has been a complete failure (USCCRHAC 1980 and 1991, Barnes 1999). Revenues from submerged lands provide for the Office of Hawaiian Affairs (OHA, ironically a State agency), a network of trustees (elected by the general public or appointed by the Governor) that interacts with its constituency through statewide and island-based councils. Although *kanaka maoli* voice their concerns regarding impacts to lands, streams, coastal water quality, estuaries, reefs, and inshore fisheries to OHA, OHA has no legal authority to manage land, water, or fisheries. These are managed through DOH, DLNR, the Legislature, and other agencies.

Another state agency, the Land Commission, was created to quiet land titles following the *Mahele* by the Constitution of 1852 (Thurston 1904, Hutchins 1946, Chinen 2002). By 1963, the Land Commission had evolved into the Land Use Commission (LUC), housed under DBED&T. LUC classifications divide the 'āina into an elaborate patchwork of land use categories, with unique specifications governing allowable types and amounts of development (Eckbo et al. 1971, Meyers 1976, OCZM and DPED 1978). The primary land use categories, which relate directly to ownership categories developed via the *Mahele* (Hutchins 1946, Meyers 1976, OCZM and DPED 1978), include Agricultural, Urban, Rural, and Conservation Lands. Two other subzones, Geothermal Resource and Exploratory Well, can be and are placed essentially anywhere (HRS, Chapter 205, 2001). Within all but Conservation Lands, the counties govern the allowable uses within each category. DLNR governs the use of Conservation Lands (including submerged land), under its Board of Land and Natural Resources (BLNR). Members of the LUC and BLNR are appointed by the Governor, as are the heads of all State Departments (Hobbs 1935, Horwitz and Meller 1966, Modavi 1992). Thus, a close-knit political alliance oversees the allocation, permitting, and use of land in Hawaiʻi today.

In addition to the BLNR, within and associated with DLNR are the following administrative divisions, boards and commissions (several others, not directly relevant, are not mentioned):

- **Division of Aquatic Resources (DAR):** managing the living component of streams and inshore waters
- **Division of Water Resource Management (DOWRM):** managing streams, wells and groundwater
- **Division of Land Management (DLM):** managing land use and development
- **Division of Forestry and Wildlife (DOFAW):** managing vegetation, land animals, wetlands, shorebirds, turtles and other reptiles, terrestrial invertebrates, and marine mammals
- **Division of Boating and Ocean Recreation (DOBOR):** monitoring and regulating small boat harbors, anchoring, boat ramps, boating safety, and a wide variety of recreational ocean activities
- **Division of State Parks (DSP):** maintaining and operating State parks and recreation planning program
- **Division of Historic Preservation (DHP):** managing preservation and record of historic sites, burials, *heiau* (alters, including fishing shrines), and other important historic and cultural features (including historic fishing and canoe houses, fish and salt preparation sites, and landmarks relating to the fishing *koʻa*).
- **Division of Conservation & Resources Enforcement (DOCARE):** enforcing all DLNR rules
- **Bureau of Conveyances:** managing Land Court documents, land titles, property transfers, etc.
- **Commission Water Resource Management (CWRM):** reviewing and permitting in-stream water uses, wells, and water diversions
- **Kahoʻolawe Island Reserve Commission (KIRC):** managing Kahoʻolawe, its waters and resources in trust for the general public until it can be returned to a native Hawaiian sovereign entity, following its cleanup and restoration from 40 years of use as a bombing target by the U. S. Navy
- **Natural Area Reserves System Commission (NARSC):** monitoring and maintaining other natural reserve areas

The divisional infrastructure of DLNR and agencies managing other aspects of the coastal environment (DOH, DBED&T, and various federal agencies) places interrelated elements of watersheds and inshore ecosystems under separate management. Federal management of inland fisheries is housed within the U. S. Fish and Wildlife Service (USFWS), under the Department of the Interior (DI), an agency that has traditionally been somewhat protective of fish and wildlife, although it was originally created to control the impacts of wildlife on agriculture and livestock (U. S. ADA 1931). Federal forestry and soil management, on the other hand, are housed within the U. S. Forest Service, under the Department of Agriculture. Because they are seen as waterways, with associated implications for flood control, commerce and civil defense (Paul et al. 1996, Paul 1999, CFRs, 2002), the Army Corps of Engineers (U. S. Department of Defense) is responsible for permitting and managing dredging, infilling, and other alteration of wetlands. The State DLNR has various divisions with responsibilities relating to wetlands management, including its Divisions of Forestry and Wildlife, Land Management, Water Resources Management, Conservation Enforcement, and Aquatic Resources (KMTPAC 1983, DLNR 1998). Finally, the DOH manages impacts to wetlands via its responsibility of maintaining water quality in streams and groundwater, and managing landfills, runoff, and point source pollution.

This brings us to ecosystems management, a concept increasingly revisited in “western” fisheries conservation science (Walters 1975, May et al. 1978, USOTA 1987, Pauly and Lightfoot 1992, Smith and Pai 1992, Lowe 1995, Englund and Filbert 1996, Parrish et al. 1997, Laukkanen, 2001, Loope, 2003, Lande et al., 2003) and recognized in government efforts to restore impaired ecosystems, especially in the coastal environment (OCZM and DPED 1978, USACE 1991, KMTPAC 1983, USOTA 1987, Anderson and Miura 1990, KBMPTF 1992, HCZMP 1995, Kanakaʻole Foundation 1995a and b, Miller and Bay 1995, Bay Pacific Consulting 1996, USEPA 1998 and 2003, DOFAW 1999, DOH, 2000, Black, 2001, LET and DOH-CWB 2001, OP 2001, DAR 2002, Ahupuaʻa Action Alliance 2003, KBAC 2003, KNHF 2003, Hanalei Heritage River Program 2003, Native Hawaiian Advisory Council, 2003, WEC 2003). Because of their importance in maintaining watersheds, providing food, and creating inshore spawning and nursery habitat, forests, soils, rivers and wetlands must be considered and managed as integrated fisheries ecosystems. Although administratively it may seem more efficient to categorize and manage ecosystem components separately, relationships in nature are multifaceted. Forests protect soils from erosion and capture primary productivity. If they are not eroded, soils sustain the trees that in turn shelter them, with their associated infauna and leaf-litter biota. Stream and wetland flora and fauna rely on a healthy overlying watershed, and these living elements provide food and nutrients for inshore ecosystems and fisheries. If any of these elements are impaired, or made to function asynchronously, excessive runoff and sedimentation can kill coral reefs, inshore productivity can be restricted or undergo cycles of monstrous production or depletion of a few species or groups, inshore ecosystems and beaches can become eroded or degraded, or any number of other human-induced calamities can arise.

The impacts to Hawaiʻi’s wetlands, beaches, and inshore fishponds due to erosion, sedimentation, and runoff illustrate the problem of partitioning watershed management (OCZM and DPED 1978, USACE 1981 and 1991, KMTPAC 1983, Coyne et. al 1996, Fletcher and Calhoun 1995, Fletcher and Hwang 1994, Fletcher 1997 and 1999, Fletcher et al. 1997, USEPA 1998 and 2003, Fletcher and Lemmo in press, Mullane and Suzuki 1997, Mullane et al. 1997, DLNR 1998, Rooney and Fletcher, 2001, Ahupuaʻa Action Alliance 2003, KBAC 2003, KNHF 2003, Calhoun and Fletcher in press, DeCarlo et al. in press). Over the past century Hawaiʻi’s forest ecosystems have decreased dramatically in size and stability, due in part to factors already described but also to fragmentation and reclassification of wetland and riparian habitats (Bishop 1888, Sather 1976, OCZM and DPED 1978, Stone and Scott 1984, Kusler and Riexinger 1986, Mueller-Dombois 1996a and b, Lande et al. 2003). Reclassification (affecting protection) and partitioning amongst agency jurisdictions at both the state and federal level affects all species and habitats but is particularly detrimental to wetlands and inshore ecosystems.

Ephemeral in nature, particularly on Hawai‘i’s volcanic soils, wetlands, estuaries, and other inshore habitats typically change with the mists and tides and receive influx of solutions and sediments via streams and groundwater emerging from the mountain slopes behind them. Beaches are a dynamic and liquid habitat, changing seasonally with storm surge, runoff, and wind and wave action. Because of this, wetlands and inshore sedimentary ecosystems are particularly susceptible to impacts from runoff, pollution, stream diversion, dredging, infilling, shoreline construction, etc. Wetland forests seem to defy definition in modern terms, the kiss of death for their conservation and management. Diverse impacts to wetlands and inshore ecosystems have arisen from the partitioning of management of Hawai‘i’s upland forests, urban, agricultural, and industrial land, waterways, shorelines, harbors, and flora and fauna (Bather 1972; Smith et al. 1981 and 1992; Stone and Scott 1984; Grigg 1985, 1994, and 1995; Kinsey 1988; DOH 1990; Stone and Stone 1992, Araki Wyban 1992, Ahuna and Fujioka 1993, Fujioka et al. 1994, Krock and Sundararaghavan 1993; HCZMP 1995; Chong 1996; Hau 1996; Mueller-Dombois 1996a and b, USEPA, 1998 and 2003). Conservative estimates acknowledge that over 30 percent of Hawai‘i’s natural lowland wetlands have been converted to other land uses, such as agriculture and urban expansion (DOFAW 1999), and that at least 24 percent of beaches on Oahu alone have been narrowed or lost in the past 70 years due to coastal development (Lemmo 1997). Actual numbers are probably much higher, but estimates are confounded by the constant redefinition of what wetlands are to begin with (Sather 1976, Kusler and Riexinger 1986, Tiner, 2002). Not surprisingly, this reclassification process is directly related to permitting requirements and regulations affecting the development and urban and industrial use of low-lying estuarine ecosystems.

As complex as coastal ecosystems may be, management of these interconnected habitats has become even more complicated. Wading through the quagmire of regulations, agencies and jurisdictions responsible for managing and protecting streams, wetlands, and inshore areas is as challenging to a concerned public as is finding their habitat to larval and juvenile fishes, migratory birds, aquatic vegetation, and invertebrate fauna that rely on these habitats (Ahupua‘a Action Alliance 2003, Envirowatch 1999-2003, KBAC 2003, KNHF 2003, Hanalei Heritage River Program, 2003, Native Hawaiian Advisory Council, 2003). Wetlands are quickly isolated and degraded through mismanagement but can recover rapidly when care is paid to maintaining the interrelationships between ecosystem components within a living marsh (KMTPAC 1983, USOTA 1987, USACE 1991, DOWRM and DWLM 1994, Miller and Bay 1995, DOFAW 1999 and 2003, DLNR 1998, DOH 2000, Black 2001, LET and DOH-CWB, 2001, Hanalei Heritage River Program 2003, KBAC 2003, KNHF 2003). In recent decades, efforts to reintegrate management at the regional, watershed, and/or ahupua‘a level are once again providing examples of the fruits of human ingenuity applied to maintaining the function and benefits of natural ecosystems (PPR 1978, USACE 1981 and 1991, KMTPAC 1983, KBMPTF 1992, HCZMP 1995, Miller and Bay 1995, DLNR 1998, DOFAW 1999 and 2003, DOH 2000, KBAC 2003, WEC 2003).

To complete the seaward flow of this discussion, it is necessary to briefly describe some of the geographic boundaries that apply to management of Hawai‘i’s shoreline and inshore coastal zone. Superimposed on the mosaic of ownership, districting, land use and land management categories from *mauka* to *makai* is a series of concentric rings of management authority by county, state, and federal government. The islands are grouped into counties in a way that makes sense ecologically with respect to pelagic and benthic fisheries, corresponding to unified island platform groups (Clark 1977, 1985, 1989, and 1990b; Smith 1993). They include (Figure 1): Kaua‘i County (Kaua‘i, Ni‘ihau, and uninhabited Ka‘ula and Lehua), the City and County of Honolulu (O‘ahu and associated islets), Maui County (Maui, Moloka‘i, Lana‘i and Kaho‘olawe), and Hawai‘i (the Big Island only). But management jurisdictions along the shores of each island are structured as a series of concentric rings, running perpendicular to watersheds, stream and sediment flows, tides, weather, and fish migrations. Each county manages its own Shoreline Management Areas (SMA), with jurisdiction extending 40 feet *mauka* of the State defined "shoreline." Until 1990, State and county laws affecting the coast under Hawai‘i Revised Statutes (HRS) contained a variety of legal definitions of the shoreline for purposes relating to districting, land uses, fisheries, wetlands forests, harbors, etc. Act 127 (State Legislature Regular Session 1990) sought to make these definitions consistent throughout the HRS. Currently, all state and county programs (including the federally-linked Coastal Zone Management Program) apply the following definition to most aspects of shoreline and coastal zone management: *"the upper reaches of the wash of the waves, other than storm and seismic waves, at high tide during the season of the year in which the highest wash of the waves occurs, usually evidenced by the edge of vegetation growth, or the upper limit of debris left by the wash of the waves"* (HRS/HAR[34] 2001). This places the *makai* edge of the shoreline roughly at the mean high, high tide level, and leaves the upper reaches of the beach in limbo, since that portion of the description is based on reference to shoreline vegetation and debris that may or may not be present[35] (Campbell 2002). For most regulatory purposes (fishing, hunting, development, etc.), the HRS define "State Waters" as extending from *"the upper reaches of the wash of the waves on shore*[36] *seaward to the limit of the State's police power*[37] *and management authority, including the United States territorial sea, notwithstanding any law to the contrary"*. The exception is seen, notably, where efforts have been made to manage erosion, runoff, and sedimentation, highlighting the purpose of this discussion. With respect to soil erosion and sediment control, "soil and water conservation districts" have been defined (HRS 180C). In this chapter, the definition of "State Waters" is *"all waters, fresh, brackish or salt, around and within the State, including but not limited to, coastal waters, streams, rivers, drainage ditches, ponds, reservoirs, canals, ground waters, and lakes, provided that drainage ditches, ponds, and reservoirs required as a part of a pollution control system are excluded."* Now, this is a definition even fish can relate to!

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[34] Hawaii Revised Statutes, Chapters 187-190 195, 205, Hawaii Administrative Rules (DLNR) Section 13-222.

[35] The *mauka* part of this description was reviewed and discussed intensively under S.B. 1546 of the Hawaii State Legislature (2003 Regular Session) and remains unresolved at this time.

[36] In portions of HRS referring to State Waters, the shore is referenced without respect to tidal changes.

[37] The limited availability of marine vessels and funding, and responsibility to enforce State conservation laws from *mauka* to *makai*, severely restricts the range of fisheries enforcement patrols by DLNR, Division of Conservation and Resources Enforcement (DOCARE). DOCARE officers have the option to "ride along" aboard U. S. Coast Guard high seas vessels, including helicopters and marine vessels headed in their direction, but conflicting goals and responsibilities mean that State enforcement needs can rarely be met effectively in this manner.

The last of the concentric rings coastal species must traverse to complete nursery, growth, and spawning migrations includes federal jurisdictions, which overlap in odd ways with state and county jurisdictions. The Federal Code of Regulations limits the inshore definition of navigable waters of the United States to *"waters susceptible to the ebb and flow of the tide and/or used (past, present or future) to transport interstate or foreign commerce"* (CFRs, 2002). The inherent problems in this definition for wetlands and beaches have already been discussed. Federal definitions further describe *"oceanic and coastal waters"* or *"The Territorial Seas,"* based on *"a zone three geographic (nautical) miles seaward from the baseline."* The *"baseline"* is defined as *"Generally, where the shore directly contacts the open sea, the line on the shore reached by the ordinary low tides."* This would correspond to the mean low tide (as opposed to the mean low, low, reached only at a specific lunar and solar season of the year). The U. S. Army Corps of Engineers definition goes further to delimit an intertidal zone, providing an upper boundary applicable on beaches, rocky coasts, in bays and estuaries, etc. This refers to the mean high water (as opposed to the mean high, high), provides leeway for a survey-based clarification if necessary, and specifically recommends alternatives to using lines of vegetation or debris (33 CFR Ch. II §329.12). The "Nation's Shoreline," used in other federal applications, utilizes the mean low, low water. Finally, the term "Waters of the United States" used to define the U.S. Exclusive Economic Zone (EEZ) in the international context reaches to within 200 miles of the shores of the Hawaiian Archipelago, based upon the mean high water definition and an archipelagic definition of the coastline that is beyond the scope of this discussion (McDougal and Burke 1962, Jones 1972, Amacher and Sweeney 1976, Sullivan 1977, Friedheim 1979, Booth 1985, Kuribayashi and Miles 1990, Morell 1992).

The fact that the various State and Federal definitions of the shoreline represent distinct physical locations along the vertical slope of the beach presents additional obstacles to monitoring and management, not to mention mapping of the coastal zone (OCZM and DPED 1978, Campbell 2002). Furthermore, the subdivision of streams, rivers, bays, and oceans and the partitioning of fish stocks amongst multiple property jurisdictions with conflicting economic goals represent potentially lethal obstacles to sharing and conservation of these resources (Ricker 1958; Luard 1974; Munro 1977; Johnston 1978; Freidheim 1979; Anderson 1986 and 1994; Craven et al. 1989; Grafton 1996; Lande et al. 1995, 1998 and 2003; Baden and Noonan 1998; Brown 2000; Laukkanen 2001 and 2003). That these differences have yet to be resolved as we enter the new millennium means regulatory gaps will continue to produce impacts to Hawai'i's fisheries and fish habitat, as pollution, coastal development, waste disposal, ocean exploration and mining, and other activities with ecological consequences fall through the various administrative and political cracks perpetuated by thinking of the shoreline as property (Luard 1974, Schmitt 1975, Amacher and Sweeney 1976, Sullivan 1977, Johnston 1978, Craven et al. 1989, M'Gonigle and Zacher 1979, Mayer and Riley 1985, Earney 1990, Schug 1991). Modern districting, zoning, and jurisdictional boundaries partition watersheds, separating monitoring and management of deep pelagic waters from inshore habitats, managing dunes and beaches apart from submerged shorelines, and regulating streams separately from groundwater (Myers 1976, Ramil 1984, DOH 1990, DAR 1996). Hawai'i's rain falls from the sky and slips through management jurisdictions, finding its way down the mountains to the sea through forests, urbanized areas, farms, golf courses, and beaches (OCZM and DPED 1978, HCZMP 1995, Mamala Bay Study Commission 1996, HBWS 2002). Endemic fishes and invertebrates and other marine and estuarine fauna and flora meet with more limited success in slipping through the maze of management in their efforts to find food, shelter, spawning and nursery habitat (Araki Wyban 1992, Hau 1996, Englund and Filbert 1996).

An Overview of MHI Fisheries and Coastal Ecosystems Today

Without the benefit of traditional conservation practices, impacts to Hawai'i's fisheries occur, either directly (via overfishing) or indirectly (via pollution, habitat destruction, reduced stream flow, and other disruption of watershed function). The direct impacts of disintegrating watersheds on marine and coastal habitat, flora and fauna are well documented. They include increased sedimentation and infilling of inshore reefs and bays (Roy 1970, Smith et al. 1973, Hollett 1977, OCZM and DPED 1978, Smith and Kukert 1995, Miller and Bay 1995, Farber 1997, Gulko et al., 2000, Fletcher et al., 2002), loss of "pristine" inshore water quality (Ferguson, Wood, and Johannes 1975, M&E Pacific 1980, Dudley et al. 1981, Laws and Redalje 1982, Smith et al. 1981 and 1992, KBMPTF 1992, HCZMP 1995, DOH 1978 and 2000, Mamala Bay Study Commission 1996, KBAC 2003), loss or degradation of beaches, dunes, wetlands, and sedimentary habitat critical to marine mammals, birds, invertebrates, fishes, and other elements of food chains and nutrient cycles (Fletcher and Hwang 1994, Coyne et al. 1996 1999, Fletcher 1997, Fletcher et al. 1997, Mullane and Suzuki 1997, Mullane et al. 1997, Fletcher 1999, Rooney and Fletcher 2001, Fletcher and Lemmo, in press), nutrient loading in marine algae associated with streams and effluents (Chun Smith 1994), dramatic fluctuations of both "good" and "bad" types of phytoplankton and zooplankton (Smith et al. 1981, Laws and Allen 1996), invasions of alien parasites and macroalgae (Evans et al. 1986, Hunter and Evans 1995, Font et al. 1996), and other impacts at various levels.

Cumulative and collateral impacts of cultural change and habitat degradation on inshore fisheries are poorly understood but have clearly occurred within the past century (Pooley 1987, Shomura 1987, Harman and Katekaru 1988, Maragos and Grober-Dunsmore 1999). In addition to overfishing, some of the mechanisms impacting inshore stocks and their habitat include reduction of stream productivity, the food source for many inshore species and their prey (leaf litter, invertebrates, etc.) due to reduction or loss of stream flow (Nakasone 1995, Chong 1996); introduction of competing and predatory alien species (Uchida and Uchiyama 1986, Hunter and Evans 1995, Friedlander et al. 1997 and 2002b, USGS 1999, Englund et al. 2000, Tagawa and Yamamoto 2000); disruption and congestion of spawning and nursery areas (KBRTF 1992, Lowe 1996, CWRM 1995); nutrient loading, eutrophication, and parasitism favoring growth of opportunistic native and alien species (Smith et al. 1981, Font et al. 1996, Chun Smith 1994, Englund and Filbert 1996); burying and overgrowth of the reef environment (Ferguson Wood and Johannes 1975, Evans et al. 1986, Hunter and Evans 1995); and changes in other habitat-related parameters within watersheds. The effects of all these impacts on the ecological balance (herbivores versus carnivores, diversity and relative species abundance, filter feeders versus other elements of marine communities, etc.) can cause diverse collateral effects, among other things prolonging resource recovery for natural storm events (Grigg 1972, 1994, and 1995; Ferguson, Wood, and Johannes 1975; Kaufman 1986, Laws and Allen 1996).

Not surprisingly, human impacts on fisheries are most pronounced in the MHI (Pooley 1987, Shomura 1987, Harman and Katekaru 1988, Lowe 1995, Gulko et al., 2000, Friedlander and DeMartini, 2002, Everson and Friedlander, 2003), which are home to the vast majority of the state's population and are visited intensively by tourists (Table 1). The contrast in resource condition between the islands to the northwest of Ni'ihau (the Northwestern Hawaiian Islands or "NWHI") and the MHI is evidence of the impacts of modern society. Although in ancient times the MHI were also densely populated, Hawai'i's roughly 800,000 to one million people were more evenly distributed amongst the eight "high islands" prior to the arrival of European and American colonists (Stannard 1994). The NWHI were once sparsely inhabited by *kanaka maoli*, but have remained essentially unpopulated with comparatively low fishing pressure since their rediscovery by "westerners" in the 18th century (Emory 1928, Thurston 1936a). Although overfishing in the NWHI and potentially related food chain perturbations have become an issue since federal fisheries development efforts began to focus on this area (Uchida and Uchiyama 1986, Wetherall et al. 1995, Dinardo and Haight 1996, Dinardo et al. 1998, Barayuga 2000, Earthjustice Legal Defense Fund 2000, Dinardo and Marshall 2001, Mundy 2003), distance alone limits the amount of fishing and other human impacts in that region. Because of this, marine resource abundance in the NWHI is still markedly greater than in the MHI (Grigg and Pfund 1980, Grigg and Tanoue 1984, Uchida and Uchiyama 1986, DAR 1988, Pooley 1987 and 1993, Friedlander and DeMartini, 2002).

Cultural practices have changed more gradually in regions of the MHI where transportation and access are limited but have accelerated everywhere in the past few decades in response to the growth of roads, ocean and airline transport, television, telephone, and Internet connections. The influences of newcomers have generally spread from accessible boat ramps and safe harbors toward other regions of each island, and more recently from local airports. Despite the homogenizing effect of recent changes in transportation and communication, geographic differences in cultural change and population growth and on each island remain evident. Superimposed on these patterns are the natural differences in geography and climate affecting Hawai'i's fisheries in various ways (Smith 1993).

Because of the geographic variation in physiography, climate, accessibility, and local history, traveling through the MHI provides an overview of a wide range of modern impacts, illustrating many of the ways cultural change has altered Hawaiian ecosystems. Each island has seen unique geographic variations in culture and history, producing different manifestations of change in inshore and coastal ecosystems. Like a window through time, a tour of the MHI provides a way to see the past, present, and future in a single frame of reference, placing cultural impacts into instantaneous perspective.

Among the MHI, the lifestyle of Ni'ihau today most closely resembles the ways of "old Hawai'i" (Tabrah 1987, Tava and Keale 1989, Meyer 1998). Moloka'i could be considered next on a continuum from older to more modernized culture, although the relative positions of the next three islands could legitimately be debated in various ways. Relative isolation, small population size, and rough terrain have conserved a lot of traditional culture on the "friendly isle" of Moloka'i (Moloka'i Subsistence Task Force 1994, Farber 1997). Lanai and Hawai'i compete in different ways for the next place in line along a historical continuum. Each manifests a different mosaic of highly commercialized areas, interspersed with rural and agricultural areas with more traditional Hawaiian culture and lifestyle. Parched by the almost complete diversion of its streams for agriculture, its shorelines increasingly blanketed by hotels, golf courses, and urbanized areas, Maui falls closer to the "westernized" end of the continuum. Yet within every island there are people who maintain *kanaka maoli* culture, in some cases speaking the language of old Hawai'i almost exclusively. Next to last on a "historical continuum" comes O'ahu, a melting pot of people from all over the world, yet even on O'ahu there are places and people that maintain the old ways (Ahupua'a Action Alliance 2003, KNHF 2003, WEC 2003). Kaho'olawe, now being rebuilt after decades of bombing by the U.S. military, represents the ultimate consequence of "westernization", yet it is also a beacon toward a better future as the tools of cultural renaissance strive to bring about its restoration (KICC 1991, Dames & Moore et al. 1997).

Understanding the patchy distribution of traditional Hawaiian culture throughout the MHI, the threads of traditional practices will wind in and out of this narrative as we travel roughly from northwest to southeast. The tour will end on the island of Hawai'i, where these threads can be woven back together to describe the tattered tapestry of Hawai'i's fisheries as we face a new millennium. It is important to keep in mind throughout this narrative that the issues are not of race, but of culture. Hawai'i's ethnic origins are diverse, but her people can choose the cultural values they wish to embrace. The purpose of this discussion is to bring into perspective the issues Hawai'i's people must cope with effectively today, if we are to restore and maintain healthy inshore fisheries and coastal ecosystems.

Ni'ihau

Ni'ihau is the oldest geologically of the MHI. It is a small island (less than 70 square miles), with steep sloping cliffs, worn by wind and waves. Because it lies in the rain shadow of Kaua'i, water is scarce, imposing natural limitations on agriculture and growth. Descendents of a Scottish family, who purchased the island from Kamehameha V in 1864, continue to own and manage Ni'ihau today (Tabrah 1987, Stepian 1988, Meyer 1998, Moriarty 2001). The fact it is privately owned makes it possible to limit access and immigration, enabling Ni'ihau to maintain a relatively modest population with an essentially traditional Hawaiian lifestyle.

Few are allowed to live on or visit Ni'ihau. Its residents number roughly 200 (Table 1). New families are established as offshoots of other Ni'ihau residents. As was once customary, children and young people on Ni'ihau are taught carefully and directly how to care for shoreline resources as they learn to fish (Tava and Keale 1989). Subsistence fishing and shoreline gathering are an integral part of life on Ni'ihau. Resources from the sea and species kept in inland fishponds for centuries (Tabrah 1987, Stepien 1988, Tava and Keale 1989) have comprised the majority of protein in the diet of Ni'ihau's people for centuries and still do (Kirch 1982, Stepien 1988, Meyer 1998). Men do the offshore fishing, in keeping with ancient traditions. Women and children have an equally important role in providing for the family, as gatherers of *limu* and invertebrates along the shoreline. On Ni'ihau this custom has specialized into a unique art form and way of life, harvesting the precious *p p 'o Ni'ihau*, beautiful, tiny, and colorful shells used to create the leis for which the island has been known since ancient times (Moriarty 1986, 2001). The diversely colored *p p 'o Ni'ihau* (shells of Ni'ihau) are listed in Table 3.

As they learn the art of gathering shells for lei making, children enjoy long days at the beach, where they gradually acquire skills of observation and cultivate an understanding of subtle differences in species, seasons, and weather conditions. These skills gradually allow even young children to recognize the times and places it is appropriate to harvest fishes, limu, and invertebrates, anticipate the arrival of spawning and juvenile schools, and thus utilize their knowledge of the sea to sustain themselves, their families, and community more efficiently. Equally important is the understanding they gain of when these resources should be left alone and when they should shift to another area or stock to allow resource replenishment and avoid longterm depletion. The children are also taught to share what they gather as a way of life, building community skills as they learn to fend for themselves along Niʻihau's rugged coast (Stepien 1988, Tava and Keale 1989).

Niʻihau residents enjoy a way of life devoted to family and spiritual enjoyment (Stepien 1988, Tava and Keale 1989, Moriarty, 2001). Much of their food comes from fishing and gathering, as well as hunting for pigs and sheep, introduced and managed similarly to fisheries resources (i.e., sustainably harvested). *ʻAmaʻama* (mullet), and *awa* are raised in fishponds and shared amongst all members of the community (Meyer 1998, Tava and Keale 1989). Naturally dried sea salt is another important resource Niihauans produce, including the regular salt (*paʻakai*) known for its fine white variety from Niihau and the red clay (*alaea*) salt required in some traditional medicines.

Since the transfer of fishing methods and conservation practices is part of growing up on Niʻihau, it is easy to maintain traditional values designed to conserve, share, and limit the harvest of shoreline fisheries within a range that allows for natural replenishment. Not surprisingly, Niʻihau has continued to enjoy abundant inshore resources, while the rest of the state has become depleted. Inshore fisheries are plentiful and conflicts on beaches and in shoreline areas are rare. Unfortunately, the lack of conflict is changing rapidly with the increasing ease of marine transportation from Kauaʻi and the promotion of fishing and dive tours to nearby areas. The fact that fishers from other areas seek to visit Niʻihau to obtain better catches and larger fish is one indication that fisheries resources there are relatively well cared for and plentiful.

Those living on Niʻihau are largely self-sufficient, living on what the land and sea can produce, and sharing or bartering for a limited number of other goods (Tava and Keale 1989, Meyer 1998). As they become elderly, Niihauans may go to live on Kauaʻi, where they have better access to medical services. Those who remain on the island continue to provide their aging relatives and extended families on Kauaʻi with fish, invertebrates, limu, and other resources that are increasingly hard to find on Kauaʻi. These include most reef fishes, *limu*, *wana* (urchins), and other inshore invertebrates. In return, the *kupuna* assist their relatives who remain on the island with useful provisions. Although it is tempting to remain on Niʻihau, this tour must proceed to another island to encounter many of the critical management issues facing the rest of Hawaiʻi today.

Table 3: *Pūpū ʻo Niʻihau**

Common name		Scientific Name		
Hawaiian	English	Family	Species	Description
* *Momi*	Dove Shell		*Euplica varians*	Oval-shaped, colors variable white to shades and mixtures of blue, gray, black, brown, yellow, orange and red (dotted lines to solids)
* *Laiki*	Rice Shell	Columbellidae	*Mitrella margarita*	Like tiny rice grains, white to off-white and beige, with light and dark brown markings
Laiki ʻāpu ʻupu ʻu or *Laiki nunui*	Bumpy/Long Rice Shell		*Anachis miser*	Fusiform, smooth or axially ribbed, white to brown or black, solids and striped patterns
* *Kahelelani* (“the royal way”, named after a chief)	Turban Shell	Turbinidae	*Leptothyra verruca*	Turban shaped, solid and striated, mixed colors (white to ivory, light to dark browns, burgundy-reds, light and dark pinks and greens)
Kamoa or *Hālili*	“Samoan” Turban Shell		*Turbo sandwicensis*	Largest Hawaiian turban shell, solid colors with spiraling green to gray, brown to black bumps
ʻŌlepe	Pecten or Scallop	Pectinidae	*Chlamys irregularis*	Fanlike, pastel colors (pinks, whites, yellows)
			Haumea juddi	Fanlike, white or mottled (reddish spot or band)
ʻĀlīlea	Large Dove Shell	Strombidae	*Strombus maculatus*	Ovoid turban-shaped, cream with brown accents. Larger than most of the shells. Mainly in leis for men.
Pō-leho (named for a place on NE Niʻihau)	Night Cowry	Melampidae	*Melampus castaneus*	Oval-shaped, solid to striated brown-white
** *Kauno’o* or *Pihi*	Sundial	Architectonicidae	*Heliacus variegates*	Convex sculptured spiral, variegated white or cream, with tans to browns and blacks

Table 3: *Pūpū ʻo Niʻihau (continued)**

Common name				Scientific Name		
Hawaiian	English			Family	Species	Description
** *Puka* or *Pihi*	*(worn)* Cone Shell			Conidae	Conus sp.	Curved to flat spiral with central hole ("puka"), usually solid white to cream colored
** *Pōleholeho*	Indo-west Pacific species with no specific Hawaiian or local name		Cowry	Cypraeidae	*Cypraea annulus*	Oval-shaped, smooth, cream colored, with orange thread around dorsum
	ʻeleʻele or *kupa*	Snakehead/ Black/Native			*Cypraea caputserpentis*	Reticulated brown and white dorsum, with brown sides. Most abundant Hawaiian species.
	ʻāpu ʻupu ʻu or *ʻakala*	Bumpy/ Pink			*Cypraea granulata*	Surface granulated, rose-brown fading to creamy brown with time, wear and exposure
	ʻōpule	Variegated			*Cypraea helvola*	Spotted and blotched purple-red to gray-brown dorsum, purplish edges & orange-brown sides
	lenalena or*k ūpe'e lima*	Yellow or Bracelet			*Cypraea isabella*	Cylindrical, orange-brown with linear black streaks and dark brown extremities
	Puna	Coral or White Money			*Cypraea moneta*	Pyriform to triangular, pale yellow in color
	(no further descriptive Hawaiian or English name)				*Cypraea sulcidentata*	Oval, inflated, creamy brown, with four darker bands

Table Legend
* The name *Pūpū ʻo Niʻihau* ("shells of Niʻihau") is used to refer generally to the three principle species that make up the body of the beautiful shell leis for which the Island of Niʻihau has been known for centuries.
** Species used to close the leis, diverse species in these groups are used.
Sources: (Moriarty 1986, 2001, Kay 1979)

Ka‘ula Rock

Ka‘ula Rock is uninhabited and remote from other islands, yet visits from tourists and fishers are becoming more frequent. Spear fishing is an increasingly popular method on Ka‘ula Rock, since large predatory fishes are more abundant on such a small and remote land mass, where fishing pressure is reduced and the food chain is nearly pelagic. The development of marine resources within the splash zone is limited by the small amount of habitat available on this rocky bluff protruding abruptly from the ocean. But the abundance of large predators indicates that Ka‘ula Rock is less heavily fished than more accessible sites along the Kaua‘i Coast.

A few tour groups frequent Ka‘ula Rock, but local divers with specialized knowledge of the area are also regular visitors. Commercial tour entrepreneurs wish to conserve large game fishes there. Their prestige, business interests, and appreciation for marine life is enhanced by the rare opportunity to see large *ulua* (jacks and trevallies), *kaku* (barracuda) and other predators on shallow dives. With their knowledge of marine life, divers (including spear fishers and those using other catching methods) generally acquire respect for sea life and a desire to conserve fish populations. Even sharks are recognized as essential elements of the reef community, commanding both awe and respect for the undersea world, as they have done amongst *kanaka maoli* for centuries (Meyer 1998). The role of sharks in eliminating sick and/or weak individuals is apparent in an environment where fish are allowed to reach senescence, just as the fact human beings are part of the ecosystem becomes apparent when one is swimming freely underwater.

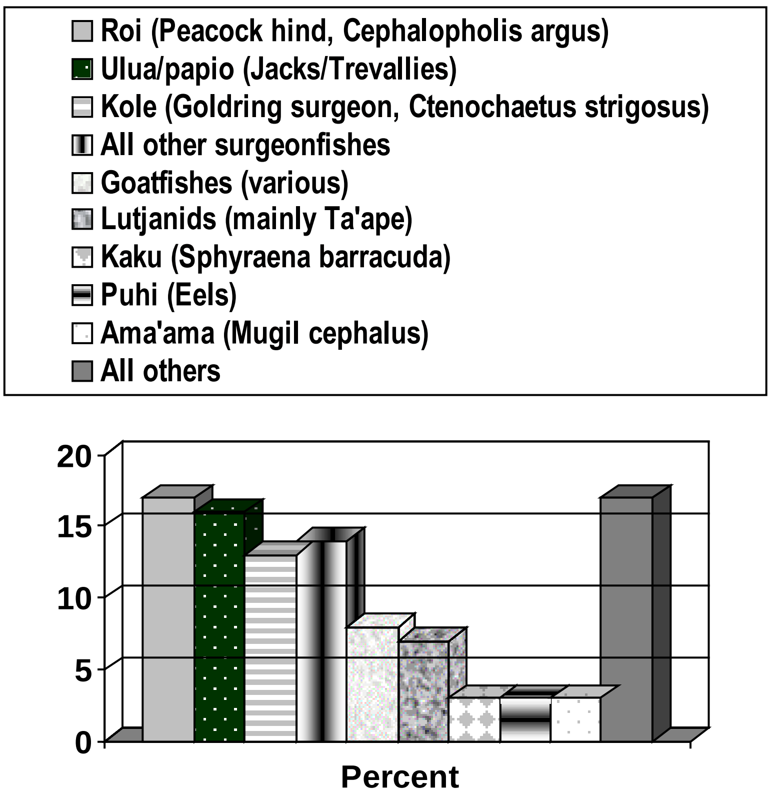
Despite the occasional dispute over limited space and the tendency for novice divers to damage corals and other sedentary species, those who view fish (in modern terms, “non-consumptive users”, as opposed to “consumptive users”, who fish for food and income) can sustain their activity at low levels for long periods of time with relatively low impact. As the volume of “non-consumptive users” increases, so does their impact. Its distance from heavily populated islands (the southwest shore of Kaua‘i, with only 58,300 residents, is closest) and the difficulty of approach for swimmers and small vessels (especially during the winter) allows Ka‘ula Rock to flourish to date with relatively low fishing pressure and excellent water quality.

Kaua‘i

Blessed by heavy rainfall and relative isolation, Kaua‘i is also characterized by periodic northerly storms and broad wetland areas, even at high elevations (Hutchins 1946, Fletcher and Calhoun 1995, Friedlander et al. 1997). The slopes and shores of Kaua‘i are heavily impacted by erosion, sedimentation, dredging, and reduced stream flow. Contributory human causes include shipping, coastal development, and agriculture-related deforestation, stream channelization, and dredging (Clark 1990b), but latitude, climate, and other related natural causes are also important (Smith 1993).

Associated with excessive coastal erosion, sedimentation, and disturbance (IFRECOR, 2003, Woods Hole Oceanographic Institute, 2003), blooms of the dinoflagellate *Gambierdiscus toxicus* are the cause of fish poisoning (or “*ciguatera*”), which is an important issue on Kaua‘i. Both heavy rainfall and human impacts probably contribute to this problem. Spear fishers and shoreline gatherers on Kaua‘i share concerns about *ciguatera* with local *kupuna*. All agree that its incidence has increased in recent years. Although only 26 cases have been reported in the past five years, this is the second highest number seen on any of the Main Hawaiian Islands (Figure 2). The good news is that, while ciguatera inhibits human fish consumption and sales, it is a strong deterrent to overfishing and may be relatively harmless to other predatory species in the coastal zone.

Heavy rainfall and broad lowlands create long, shallow riverbeds and a far-reaching estuarine effect around the island of Kaua‘i. Coupled with inshore fishing impacts, this contributes to the large proportion of small fishes available for the catching in inland areas. This constitutes a challenge to fishers, who must exercise restraint in their selection of fish to throw back versus taking home or to the market



O‘AHU	(56, 44.0%)
KAUA‘I	(26, 21.0%)
MAUI	(23, 18.0%)
HAWAI’I	(18, 14.0%)
MOLOKAI	(2, 1.6%)
LANA’I	(1, 0.8%)

Source: State Department of Health (2001)

Figure 2. Incidence of Ciguatera MHI 1996-2000 (126 incidents, 214 cases)

Because of its abundant water, Kauaʻi sustains one of the few remaining river mouth fisheries for native *oʻopu* (gobies). The largest species (*oʻopu nakea*, *Awaous stamineus*) is a popular element of fisheries, particularly along Kauaʻi's northeastern shore, which is subject to even greater rainfall than Kauaʻi's mean record highs in the MHI (Smith 1993). Estuarine species, including a variety of ulua/pāpio (adult and juvenile jacks and trevallies (Honebrink 2000)), striped mullet (*Mugil cephalus*), *āholehole* (*Kuhlia sandvicensis*), *weke* (various goatfishes), represent a prominent component of Kauaʻi's coastal fisheries (Friedlander et al. 1997, DAR, 2003).

Fishers from other islands have commented that Kauaʻi residents use extremely small (illegal) mesh sizes to catch fish on a regular basis. If this is done without outrage in the presence of other fishers (not entirely true), it means that standards of what is acceptable are somewhat different on Kauaʻi versus other islands. This is partially due to habitat differences on Kauaʻi and partially due to upbringing. Juvenile fishes harvested with small mesh nets are targeted by Kauaʻi's inshore fishers, as they have been for generations. But many other factors have changed in the interim, and the practice of having a local expert to remind people when it's time to let resources rest awhile has been lost for the most part, leading to concerns over the possibility of recruitment overfishing. The management issues are difficult to evaluate scientifically, since few data are available other than for commercial landings. In 1992, the Division of Aquatic Resources' Main Hawaiian Islands Marine Resources Investigation (MHI-MRI) sponsored a baseline survey of inshore fishing in the Hanalei region (Friedlander and Parrish 1997, Friedlander et al. 1997), but efforts to implement in-depth catch and recruitment studies have been thwarted by a lack of funding.

Other important resources gathered along the shoreline on Kauaʻi include the reddish alga *limu kohu* and *aʻama* crabs (rock crabs, *Grapsus grapsus tenuicrustatus*). Sedentary inshore species are among the first to be depleted, because they are easy to reach and capture. Low intertidal species found below the splash zone, such as ʻ*opihi* (limpets, *Cellana* spp.), represent a partial exception to this rule, since only the most intrepid rock climbers can reach them on the treacherous wave-swept rocks where they are found. Although somewhat protected by the location of their habitat, even ʻ*opihi* have become depleted on most islands, surviving to larger sizes and numbers on less populated islands and in areas with the most wave action, particularly on Kauaʻi and the Big Island. Although some of Kauaʻi's inshore fisheries show signs of depletion, including those for *he'e* (octopus), *opihi* (limpets), and lobsters, fishermen say the resources are there if you know how to find them.

Despite the prevailing idea that fish are abundant, intensive conflicts between fishers arise at places where access to pulse-fisheries is limited and seasonal. "User conflicts" are typical when the bite is on for the popular hook and line catch of *akule/hahalalu* (bigeye scad, *Selar crumenophthalmus*) at any harbor or boat ramp. Controversy is exacerbated by the occasional arrival of boats capable of surrounding more catch than all fishers combined, just out of reach of the shoreline. Pole and line fishers complain of "greed" and waste, especially when they observe fish that die in the nets and wash ashore. Despite the large surround/purse net harvests, assessments of akule stocks indicate they are not over fished (Weng and Sibert, 2000). As a result, beyond the usual minimum size rules and closed seasons, most fishing regulations tailored to this island are geared toward reducing gear conflicts and encouraging shoreline fishers to share resources and access to the shoreline (DAR 2003).

Because of its small population, Kaua‘i’s inshore fisheries are still fairly abundant, compared to more populated islands. Despite this, there are indications that inshore resources in accessible regions are being harvested at or near their capacity (Friedlander and Parrish 1997, Friedlander et al. 1997). Military reserves dot the shoreline of this small island (Clark 1990b). The rapid increases in abundance and size distribution of inshore fishes seen in areas recently closed to the public due to homeland security issues provides an additional indication that fishing pressure contributes significantly to structuring inshore resources.

Kaua‘i is less stressed by tourism in comparison with some of the other MHI, particularly in areas that are remotely situated from hotels and boat ramps. However, the limitation of launch facilities and the large number of visitors in proportion to residents[38] creates additional conflict between the commercial boating/tourism industry and other ocean users (including fishermen), especially along Kaua‘i’s north shore (DLNR 1998, Hanalei Heritage River Program, 2003). Hanalei Estuary shows particularly intense crowding, as commercial tours vessels, fishing boats, and an entire local community utilize a single pier to access much of the north and northwestern shores. But these problems are not unique to Kaua‘i’s north shore. Day and nighttime fishing at Nawiliwili Harbor is restricted due to passenger liner, tugboat, barge and other large vessel traffic. Shoreline access for boats and fisherpersons at Nawiliwili, Port Allen, and in the Wailua River are also affected by small and large tour groups and encroaching development. Thus, even on a less populated, more rural Hawaiian island, inshore fisheries interact with resources in a milieu of other human impacts.

[38] Almost one million visitors annually (Gulko et al. 2000)

O‘ahu

> *"Where I live we don't have all these boats coming in and out and we don't take more fish than we need."*
>
> - *Kupuna* Harry Pahukoa, from Ke‘anae[39], Maui (1997)
> (upon first observing the "Ahi Fever in Wai‘anae[40] Fishing Tournament")

> *"My grandparents told us that when we were feeling ill, we should go to the ocean and immerse ourselves in the water, and this is what we did at Waikīkī. It was to spiritually cleanse ourselves because much of the time the illness was brought about because of actions in our lives that were not pono [spiritually, morally, and in every way right]. It was a prayer (the cleansing), and a belief in making things pono through proper action. I believe that my grandparents had it right, that the illnesses we suffered, then and now, were the result of an imbalance in nature. Even more, our total dependence on western medicine today to heal us, which uses a framework that fails to take into account the need for the ‘āina, kai and wai to also be well, does not help. We seem to be trying to heal the body in a world that has become pono‘ole [not pono]. How much sense does that make? So we can no longer spiritually cleanse ourselves in an ocean that is polluted and might cause us harm, and this is because people no longer love the ocean. In effect, we have been cut off from healing ourselves, from becoming and staying pono, because the means to do that is no longer accessible."*
>
> -Lynette Cruz, Ahupua'a Action Alliance, and resident of Palolo (2001)[41]

The most heavily impacted of the Hawai‘ian Islands (next to Kaho‘olawe), O‘ahu sits alone on its own coastal platform to the southeast across the Kaua‘i Channel (see Figure 1 and Smith 1993). Stressed by its large resident and visitor population (Table 1) and threatened by overfishing and multiple ecological insults, O‘ahu has the largest proportion of urban and industrial impacts to watersheds and inshore nursery areas of all the MHI (Table 4). A glimpse of inshore bays, and natural and manmade inlets, such as the Pearl Harbor, Ke‘ehi Lagoon, Honolulu Harbor, Kewalo Basin, Ala Wai Canal, and the Hawai‘i Kai regions of O‘ahu's leeward shore[42] illustrates the challenges of maintaining habitable watersheds and healthy reef and estuarine fisheries amid the sprawl of urban and industrial development (DOH 1990, HCZMP 1995, Bay Pacific Consulting 1996, Mamala Bay Study Commission

[39] Kupuna Harry Pahukoa, now deceased, always shared his thoughts openly and with a great sense of humor. He is among the beloved contributors to this writing. The name of Uncle Harry's home on Maui means "the mullet" (Pukui et al. 1974).

[40] Wai‘anae, O‘ahu. The place name means "mullet water" (Pukui et al 1974)

[41] Portion of a statement at the "Hawai‘i Fisheries & Ocean Users Forum" (January 13 2001. Honolulu, Hawai‘i), sponsored by the Western Pacific Regional Fisheries Management Council, Hawai‘i Dept. Land & Natural Resources, Univ. Hawai‘i SOEST & Sea Grant College Program, Hawai‘i Coastal Zone Management Program, The Oceanic Institute, Mālama na I'a, and American Fisheries Society, Hawai‘i Chapter.

[42] All but one of the six areas listed are among Hawai‘i's 16 officially "Water Quality Limited" segments, watersheds needing remedial relief due to human impacts (HCZMP 1995). Of the 16, four others are also located on O‘ahu.

Table 4: Summary of Watershed and Water Quality Information for the MHI[1]

Island	Indicator (see Table Legend)	Rank[2]	Principle Concerns (% waterbodies affected): Streams	Principle Concerns (% waterbodies affected): Bays, Coasts & Estuaries	Leading Sources[3] (% affected): Streams	Leading Sources[3] (% affected): Bays & Estuaries
O'ahu	Water quality[2]	60-70	nutrients 100% sediments 100% metals 33%	sediments.100% nutrients 88% metals 25% pathogens 25%	A (67%) U (67%) I (33%) L (33%)	U (88%) A (38%) N (25%)
	Impaired watersheds[2]	70-80				
Maui	Water quality[2]	40-50	NA	sediments 100 nutrients 50	NA	A (100) U (100)
	Impaired watersheds[2]	40-50				
Moloka'i	Water quality[2]	70-80	NA	sediments 100	NA	A (100)
	Impaired watersheds[2]	30-40				
Kaho'olawe	Water quality[2]	NA	NA	NA	NA	NA
	Impaired watersheds[2]	0-10				
Lanai	Water quality[2]	0-10	NA	NA	NA	NA
	Impaired watersheds[2]	0-10				
Ni'ihau	Water quality[2]	NA	NA	NA	NA	NA
	Impaired watersheds[2]	0-10				
Kaua'i	Water quality[2]	30-40	NA	sediments 67 nutrients 33	NA	A (100) U (33)
	Impaired watersheds[2]	50-60				
Hawai'i	Water quality[2]	20-30	NA	sediments 100	NA	A (100) U (100)
	Impaired watersheds[2]	30-40				
Statewide (MHI)	Water quality[2]	20-30	nutrients (100) sediments (100) metals (33)	sediments (93) nutrients (67) metals (13) pathogens (13)	A (67) U (67) I (33) L (33)	U (73) A (67) N (13)
	Impaired watersheds[2]	0-10				

Overall Watersheds Rankings by County

County	No. Impaired Waterbodies[4]	% Watershed Impairment[5]
O'ahu	11	8.73
Maui (includes Lanai, Moloka'i, Kaho'olawe & Molokini)	3	7.35
Kaua'i (includes Ka'ula and Ni'ihau)	3	2.20
Hawai'i	1	.65

Table Legend

[1] **Source:** U.S. EPA Clean Water Act and Pollutant/Stressor Reports 1998-2002 (**available online at Scorecard.org**)

[2] **Rank for each island's Water Quality/Number of Impaired Waterbodies based on percentile of National averages for the values described in footnotes #3 and #4 (below):** 0=Cleanest/Least Impaired, 50%=National Average, 100%=Dirtiest/Worst in the Nation

[3] **Leading Sources of Water Quality Problems:** Island percentage of waterbodies affected by sources of pollutants due to A=Agriculture, U/S=Urban runoff and storm drains, I=Industrial point sources, L=Land disposal, N=Natural sources

[4] **Number of Impaired Water Bodies in Each County:** based on State and EPA data for numbers reported (not a percentile)

[5] **Percent Watershed Impairment:** based on State data % of County's Surface Waters with Impaired or Threatened Uses

NA = not available

Note: All data herein are limited by the extent of research and reporting. All watersheds were not studied on each island. The overall EPA assessment that data for the State of Hawai'i are insufficient indicates all impacts are probably underestimated.

1996, Englund et al. 2000, BLR 2001 and 2000, NRDC 2003). Built between 1919-1928, the Ala Wai Canal was designed to *"reclaim a most unsanitary and unsightly portion of the city,"* receiving drainage from the *"swamps"* that had once been the well-tended *lo'i*, fishponds, and natural wetlands of Waikīkī (Pukui et al. 1974). The shores of Waikīkī, once known for its sparkling waters (see footnote under "modern ways"), are now fed by polluted streams and canals, choked with sediments and human debris, congested by boaters, commercial tour groups, surfers, swimmers and sunbathers, and ringed by massive hotel development (DOH 1990 and 2000, HCZMP 1995, Ala Wai Watershed Association 2003, Mālama o Mānoa 2003).

Shipping, tourist, and military activities affect water quality and fishing at all Hawai'i's harbors; but on O'ahu, Pearl, and Honolulu Harbors, Kāne'ohe Bay and the Barbers Point region are most heavily impacted (HCZMP 1995, DOH 1990 and 2000). Barber's Point is also the main site of petroleum shipping, fueling, and storage operations, with associated daily spillage and environmental risks (Tummons 1990, Pfund 1992, Chevron 1994). Military impacts at Pearl Harbor have placed it on the priority list for environmental cleanup due to soil, groundwater, and sediment contamination with metals, organic compounds, and petroleum hydrocarbons (USEPA 1994, US Navy 1999). Access to fishing in Pearl Harbor is extremely limited by military and airport activity, but watershed impacts there mean the catch from these areas is potentially harmful anyway. Honolulu Harbor is also heavily transited by shipping vessels, ocean liners, and other commercial vessels, most of which make this their homeport on O'ahu. This includes large commercial fishing vessels that offload their catch directly to the marketplace at Kewalo Basin (between Honolulu Harbor and Waikīkī). An even larger seafood marketplace is being designed for Honolulu Harbor, as well as a new ocean liner terminal. Both promise to increase commercial activity in the area. Interspersed between commercial docks along the Honolulu shoreline, families and individuals fish with pole and line and an occasional throw net is seen. From Honolulu Harbor to Waikīkī, throw and laynet fishing increases, since there is more appropriate terrain for these fishing methods and less danger from transiting vessels. Freshwater and estuarine habitats along O'ahu's south and western shores are the most heavily impacted by ecological degradation and alien introductions on the island. Fisheries impacts are part of this legacy. Surveys of coastal wetlands, stream mouths, and inshore estuarine areas of O'ahu's south and west shores show a high proportion of alien fishes, invertebrates, and other introduced organisms (Englund et al. 2000, Yamamoto and Tagawa 2000). In strictly freshwater habitats, the proportion of alien species is almost 100% (Englund et al. 2000). Aliens introduced to Hawaiian streams may bear a special advantage over native species, since they are more resistant to their own parasites, introduced as "ride along companions," many are more resilient to living under conditions of poor water quality, and most are omnivorous (Font et al. 1996, Yamamoto and Tagawa 2000). Since most alien species are not consumed by residents, differential fishing pressure is another factor weighing against native species. Thus, as alien species take over an area, traditional inshore fisheries are effectively being displaced as well.

The process of displacing native species is almost complete in inland and freshwater habitats, but has not progressed as far in waters more distant from the shoreline. The further one gets from Honolulu, and O'ahu's coast in general, the better off native fish stocks seem to be doing. The notable exception is with regards to *ta'ape* (blueline snapper, *Lutjanus kasmira*), an intentional introduction from French Polynesia that feeds voraciously on crabs and polychaetes and preys on eggs, larvae, and small adult native fishes (Friedlander et al. 2002). *Ta'ape* form marauding schools in nearshore areas. Their low commercial value and undesirability to most non-commercial fishers contributes to their abundance everywhere, but they are especially numerous in areas either difficult to fish or off limits to fishing, as well as at deepwater outfalls and rocky outcroppings that are “nutrient” (sewage) “enriched” (Grigg 1994, Kaplan 2000, Friedlander et al. 2002).

Windward coastal development is less dense than on leeward Oʻahu, with the exception of Kāneʻohe Town, but watersheds of Koʻolaupoko (from Kāneʻohe to Waimanalo) and from Kahana Bay to Haleiwa are also polluted by urban and agricultural runoff, sewage outfalls, septic effluents via groundwater, and military and urban wastewater discharged into streams and inland ponds (Smith et al. 1973 and 1981, Young et al. 1976, PPR 1978, DOH 1990 and 2000, HCZMP 1995, KBMPTF 1992, Chow et al. 2001, Envirowatch 1999 and 2003, KBAC 2002). Recognizing the impacts of urbanization, windward residents implemented management measures to slow down growth and manage the impacts of development (PPR 1978). Zoning and active community involvement play a critical role in the success of these measures, as in maintaining stream flow, which benefits inshore fisheries. The windward community has risen to meet the challenge in many ways over the years and continues to be vigilant in overseeing government regulation of development, conducting their own water quality monitoring, testifying before relevant government agencies regarding the impacts of proposed development projects and participating in community-based planning for wetlands, fisheries, and inshore recreation (PPR 1978, KMTPAC 1983, KBMPTF 1992, CWRM 1995, Miller and Bay 1995, OP 1998, KBAC 2003, Chow et al. 2001, LET and DOH-CWB 2001, KBAC 2002 and 2003, Ahupuaʻa Action Alliance 2003, KNHF 2003). The lag time in coastal development and transportation, allowing time for windward residents to understand and prevent detrimental changes, coupled with the courage, foresight, and activism of residents have contributed to conserving a more habitable environment and managing windward fisheries (sometimes in the old way, by just walking out on the beach and scolding fishers seen wasting fish, taking too much, or using destructive fishing methods).

Despite water quality issues and the difficulty of obtaining unobstructed access in leeward areas, fishing is a regular activity all along Oʻahu’s shores. In order to be able to access the shoreline and avoid having fish startled by tourists, many fishers come out only at night or during twilight hours. In addition to the fact that sunrise and sunset are good times to catch fish that are feeding, catchability of most species improves at night since visual acuity is reduced. The unfortunate consequence is that the impacts of certain gears and methods (including nets, spears, and SCUBA) increases considerably at night, during the same period of time when effort by experienced fishermen increases. The combination of having to avoid the daytime congestion of recreational beachgoers, coupled with increased population size, leisure time, and utilization of more efficient gears and methods (monofilament nets, lighted lures, spearing with SCUBA, etc.), produces a lethal impact in Oʻahu’s inshore fisheries. The significant impact of fishing is demonstrated in the Waikīkī-Diamondhead Fisheries Management Area (FMA, DAR 2003), which is regulated on an open-closed to fishing annual basis. When fishing closes, fish populations gradually increase over a one-year period but are quickly fished down when the area reopens each year (Brock and Kam 1993).

Uninhibited by the slow development of roads and highways, inshore fisheries on windward O‘ahu have also experienced the stresses of overfishing (KBMPTF 1992, Everson 1994), as well as the impacts of reduced stream flow on estuarine fisheries (Lowe 1996, CWRM 1995). O‘ahu is known for a wide variety of shoreline fisheries, including many for estuarine and reef species. Because of its wide coastal shelf in most places and relatively low rainfall, there are few estuaries and even fewer areas where reefs coincide with estuarine embayments. Kāne‘ohe Bay on windward O‘ahu is one such special place. Once known as “The Coral Garden of the Pacific”, Kāne‘ohe Bay today is an urbanized watershed with remnant taro and other agriculture, sustained by what remains of the water (30-50%) from once well-fed streams of the Ko‘olau Mountains (CWRM 1995, Puhipau and Lander 2003). Estuarine fisheries of Kāne‘ohe Bay have been starved of freshwater input since the late 1930s, when streams of the Ko‘olaus were largely channelized and diverted to leeward portions of the island for agriculture (CWRM 1995, Wilcox 1996). The loss of the *lo‘i and upland deforestation has* increased sediment runoff, affecting reefs and algal growth within the Bay (Hunter and Evans 1995). Healthy reefs have also been impacted by direct destruction by humans (Devaney et al. 1982). Kāne‘ohe Bay is now affected by runoff from streets and highways, golf courses, parks, pig farms, cemeteries, urban development, and largely deforested uplands. The presence of a sewage outfall within the Bay’s waters in the 1970s, (now removed to the outer ocean), and continuing input from smaller inland outfalls have contributed to wildly fluctuating alien and native planktonic and algal communities in the Bay (Smith et al. 1973, Laws and Redalje 1982, Taguchi and Laws 1989, Hunter and Evans 1995, Laws and Allen 1996).

In addition to the impacts on streams and groundwater, Kāne‘ohe Bay is plagued by a waning sense of community, over fished on many levels, and yet blessed with fisheries that continue to produce, despite all these impacts. Coastal depletion of *limu*, fishes, and most sedentary invertebrates are apparent all along the leeward shores, but more so in urbanized areas like Kāne‘ohe. In one case, specimens of a preferred *limu* have been whisked away to a safe location on another island by knowledgeable *kupuna*, in hopes they may be replanted someday when cultural times improve and people can learn to take better care of their fisheries. There are other fisheries that continue to do well, due to natural gifts. One such exception in Kāne‘ohe Bay is the *he‘e* fishery (also known as *tako* or octopus, generally *Octopus cyanea*), which continues to thrive because of the diverse habitat provided by Kāne‘ohe’s patch reefs, the high skill level (known as the “*tako*-eye”) needed to locate the *he‘e* underwater, minimum size regulations, and the combination of short lifespan, great intelligence, and seasonal migrations of the *he‘e* in response to temperature changes. Kāne‘ohe Bay is a nursery area for many species, and because it is a sheltered bay, it is also a preferred recreational area for residents and commercial vessels seeking a protected playground for tourists (KBMPTF 1992). The resulting “user conflicts” have been the subject of many years of discussion, debate, litigation, and unsuccessful attempts at allocation (KBMPTF 1992, OP 1998b). In addition to these, there are conflicts between fishers using different geartypes. Surround and gillnet fishing takes a major proportion of the inshore catch of certain species, also sought by fishers with pole and line standing on the shoreline (KBMPTF 1992). This is a source of contention. The combination of “gear conflicts” and the seasonal migrations of spawning mullet, pāpio and other fishes creates a management nightmare in Kāne‘ohe Bay.

The high and increasing gear-effort (longer nets, more hooks, longer trips, etc.) and large number of residents makes overfishing a significant problem almost everywhere on O‘ahu. O‘ahu has the lowest catch per unit effort values for any of the MHI (Smith 1993, DAR 2003), yet discussions about overfishing or gear limitations (net lengths, mesh sizes, etc.) with O‘ahu residents indicate a relative insensitivity to the problem (KBMPTF 1992). Coupled with increasing offshore and nighttime fishing to avoid tourism, shipping and other daytime activities, many factors contribute to inshore fisheries depletion.

The natural beauty of O‘ahu’s *pali* (cliffs), her watersheds, blossoming reefs, and abundant bays have been praised for centuries in hula and chant (Clark 1977, Pukui 1983) and in the last century also in music and cinema. The question is, can we learn to live within the limitations of nature and sustain these treasures? There are many examples of the resiliency of the beautiful island of O‘ahu and there are many communities striving to unite and restore the islands watersheds (KMTPAC 1983, KBMPTF 1992, CWRM 1995, Miller and Bay 1995, OP 1998, Ala Wai Watershed Association 2003, DOFAW 2003, KBAC 2003, LET and DOH-CWB 2001, KBAC 2002 2003, Ahupua'a Action Alliance 2003, KNHF 2003, WEC 2003). There are still many areas of high quality and value to protect, and there is much work to be done to restore inshore habitat and fisheries. Even O‘ahu's degraded fisheries can be rebuilt from these pockets in time and space. But we must wake up and smell the coffee. Like some “ghost of Christmas past,” O‘ahu stands up to illustrate the future of MHI fisheries, unless we change our course.

<u>Moloka‘i</u>

> *“Moloka‘i is the last Hawai‘ian island. We who live here choose not to be strangers in our own land. The values of aloha ‘āina and mālama ‘āina (love and care for the land) guide our stewardship of Moloka‘i’s natural resources, which nourish our families both physically and spiritually. We live by our kupuna’s (elders’) cultural heritage, no matter what our ethnicity, and that culture is practiced in our everyday lives. Our true wealth is measured by the extent of our generosity.*
>
> - *We envision strong ‘ohana (families) who steadfastly preserve, protect, and perpetuate these core Hawaiian values,*
> - *We envision a wise and caring community that takes pride in its resourcefulness, self-sufficiency and resiliency, and is firmly in charge of Moloka‘i’s resources and destiny.*
> - *We envision a Moloka‘i that leaves for its children a visible legacy: an island momona (abundant) with natural and cultural resources, people who kokua (help) and look after one another, and a community that strives to build an even better future on the pa‘a (firm) foundation left to us by those whose iwi (bones) guard our land.”*
>
> - Vision Statement of the Community of Moloka‘i (1999)
> (in response to a 1999 White House initiative to create “USDA Empowerment Zones”, designed to stimulate economic development in rural areas through grant opportunities)

> *“Initially we deemed it prudent to involve a wide cross section of the entire community and to this end invited well over 300 island residents to participate in the application process. We divided the attendees into "sub-groups" according to their interest and expertise, e.g. health, education, culture, youth, religious, business,*

government, environment, indigenous people, newly transplanted residents, NGOs [non-government organizations], *homesteaders, etc. One of our first orders of business was to develop a vision statement that would accurately represent the ideals and wishes of our island community. While this activity resulted in only a few sentences, our experiences proved it to be one of our most appreciated accomplishments. With such a diverse group of people, it was not always easy to achieve consensus. From the beginning we had this vision statement printed on a banner and displayed it at each meeting. Whenever we came to loggerheads, we would stop and reflect on the words to remind us of our stated goals. Each and every time, it pulled us back from our biases and ultimately to group agreement. To this day, I continue to contemplate the wisdom of those few sentences. It is not coincidental that they are steep with native mana'o. We are an island with deep and historic attachment to the 'āina, and understand our responsibility to sustain its integrity for following generations to enjoy."*

- Bill Puleloa, resident of Moloka'i and DAR Aquatic Biologist (2003)
(reflecting on the foregoing effort and its remarkable progress)

Moloka'i has remained fairly protected from overpopulation due to various factors that have resulted in its relative isolation, and ultimately in the conservation of a strong sense of community. These include the island's rugged cliffs and swift coastal currents on the north shore; low, flat coastal platform on the south shore (unsuitable for construction of a deep-draft harbor); human disease; and other mixed blessings of nature. Cultural changes have shaped the history of the island in many ways. There are many examples of severe cultural impacts on fishing villages, met with strength and resiliency. Probably the best known is the arrival of leprosy from the Asian continent in the mid-1800s; the resulting epidemic amongst *kanaka maoli*; the 1866 decision by the Board of Health to isolate the sick at Kalaupapa, site of a small fishing settlement on the north shore of Moloka'i; the resulting replacement of a community of fishermen and their families with a settlement of desperately ill patients; and the subsequent development after 1873 of a small and close knit community of patients and their families at Kalaupapa, due in large part to the work of a dedicated physician and spiritual leader (Clark 1989). Following the formation of the American Sugar Company[43] on Moloka'i in 1898, just prior to annexation, the wharf at Kaunakakai[44] was built on Moloka'i's south shore, and subsequently repaired, replaced, and expanded (Clark 1989). As cattle ranching developed, erosion and sedimentation advanced at a phenomenal rate (Tummons 1999, DOH 1990 and 2000, Field et al. 2000 and 2003, Roberts 2001, Loope 2003), expanding and deepening beaches and mudflats, and making it increasingly difficult for large vessels to approach the shoreline. The rough terrain and lack of large airports completed the barriers protecting Moloka'i from mass immigration and limiting tourism. Thus, Moloka'i's population was able to remain small and maintain its traditional sense of '*ohana*, which clearly will endure into the new millennium.

Just as its lands are blessed with certain natural gifts, the adjoining ocean holds unique natural treasures for Moloka'i and nearby O'ahu, which because of geography is also close to the broad coastal shelf of Moloka'i's Penguin Bank (Figure 1). Penguin Bank offers extensive, safe and

[43] ASC later became Moloka'i Ranch, Ltd.
[44] Americanization of *Kauna-kahakai*, which means "beach landing" (Pukui et al. 1989, Clark 1989)

shallow access to fisheries for bottom fishes (deep slope snappers, groupers and carangids[45]) and Kona crab (*Ranina ranina*[46]). This shelf and inshore areas of Molokaʻi also support reef and crevice fisheries for *uhu* (parrotfishes), *ʻūʻū* (various soldierfishes, *Myripristis* spp.), *ʻāweoweo* (glasseye, *Heteropriacanthus ruentatus*), *heʻe/tako* (day and night octopus, *Octopus cyanea* and *Octopus ornatus),* and various surgeonfishes (Acanthuridae), as well as estuarine and sediment loving species, such as *ʻoʻio* (bonefish, *Albula vulpes*), *ʻamaʻama* (striped mullet, *Mugil cephalus*), *āholehole* (Hawaiian flagtail, *Kuhlia sandvicensis), moi* (Pacific threadfin, *Polydactylus sexfilis*), and *weke* (various goatfishes).

Although increasing vessel capabilities, gear efficiencies, and other modern developments have also had an impact on Molokaʻi's fisheries, its residents have taken action to conserve limited inshore resources for subsistence and to restore coastal ecosystems for the benefit of all who rely on them (not only humans). These community projects are characterized by young and old of all ancestries, working together with resolve and unity, combining the eagerness and vigor of the *kamaliʻi* with the knowledge, patience and strength of *makua* (parents) and *kupuna*, and employing and relearning skills and techniques (including ways of sharing and showing respect), based on native *manaʻo*, adapted to modern materials, social, legal, and physical constraints. In recent years, this has resulted in the delineation of the state's first official Subsistence Fishing Area (SFA) at Moʻomomi, on Molokaʻi's north shore (Hui Mālama o Moʻomomi 1995 1996). Moʻomomi SFA has brought increased national and international recognition of the *manaʻo* of those who fish and live by the sea, contributed to efforts to reincorporate lay-knowledge of natural production cycles and traditional management methods that work, helped redevelop community understanding of and respect for natural limits to production, and attempted to restore the flexibility management needs to provide harvest opportunities when resources are abundant, yet restrain tendencies to over-harvest when replenishment is needed (Johannes 1981a and b, 1996, and 1997; Johannes et al. 1993; Poepoe et al 2003; Friedlander et al. 2002a). Although it is a relatively new experiment in restoring inshore resources, the Molokaʻi community recognizes the need to restore traditional knowledge and habits to produce lasting changes. Because of this, *kupuna* and *makua* work tirelessly to directly transfer a sense of responsibility to take care of the resources that sustain life to children who will become fishermen, parents, and teachers of future generations.

Molokaʻi's efforts to restore inshore ecosystems include the restoration of many of the fishponds for which the island was once known (Farber 1977, USEPA 1998 and 2003, King 2001). These sediment traps, which once contributed so much to local restocking and production efforts, were largely destroyed and filled in with sediments over the past century. Undaunted by past events, those who still know how are now helping to restore the fishpond walls, finding ways to work with government to rekindle fishpond production, and even helping to monitor and test the results in restoring inshore fisheries and water quality (USEPA 1998 and 2003, King 2001).

Molokaʻi stands as living proof that the people and culture of Hawaiʻi will determine what can be done and how MHI inshore resources and coastal ecosystems will recover. Molokaʻi's people made an excellent synthesis of what has been explained in so many words before this section. Given the cultural changes prior to the new millennium, their process was laborious until the

[45] See Ralston and Polovina (1982).
[46] See Onizuka (1972), Fielding and Haley (1976) and Vansant (1978).

concept of "user groups" was discarded and the feeling of community was reaffirmed, acknowledged, and given precedence. By recognizing that this is a community effort and that the adversities encountered along the way can be resolved through an understanding of the *mana'o* of past generations and a rekindling of *ho'olōkahi* (the development of unity/harmony), the keys to success were restored to *kupuna* and *makua*, to be passed on to future generations.

Lāna'i

> *"…We are not anglers, not inclined to* <u>*fish*</u>*, unless it would be for men. But we took pleasure on this occasion to note what vast treasures are in the sea, and so worthy of our attention. On this rocky coast of Lanai, which is lined with caves, and ponds, and gulfs, and little straits of sea, where the tide is ever surging and breaking and pouring over crests in cascades, and buffeting in and out of the hollow chambers of the coral shore, you can see anywhere in the fretted yet lucid brine swarms of the selerodermes or hard skinned and party colored fish of tropic seas."*
>
> - Walter Murray Gibson, resident and eventually owner of a large section of Lāna'i (1873) [47]

> *"Lāna'i is about 60 miles from the cannery, so we need a harbor. By cutting away the cliffs on one side, running a heavy breakwater into the ocean and then dredging, we got it."*
>
> - Jim Dole (1923)[48]

Since I have not spent much time on Lāna'i, it would be presumptuous to pretend to know much about the processes and development of inshore fisheries there, but several things can be inferred from the literature and from brief observation and interaction with Lāna'i's fishermen. Although Lāna'i was surrounded by fishing villages in traditional and early historic times, the native population was significantly impacted by the wars between ruling chiefs of the Maui group of islands and the islands of Hawai'i and O'ahu (Maly and Pomroy-Maly in prep.). The coastal fishing villages were essentially deserted at Mānele Bay (by 1853), Kaunolū (by 1895), and Lōpā (by 1878), coinciding with the Mahele and associated changes in land use and land ownership (Gay 1965, COH 1989, Clark 1989, Black 2001b). Prior to this (Maly and Pomroy-Maly in prep.), the island was legendary for its pelagic fisheries, such as for *aku* (skipjack, *Katsuwonus pelamis*) and *a'u* (various marlins, swordfishes and spearfishes), which occurred both at great distances and even very close to shore at special *ko'a;* for inshore fisheries, such as for *uhu* and diverse reef and rock crevice species; and for the nesting and hatching of *honu* (various sea turtles).

The consequences of the changes that occurred on Lāna'i between the early and late 1800s included a drastic reduction of the island's population, a loss of control of their own destiny, and hunger amongst *kanaka maoli* [49]. As they did throughout the MHI, local people of increasingly

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[47] In: Maly and Pomroy-Maly (in prep.)
[48] In: Tabrah (1976)
[49] The name Lōpā means one who farms under a tenant, and is a derogatory epithet, associated with a lack of control over one's destiny, homelessness, and marriage with distant relatives (Pukui and Elbert 1986). It is not clear what

diverse ancestries adapted to change by befriending and sharing with each other and anyone new, lovingly caring for their families, and maintaining cultural traditions (including the *aloha* spirit) to the extent possible, in the face of homelessness, illness, starvation, and the disrespect of their native culture. Land privatization and the resulting massive ungulate ranching (sheep, then cattle and goats) and mono-crop agriculture (sugar, then pineapples) brought with it transformation of the land, deforestation and erosion of much of the island's topsoil, and diversion and depletion of water resources (Tabrah 1976, COH 1989). But like Niʻihau, complete privatization of the island also afforded a source of unity and a buffer of sorts to the changes of time, so that *kanaka maoli* and the extended families they formed maintained their language, memory, and knowledge of many traditional practices. The result has been a conservation of many of the inshore resources that are still available today for subsistence fishing.

Lānaʻi's inshore fisheries seem to be doing just fine, thank you. *Uhu* can still be seen sleeping along the shoreline at night and many of the typical reef fisheries described above and for Molokaʻi remain alive and well. This is fortunate for subsistence fishers, since another element of change makes it unlikely that locals can purchase fish they do not catch themselves or receive from friends and neighbors. In recent decades, the shift from agriculture to resort development has caused Lānaʻi to evolve into a dichotomous patchwork of elite resorts and private residences, vast stretches of parched earth and agricultural land, and zones with limited rural dwellings (COH 1989). As a result of catering to a high-priced visitor market, the cost of seafood even in one of the few local restaurants outside the resorts is beyond the means of the average resident. Yet, because fish, *limu*, and invertebrates can be caught or gathered along fairly abundant shorelines, those who know how to fish and what to look for do not go hungry.

Inshore fish populations on Lānaʻi are more abundant and the average size of fish is larger in comparison with resources on other islands (Brock and Kam 1993). Surveys inside and outside the Mānele-Hulopoʻe Marine Life Conservation District on Lānaʻi (MLCD, see DAR 2003), showed that abundance, weight, and biomass of fishes was even greater <u>outside</u> the MLCD than in an adjacent area where access to fishing and ocean recreation was limited. Although only limited fishing is allowed within the Mānele-Hulopo'e MLCD (with pole and line and various hand methods), the boat harbor, protected bay, and access roads make it easier to fish there; and nearby resort development encourages visitors to utilize the harbor, beach, and inshore reef. Erosion, sedimentation, and polluted runoff are all problems within the Mānele-Hulopoʻe MLCD. Boating rules limit anchoring and certain other activities, but the result is a higher level of fishing, disturbance, and vessel traffic in the MLCD compared with other coastal regions. As a result, fish populations are healthy but reduced in this area. Still the small population and limited use of the island mean there is an overall conservation of fish stocks on Lānaʻi. Comparisons between the Mānele-Hulopoʻe area and the Waikīkī-Diamond Head FMA on Oʻahu showed mean fish biomass at all sites surveyed on Lānaʻi's southeast coast (in or outside the MLCD) was higher than at the Waikīkī-Diamond Head FMA, regardless of whether the Waikīkī-Diamond Head FMA was open or closed to fishing (Brock and Kam 1993).

Despite disruptions, cultural memory of traditional fisheries conservation is also alive and well on Lānaʻi (Gay 1965, COH 1989, Black 2001b). Younger fishermen openly acknowledge the

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came first (the name or its connotations), but this is the name of one of Lānaʻi's deserted fishing towns, once the site of a remarkable fishpond which fell into disrepair after becoming the property of a private estate (Clark 1989).

need for *kupuna* and *kamali‘i* to be able to fish in the inshore area, so they don't mind going out deeper to catch their fish when necessary to make sure others can find fish close to shore. Public meetings and hearings held in 1998 and 1999, to discuss increasing minimum take-home sizes for various fishes to allow these species to reproduce, met with old and young people on Lāna‘i who understood the need for restraint in fishing, did not have a problem with minimum size rules, but were a little surprised these common sense practices were not already being observed elsewhere.

Maui

An extensive discussion of Maui's history and fisheries impacts could be the subject of an entire volume. To highlight a few recurring themes briefly, this island's coastal zone has also been heavily impacted by agriculture throughout most accessible regions, and by tourism and overfishing in recent decades. In addition to erosion and runoff, among the most notable agricultural impacts on Maui's coastal ecosystems is that few streams are allowed to flow to the sea throughout the majority of the year. This includes streams on the north and southwestern shores in most "developed" areas of the island. Water is diverted from Maui's streams to a series of ditch irrigation systems built between about 1870 and 1900 to feed the sugar plantations, and later on pineapple plantations (Clark 1989). The impact of "stream de-watering" on native amphidromous gobies that rely on the streams as a highway along which to complete their oceanic larval-juvenile migrations has of course been devastating (Hau 1996). The lack of freshwater also affects estuarine species, such as *ama‘ama* and *āholehole*, that would otherwise migrate as adults and juveniles into embayments like Māla Wharf (near Lāhainā) and other areas.

Deforestation due to agriculture, innovative forestry efforts that introduced alien species, runoff, and development along the shoreline have all added to Maui's flow-through watershed impacts, including impacts to coral reefs, sand dunes, and beach habitat (Mueller-Dombois 1996a, Mullane and Suzuki 1997). Maui's beaches continually erode as a result of seawalls and other coastal structures, which also affect the long-shore transport of sediments and algal communities (Rooney and Fletcher 2000 and 2001). Interference with the long-shore current exacerbates the impacts of alien algal blooms, particularly along the coast between Mā'alaea and Mākena, with a resulting outcry from resorts and public beaches covered with rotting algae. Although locals understand that there were always *limu* along this portion of the shoreline, these were gathered for food and did not include alien species. Local fishes and shoreline gatherers prefer the native species, adding to the competitive advantage of aliens. Nutrients from runoff, unsewered coastal development, and agriculture lay a fertile ground for localized algal blooms, then long-shore transport deposits algae at certain points along the shoreline (Bay Pacific Consulting 1996; DOH 1978, 1990, 2000, and 2003; Rooney and Fletcher 2001). In recent years, Maui's watersheds. are recovering to a certain extent, facilitated by the development of watershed partnerships and an improved understanding of coastal erosion and sediment transport (DLNR 1998, Fletcher 1999, Fletcher et al. 2002, DOFAW 2003).

In addition to watershed changes and the well-known whaling impacts, places like Māla, Lāhainā, and Mā'alaea have experienced various impacts from harbor, pier, and boat ramp development. As is often the case, dogged development efforts didn't always produce the intended results, but some things were changed forever. For example, what was supposed to have been a terminal for large oceangoing passenger vessels was built at Māla in 1922 (Clark 1989). Instead, the prevailing winds and waves, as well as heavy traffic at Maui's other boat ramps and harbors, dictated that Māla Wharf would be for small fishing boats and other vessels that could maneuver onto its wave-swept shore. These physical factors determine the locations of harbors and boat ramps around Maui, as on all the MHI, and fishing activity predictably follows the locations of safe harbors (Smith 1993). Fishers line the coast at boat ramps, piers, and harbors, taking advantage of easy access to the shoreline in certain areas of Maui just as they do on other islands. Yet because of the scarcity of safe deep-draft harbors, ocean liners continue to anchor off the Lāhainā coast, as they have done throughout the past century (Clark 1989), with resulting pollution and anchor damage to shallow nearshore reefs. Meanwhile, fish swim back and forth looking for the scent of water.

Well-paved roads did not reach the whole island of Maui until the past few decades, delaying coastal impacts in areas spared by relative isolation. Since the late 1970s, portions of the southwestern coast have become lined with resort development in two main areas, from Nāpili to Lāhainā and from Mākena to ʻĀhihi-Kīnaʻu. The construction of boat ramps, parks, and marinas along the Kihei Coast contribute to runoff, coastal sedimentation and nutrient loading (Fletcher 1999, Rooney and Fletcher 2000 and 2001, Fletcher et al. 2002). Marine and shoreline traffic includes commercial vessels via the deep-draft harbor at Kahului, crowded small boat harbors at Mā'alaea (servicing many commercial tour boats headed for Molokini) and Lāhainā, and boat ramps at sheltered locations around the island. In addition to conventional vessel traffic, windsurfing is popular in the Kihei and Kahului areas. The protected shelf near Wailuku and Kahului provides an ideal habitat for *heʻe*, similar to Kāneʻohe Bay, and like Kāneʻohe, *heʻe* fishers at Kanahā Park must time their fishing around the presence of commercial and non-commercial recreational users. In the case of Maui, windsurfers come from all over the world, making it difficult for fishers in the Kahului and Kihei area to access some areas safely during the daytime. Where windsurfing is not a challenge, the fact that hotels and exclusive resorts line the shoreline is often a deterrent to daytime fishing access, or in some cases to access period.

An area in the Mā'alaea-Keālia region highlights the interaction between a wide variety of human impacts on Maui. Mā'alaea Bay Beach and Keālia wetlands, once a unified coastal habitat, is now partitioned into harbor, public beach and wetland areas under varying jurisdictions. A road built through the wetland, isolates the dunes fronting Keālia (an ancient Hawaiian fishpond) from additional inland dune and wetland habitat. Now fighting erosion and sedimentation impacts, and used by tourists, residents, shorebirds, and nesting sea turtles, an additional concern in the area is that some turtles inevitably attempt to cross the road before or after nesting. Intensive community and government efforts, especially during the nesting season, include work to rescue turtles, maintain beach sand, protect vegetation, and reduce impacts of runoff and off-road vehicles to the shoreline.

One area that was spared from development, although hotels and golf courses encroach heavily to the north, is ʻĀhihi-Kīnaʻu Natural Area Reserve at the southwestern tip of Maui (NAR, Clark 1989, DOFAW 2003). Like many areas intended as a reserve, ʻĀhihi-Kīnaʻu receives unusually heavy traffic from tourists, making it a less-than-natural area in the long run. Visitors, not all of whom respect this unique place, crowd its narrow shoreline, trampling, picnicking, and leaving rubbish. Its fisheries are harvested at times by poachers. ʻĀhihi-Kīnaʻu's protected waters are somewhat more abundant than adjacent areas, although they are also swarming with schools of the alien *ta'ape*, which take advantage of the closure to fishing (Kaplan 2000). Although fishing is generally not allowed at 'Āhihi-Kīna'u, in recent years an effort is being made to restore subsistence fishing rights to a small number of native Hawaiians whose ties to the area are recognized by all. Others who once fished there defer this privilege so that some may enjoy it with their children and grandchildren.

Many factors contribute to improving the conservation of Maui's coastal resources today, including County funding to understand and improve shoreline management, an increasing number of watershed partnerships, volunteer efforts to clean beaches and monitor water quality, and groups such as *Na Kupuna o Maui* that help *kupuna* to be heard in planning the future of the island. In this regard, the federally-funded Hawaiian Islands Humpback Whale National Marine Sanctuary (USNOAA 2003, DAR 2003) and the Kaho'olawe Island Reserve Commission have also contributed to restoration of ecological integrity. The general recognition that the ocean and lands of this area function as a unit and must be healthy as a unit is the fruit of a cultural renaissance, promoted by the tireless work of many people whose ancestry on Maui and the surrounding islands goes back for generations. This effort and its many recent successes hold great promise for inshore fisheries and coastal ecosystems throughout the region, yet much work remains to be done.

Kaho'olawe

E ke akua
he pule ia o holoi ana i ka pō'ino ka o ka 'āina
a me ke pale a'e i pau ko ka 'āina haumia.
He pule ia e ho'opua ana i nā hewa o ka 'āina a pau:

i pau ke a'e me ke kawaū
i pau ke kulopia a me ke peluluka,
i pau ka hulialana.

Alaila…
nihopeku, ho'emu, huikala,
malapakai, kāmauli hou i ke akua.

Ye deities,
offered is this prayer to wash away the troubles of this land
and to offer safeguard so that this land's defilement may never return
offered is this prayer to end the wrongdoings that these lands have experienced:

to terminate blight and mildew
to halt decay and destruction
and to end barrenness the resulting barrenness to the fields.

As a result, buds shoot forth, weeding of tender plants shall take place,
the ground shall be covered with herbage,
verdant foliage will grow uncontrollably.
And thus, the first fruits of the land shall be offered as thanks to the deities.

- Traditional *Pule Ho'ōla 'Āina* (Land Healing Prayer) [50]

[50] In: Kanaka'ole Foundation (1995)

The story of Kahoʻolawe has been told by many people much more knowledgeable in cultural practices and history than the author (Clark 1989, KICC 1991, Kanakaʻole Foundation 1995a and b, Dames & Moore et al. 1997, Maly and Pomroy-Maly, in prep.). Once the site of sacred ceremonies and small, productive fishing villages, Kahoʻolawe (meaning "blown away" or "carried away", either by currents or winds; Pukui et al 1989; KICC 1991), lived up to the *kaona* (hidden meaning) of its name. Between 1941 and the early 1980s, the island and its resources were literally blown away by an invading culture.

Having endured decades of military "use," including bombing and contamination of its entire body and inshore waters, Kahoʻolawe was completely destroyed and eroded. Its land ran into the water, its vegetation was lost, and its shoreline resources were decimated. But like many mixed blessings in the history of *Hawaiʻi Nei*, this process may have ultimately protected the island and much more in many ways. Inaccessible to almost everyone over the years, Kahoʻolawe's submerged resources were in a sense protected under a *kapu*. Kahoʻolawe's inshore resources and fisheries survived, even thrived, in the near absence of fishing (Kanenaka et al. 1993). Although erosion and bombing impacted the reefs within a limited distance of shore, tenacious fishermen trolled and fished the area with other methods to a limited extent. Yet impacts to the ocean were nothing in comparison to what happened to inshore and intertidal habitats.

But the assault on Kahoʻolawe united people from all generations, cultures, islands, and nations to defend their right to care for the land and sea surrounding Kahoʻolawe. Leading the charge were *kanaka maoli*, whose courage stimulated the rebirth and survival of the native culture and the child of Kanaloa (Pukui, et al 1989). Today, the same individuals and communities that fought for the end to bombing and opened the door to the restored protection of Kahoʻolawe by native people are carefully replanting the soil, beginning with the tiniest plants needed to hold the moisture and allow larger seedlings to survive. Through their righteous actions, the people that protect Kahoʻolawe are restoring the life of the land, as well as the inshore resources that create and bask in its aura.

From its ashes, Kahoʻolawe is being reborn as an island, and with it the connections between past, present, and future generations. Not only did the bombing discourage other "uses" of the waters around Kahoʻolawe, but Kahoʻolawe's history has provided a reason for *kanaka maoli* and their extended villages, multi-cultural communities, and families, to meet cultural challenges as a unified front. The benefits of this expanded awareness are part of the legacy of the millennium.

<u>Hawaiʻi</u>

> *Indigenous peoples' very survival has depended upon their ecological awareness and adaptation… These communities are the repositories of vast accumulations of traditional knowledge and experience that link humanity with its ancient origins. Their disappearance is a loss for the larger society, which could learn a great deal from their traditional skills in sustainably managing very complex ecological systems. It is a terrible irony that as a formal development reaches more deeply into rain forest, deserts, and other isolated environments, it tends to destroy the only cultures that have proved able to thrive in these environments.*
>
> \- The Brundtland Commission 1987

Hawai‘i, “The Big Island”, is comprised of three connected mountains, arising from the ocean floor. The largest of the Hawaiian Islands, it is also the youngest island above the surface of the ocean, so Madam Pele is still actively involved in raising this child. As volcanic fires have shifted and changed her surfaces, nature has created underground rivers of water and molten lava, scorching the landscape at times, inundating it with tidal waves and abundant streams, rivers, and waterfalls, and connecting the land to the sea via lava tubes, wetlands, inland ponds, and flow-through shoreline areas . Like other Hawaiian Islands, the geography and orientation of mountains with respect to the direction of the trade winds largely determine whether an area is rainy and wet (windward side of mountains) or dry and hot (leeward areas). As has been described elsewhere, protected bays (which tend to be produced by rivers) determine the locations of safe harbors, as well as the predominance of wetland, reef, and estuarine fisheries. This in turn shapes the development of coastal fishing communities, their access to the shoreline, and the species that will make up their catch (Smith 1993). This was equally true in ancient times as it is today.

Humans have also had a hand in shaping the face of the Big Island. *Kanaka maoli* first molded Hawai‘i’s forests via upland and lowland agriculture (including all types of fishponds and *lo‘i kalo*), wild harvest, and introduction of a few alien species (notably the wild pig). Like other islands, Hawai‘i was once politically subdivided into various *moku* and *ahupua‘a*, shaped and united in such a way as to provide adequate forest, fisheries, and water resources for each unit to feed its people (Stannard 1994). The history of the Island of Hawai‘i is too massive to describe here, even briefly. It is overwhelming, because of the phenomenal size and *mana* (spiritual power, authority, and strength) of the Big Island, as well as the magnitude of the tragic and heroic events that began there with the arrival of Captain Cook and transformed the entire Hawaiian Islands in the span of a few generations. Many others have told portions of this history (Kamakau 1842-1868, Kihe 1914-1930, Bishop 1916, Bingham 1849, Kelly 1969, Wong and Rayson 1987, Barnes 1999, Cahill 1999), and have described the important fishponds, fisheries, and *heiau* of the Big Island (Kihe 1914-1930, Kelly 1969, Kikuchi and Belshé 1971, Stokes and Dye 1991, Maly and Pomroy-Maly, in prep).

It should be understood that an extensive oral history preceded the written history of Hawai‘i and other islands. In addition, the natural history of the Big Island (and all the MHI) and its ecological function was recorded in the location, shape, and orientation of coastal fishponds, *heiau*, *lo‘i*, *hale wa‘a* (canoe houses), *hale i‘a* (fish houses where seafood was processed), *ahu* (pile of stones marking a shrine, altar, place of tribute or other important location), *pōhaku ‘aumakua* (stones representing ancestral gods), *ko‘a* and other structures along the coasts and uplands. Natural features, such as coastal currents and submerged topography, *lae* (capes or prominent points), *pu‘u* (diverse types of hills), *lapa* (ridges), *pali* (cliffs or bluffs), *puna* (springs), etc. were also important markers of watershed features and other aspects of coastal ecology important to fishermen (Costa Pierce 1987, Smith and Pai 1992, Araki Wyban 1992, Smith 1993, Lowe 1995, Dieudonne 2002). All these were carefully recorded in the chants and place names of Hawai‘i (Pukui 1983, Pukui et al. 1989), along with instructions on how to care for and benefit from them. This valuable *mana‘o* was also recorded in recognized and unrecognized archaeological features. What is often overlooked is that the culture associated with these physical structures is the key to understanding their meaning.

Although districting on the Big Island has remained somewhat similar to what existed in olden times, largely due to natural constraints, the two centuries after arrival of Captain Cook brought about a complete transformation of the landscape and politics of this beautiful island. Following the Mahele, there was the usual pattern of land acquisition and reappropriation. Despite the fact that residents retained their knowledge of the *ahupuaʻa*, their function was decreasingly recognized by government. Although the processes of change proceeded more slowly in areas more difficult to reach from major ports, lands were leased, joined, leveled, and placed into agriculture and ranching where the terrain allowed it. This included the eradication of many of the natural and manmade structures described above, a change in educational and religious practices, silencing of the Hawaiian language, and the gradual Americanization of many place names. Although this process began on the Island of Hawaiʻi, some of the most intact cultural communities held out there for generations, in part because of the island's sheer size, but also because of the tenacity and strength of its people. The fires of Pele still burn at many levels in isolated regions of the Big Island, as is reflected in various ways throughout its fisheries.

Roving surveys of the Hawaiʻi shoreline have provided a wealth of information about fishing, scuba diving, surfing, tour group activities, and their interaction with climate and other coastal features of the Big Island. Much of this information is the subject of another publication, which will be reserved for separate discussion. Instead, a few general observations will be made regarding fisheries status and impacts, briefly summarizing the results of roving surveys, field studies of coastal tidepools and anchialine ponds, underwater transects, stock enhancement studies, and interactions with local community-based fisheries management efforts.

Geography determines the character of Hawaiʻi's fisheries and delimits zones with distinctive fisheries (Smith 1993). Generally, because of its youth the Big Island's steep coastal platform brings pelagic fisheries inshore in many areas, particularly in the lee of cliffs and mountains. Rocky, wind-blown bluffs and cliffs prevail on points at the north (ʻUpolu Point) and south (Ka Lae) extremes of the island. Points at the western (Ka Lae o Keāhole) and eastern (Cape Kumukahi) extremes are lower and flatter, each in its own way, but beneath the surface is eventually found a steep drop-off. Prevailing currents and intermittent streams, springs, and rivers along Hawaiʻi's shores complete the longshore currents and distribution of inshore habitats. Large predatory fishes abound, including all the billfishes (see Lānaʻi), bottomfishes (see Molokaʻi), *kākū* (barracuda, *Sphyraena barracuda*), *ulua/pāpio*, *mahimahi* (dolphinfish, *Coryphaena hippurus*), *kamanu* (rainbow runner, *Elagatis bipinnulatus*), and various tunas and dolphins. These species and groups dominate fisheries at the northern and southern extremes of the Big Island and frequent the deep ocean everywhere. Their prey include the huge schools of *ʻōpelu* (mackerel scad, *Decapterus macarellus*) that represent the island's most productive fishery. Reef fisheries are distributed all along less sheltered coastal areas with less runoff and rainfall. In rainy and protected areas where streams and rivers reach the ocean, sedimentary and estuarine conditions prevail and with them the usual fisheries for *weke*, *ʻamaʻama*, *āholehole*, *moi*, etc. are found. Where there is more embayment, bait species such as *akule* (bigeye scad, *Selar crumenophthalmus*) and *nehu* (Hawaiian anchovy, *Encrasicholina purpurea*) are also found, followed closely by predatory *ulua* and *pāpio*.

A brief, clockwise trip around the Big Island will illustrate these features and outline coastal fisheries and cultural interactions. From northernmost ʻUpolu Point to the Hamakua Region, steep cliffs and heavy rainfall produce a fairly broad coastal shelf. *Ulua*, reef species, and *ʻopihi* are among predominant elements of the fisheries in the area, characterized by a rugged breed of fishers not afraid to climb down steep cliffs or hang on to slippery rocks while waves crash around them during casting, spear fishing, or picking *ʻopihi*. The estuarine fisheries of Hilo Harbor are described in numerous reports, as are the impacts to the area from shipping, dredging, and flood control projects, sugar mill operation, and arsenic (Welsh 1949, Smith et al. 1992, Smith 1993, Kahiapo and Smith 1994, Lowe et al. 1995). Hilo is blessed by lots of rain, thus avoiding some of the heavy coastal tourism impacts. Fisheries outside Hilo Harbor resume their reef fish and open ocean character for the most part, including on Hilo's outer breakwall where a few daring souls risk rough waves at times to reach *ʻopihi* resources.

From the outer Hilo Breakwall to Ka Lae, except for certain areas of Puna, there are more reef and pelagic fisheries. As new land is created on the island's southeast coast, coastal upwelling and circulation through caves and lava tubes stimulates unique fisheries ecosystems. The low population density and relative isolation produced by the coastal hazards, such as lava flows, heavy rains, tidal waves, and other wave action (Fletcher et al. 2002), and the existence of few rural roads has preserved much native culture in the Puna to Kaʻu regions. Relatively low fishing pressure and sharing of fisheries resources areas along a broad coastline in this region are a stark contrast to the congestion seen on the Kona Coast on the leeward side of the island. Like Hilo, the Puna District is also blessed with minimal resort development, leaving a lot of open space and beautiful deserted shorelines, where fisheries for *ahi* (tunas), *wana* (sea urchins), *limu*, and reef and estuarine fishes seem to thrive despite localized overfishing.

But unlike nature's mixed blessings, a manmade threat has wreaked nothing but havoc on the region from Hilo to Puna, and from Ka Lae to Keāhole. Previously unknown, an illegal drug called "ice" (or crystal methamphetamine) has been introduced to the MHI, partly via the Big Island. Its use has burnt as deeply into communities and families as the flowing lava. Faced with an unlimited financial need, the ice addition has driven fisherman in some areas to harvest indiscriminately, entering even closed areas to poach high-priced *uhu* and aquarium species. The drug has also affected the safe and peaceful atmosphere of some fishing areas. The lava shadow of Mauna Loa affects Hilo, Puna, Kaʻū and South Kona today, and both Mauna Loa and Hualālai have threatened Keāhole to Puakō (North Kona) in recent history (Clark 1985). Lava flows can destroy homes and make is difficult to reach fishing areas, although this is rarely a long-term obstacle to determined fishermen. Fishermen from Puna to South Kona climb down cliffs and weather any storm to go fishing and be able to feed their families. Now, in addition to other adversity, some Big Island fishermen are faced with the impacts of fire <u>and</u> ice. This epidemic presents huge challenges, which the Big Island community is again seeking to answer by helping each other.

From Kaʻu to Keahole and from Keahole to South Kohala, the impacts of urbanization, tourism and changing culture are apparent. As roads are expanded and areas become increasingly accessible and frequented by visitors, the conflicts between subsistence and commercial fisheries, and between urban and rural communities are also increasing (Kelly 1969, Schilt 1984, Walsh this volume). The resulting "user conflicts" have been described in the region from

Miloliʻi to Hoʻokena, South Kona (Lowe 1998), where traditional subsistence fisheries for reef species, shoreline *limu* and invertebrates and pelagic fishes such as *ʻōpelu* and *ahi* interrelate closely (Hoala na Pua 1996) and interact with coastal tourism and commercial fishing. Large and small commercial tour vessels approach the shoreline in motorized vessels with bright lights and loud generators, disrupting nighttime peace and daily fishing activity. Tour groups descend on public beaches and fishing areas, with dozens of newcomers trying to master kayaks and other recreational vehicles and paddle through the fishing *koʻa*. These beach users tax unsewered public restroom facilities along beaches with Kona's unique flow-through groundwater environment, disrupting shoreline water quality. The *koʻa* are also disrupted by "chase-the-whale-or-dolphin" tours, as they are referred to by locals. Traditional fishing methods around fishing *koʻa* in this area included feeding with vegetable *palu* (chum), tending and nurturing juvenile and adult *ʻōpelu* prior to spawning. Sharing between neighbors and season *kapu* to allow growth and reproduction were also part of traditional practices in the Miloliʻi-Hoʻokena area. Still practiced by some, these concepts have been abandoned by others. Thus, the use of *ʻōpelu koʻa* is also disrupted today by fishermen using *palu* containing blood. This invokes a feeding response of predators, disrupting the careful training process previously employed to school up fish for harvest during certain times of the year. Although it is illegal in this area, the use of animal *palu* continues unabated, making it difficult to catch fish with traditional methods. The conflict between old and new values comes to a boiling point at times. Night spearing of *uhu* and daytime netting of schools of *panuhunuhu* (a small species of uhu) adds to depletion of inshore resources. Commercial fishers catch large numbers of aquarium and food fishes, impacting subsistence and other fishers and affecting the enjoyment of species appreciated simply for their colorful beauty by visitors and residents. The high market price of *uhu*, *ahi* and aquarium species, and the lower price but steady demand for *ʻōpelu* (both as bait for *ahi* and for direct consumption), drives fisheries exploitation and at times pits fishermen against each other.

Just the opposite of the Big Island's east coast fisheries, blessed with isolation because of constant rain and other factors, the climate on the Kona (leeward) Hawaiʻi is usually sunny and dry. Even the Kona breeze is calm, since the region falls in the wind shadow of both Mauna Kea and Mauna Loa. This balmy weather favors tourism and leads to congestion and conflict in fishing areas. Anchor damage to reefs and congestion from commercial tours are common elements of most of Kona's inshore fisheries. Seals and turtles bask on beaches covered with tourists. The solution to anchor damage has been to install mooring pins all along the coast, with the resulting concentration of recreational and commercial tour boats in areas once preferred by local fishermen. The "user conflicts" at Kona are almost too numerous to mention. This is just a sample of some of the interactions taking place within the realm of Hawaiʻi's inshore fisheries.

Conclusions: Human values shape the future of Hawaiʻi's fisheries

If you plan for a year, plant kalo
If you plan for ten years, plant koa
If you plan for one hundred years, teach the children

- Hawaiian Proverb (In: Native Hawaiian Advisory Council 2003)

The challenge for the anthropologist and for the policy maker concerned with traditional Hawaiian social and religious beliefs is to resist the ethnocentrism

> *that arises from the unquestioned assumption that one's own world view is somehow the only correct one.*
>
> - Iversen et al. (1990) [51]

Besides cultural change, no single factor can be found that explains as many of the ecological problems encountered today in the inshore fisheries of the MHI. The society that once looked down on the connections that allowed *kanaka maoli* to care for ecosystems without formal science (Bishop 1888 and 1916, Brower 1974, Kirch 1985, Hui Mālama o Moʻomomi 1996, Pacific American Foundation and Hui Mālama o Moʻomomi 2001), now struggles to sustain healthy fisheries and coastal resources in the face of complex ecological challenges (Bosselman and Callies 1971, Anderson and Miura 1990). The course of history, misrepresentations in the written record, and other factors (Liliuʻokalani 1898, Barrère 1969, Reeves 1992, Buck 1993, Wood 1999) have left modern residents without the information, understanding, skills, and political power to maintain a proper balance between the use and production of natural resources (Kamakau 1842-1868, Anderson and Miura 1990, Hui Mālama o Moʻomomi 1996). Given the tradition of compassion for and integration with other elements of nature, and the need to maintain such balance as part of a sense of normalcy and wholeness, the symptoms of disease found amongst *kanaka maoli* in the past century (Hoffman 1916, DBED&T 1968-2001) may represent some of the physical manifestations of ecosystem perturbation only native science can understand and cure by reasserting political sovereignty and providing a pathway back to ecological harmony.

Although the symptoms affecting Hawaiʻi's fisheries today are complex, the relationship is simple between these warning signs and the changes in the values and practices of modern residents (Tabrah 1980, Meyers 1976, Johannes 1978, Devaney et al. 1982, Grant et al. 2000). Having shifted from spirituality and the life of the land to optimizing monetary yield from every aspect of life, the basis for the economy has also changed from providing for family and community via fishing, farming, and other productive trades to attaining wealth from investments in tourism, marketing, and land development (Meyers 1976, Modavi 1992). Traditional fisheries conservation teaching has been abandoned or outnumbered by other practices in most areas over the past century. Although even today some *kupuna* and *makua* still teach traditional techniques and respect for fisheries ecosystems to *kamaliʻi* (Kelly 1984, Kameʻeleihiwa 1992, Kanakaʻole Foundation 1995a and b, Hoala na Pua 1996, Hui Mālama o Moʻomomi 1996, Dames & Moore et al. 1997), overall Hawaiʻi's fishing methods have undergone significant changes. Many residents today do not understand that there must be restraint in fishing to allow resources to replenish themselves. Coupled with declining recognition of, kinship with, and responsibility for other components of nature, the growing cultural allegiance to economic objectives has ensured the decline of diverse coastal resources, including inshore fisheries.

A value system that is out of synch with the natural productivity of Hawaiian ecosystems is the proximate cause of the decline in Hawaiʻi's fisheries. Most seem to have lost the basic concern for and understanding of the ocean's limitations or needs. In a society that rewards excess in fishing that would once have provoked the scorn of the community, fishermen now speak of their

[51] In: USWPRFMC 2001.

losses in dollars rather than fish. Fishing rights are claimed without recognition of fishing responsibilities. Unlike the days when nets and other fishing gear were made by hand from products of nature (Green and Kelly 1970, Kirch and Dye 1979, Kirch 1985), readymade, synthetic gears can now be purchased without taking the time to repair or retrieve them. Time once spent sharing *mana'o* about how to fish and take care of fisheries while making nets, traps, etc. by hand, can now be spent in front of the television, at the bar, catching more fish, or in a hundred other ways.

Today's fishermen need money for fishing supplies (bait, tackle, gas, and ice of various kinds). Whereas the old society provided effective alternatives to local overfishing, alternated fishing with farming, and took care of those who sustained the village from the sea when fish were scarce, today, there is seemingly unlimited economic need and the choice not to catch when fish stocks decline takes food off the table for families that fish for subsistence or for income. Additionally, many fishers today are "weekend warriors," fishing part time and making the majority of their income from another job. At times having another source of income may undermine the conservation ethic among part-time fishermen, although there are responsible, conservation-minded fisherpersons in all "user groups".

To a large extent, economic factors drive fishermen to exploit resources already under stress, but Hawai'i's modern market economics affect fisheries conservation in complex ways. For the consumer, less abundant fish means higher prices for what is available. Market losses are passed on in part to the consumer, but eventually reduced catches mean reduced profits for fish dealers, too. Yet there are many confounding economic tradeoffs. For example, because of bulk cost considerations and since many of Hawai'i's consumers prefer good "table-size" fish, smaller fish often bring a higher price per pound. This can stimulate both buyers and fishers to target less mature fish. Compounding this, smaller fish can are usually be found in greater numbers (particularly inshore), until stocks dwindle significantly. By then resources can be in serious trouble. To go one step further, when fish are super abundant, prices drop and fishermen respond by targeting other species. So, against conservation interests, the response to depletion may be targeting, while the response to abundance may be switching to other fisheries.

Commercial tourism is another economic activity affecting Hawai'i's fisheries today, especially in shallow inshore areas (DBED&T 1991, KBMPTF 1992, Smith 1992, Mamala Bay Study Commission 1996, OP 1998), but again there are complex tradeoffs. Because of the importance of tourism to the state's economy, a tremendous socio-economic pressure is exerted to provide this industry with whatever it needs to be successful. Among other things, this means considerable political pressure is brought to bear in closing or limiting fisheries that adversely affect tourism or are perceived to do so. Areas closed to fishing are often heavily used by visitors, driving residents to fish and relax elsewhere. Despite the protections afforded to fish populations, high concentrations of swimmers and waders, and fish feeding to bring bright and colorful tropical species into easy view for tourists can restructure natural communities and increase relative abundance of opportunistic and aggressive species. Yet only in recent decades has consideration been given to the impacts of tourism and other ocean recreation on fisheries ecosystems (HOMD 1982, Aotani and Associates, Inc. 1988, Reynolds 1991, KBMPTF 1992, Smith 1992, Oishi 1992, Wilson Okamoto and Associates 1992, DLNR 1995, Hunter 1996, Mamala Bay Study Commission 1996, OP 1998, HDDC 1999). Management decisions relating to this uniquely modern economic pressure have produced increasing restrictions on fishing, while negatively impacting spawning and nursery areas, creating unnatural marine communities, making some areas and times of day unsuitable for fishing, and in some cases damaging inshore reefs and their flora and fauna (KBMPTF 1992, Oishi 1992, Hunter 1996, OP 1998).

Ironically, because of their expertise and experience in the ocean, former fisherpersons are often employed by the same commercial tour companies that restrict fishing access (KBMPTF 1992). Thus, Hawaiʻi's complex modern economy displaces fish and fisherpersons at times, yet provides jobs to fishers at others, protects resources to a certain extent by promoting closed areas, yet distorts natural inshore communities through overuse and drives overfishing with rewards for catching undersized and rare fishes, yet shuns fishers when harvests exceed natural productivity completely. Hawaiʻi's fishers today still have the need to sustain fish stocks in order to sustain their way of life, but they experience this need in a vacuum of ecosystem conservation, funding, and management support. With all this, it is not surprising Hawaiʻi's fishers at times appear angry, frustrated and fed up.

The complex economic climate in Hawaiʻi today makes implementing fisheries conservation measures a painful, elaborate, and counterintuitive process, characterized by extensive discussions about not giving up too much. At all levels, it is difficult to accept that the future of Hawaiʻi's fisheries may lie in reestablishing the customs of sharing and self restraint and recognizing that what will sustain fisheries may be uncomfortable and unprofitable for human beings over the short term yet rewarding for future generations. Infilled and buried fishponds, reefs and beaches, de-watered streams, reduced and contaminated springs, groundwater and inland reservoirs, congested and restricted spawning and nursery grounds, overfished and depleted inshore fisheries, and other complex ecological impacts are the legacy of Hawaiʻi's culture in the new millennium (Smith et al. 1973, Laws and Redalje 1982, DOH 1990, HCZMP 1995, Smith and Kukert 1995, Chun Smith 1994, Gulko 1995, Laws and Allen 1996, Mamala Bay Study Commission 1996, HBWS 2002). Reestablishing sustainable fisheries ecosystems is the challenge facing fisheries scientists, fishermen and resource managers.

Although the sense of responsibility to the places their ancestors and teachers lived and cared for is still alive amongst *kanaka maoli* today (Kanakaʻole Foundation 1995a and b, Hui Mālama o Moʻomomi 1995 and 1996, Farber 1997, Tabrah 1987 and 1988, Moriarty 2001, Friedlander et al. 2002a, Poepoe et al. 2003), many factors inhibit their effectiveness in caring for natural resources, including restricted access to ancestral lands, diversion and pollution of streams and groundwater, urbanization and congestion of cultural sites, and lack of cooperation and respect from others (Schilt 1984, Iverson 1990, Hui Mālama o Moʻomomi 1996, Pacific American Foundation and Hui Mālama o Moʻomomi 2001). This observation would be deficient if it were not recognized that oases of concerned individuals, organizations, and communities can be found throughout the MHI, in which *akamai* (wise, clever) people of all ethnic backgrounds strive to keep the life of the land and sea alive. At the heart of many of these efforts are the *kanaka maoli* (without regard for blood quantum and recognizing the importance of *hānai*[52]). These selfless acts in modern society are performed at great personal cost (financial and otherwise), often

[52] Under the old customs, still alive in many people in Hawaiʻi today, anyone can become *hānai* (adopted and brought into family and spirit of native people, including understanding how to share and uphold the *aloha āina*). This would include many kama'āina and residents not born in Hawaiʻi who have learned these customs.

requiring individual and group risks, legal and political action, civil disobedience, research, monitoring, and hands-on care and tending of streams, forests, and inshore areas. What is encouraging is that many people willingly make this investment in *Hawai‘i nei* today, so great battles are being won to restore and conserve watersheds., streams, and coastal areas throughout the MHI.

Hawai‘i has begun to develop solutions to problems facing her fisheries and coastal areas in general. The diverse ecological and socio-political aspects of the problems Hawai‘i must face clearly indicate this goal must be approached in a way that integrates water, land, fisheries, economic, and human resource management. Finding this innovative approach is the challenge of the new millennium. In the meantime, Pele’s tears[53] create rivers of fire and water as Hawai‘i struggles to reconnect the land, sea and living elements in a way that will heal her fisheries. In recent years, the problems associated with cultural changes in watershed management have been recognized and the beginnings of efforts to restore coastal ecosystems and communities are clearly visible and actively supported by volunteers (KMTPAC 1983, USOTA 1987, Anderson and Miura 1990, KBMPTF 1992, HCZMP 1995, Kanaka‘ole Foundation 1995a and b, Miller and Bay 1995, Bay Pacific Consulting 1996, Stepath 1999, Brown 1999, DOFAW 1999 2003, DOH 2000, Black 2001a, LET and DOH-CWB 2001, DAR 2002, Hanalei Heritage River Program 2003, Friedlander et al. 2002a, Ahupua‘a Action Alliance 2003, KBAC 2003, KNHF 2003, Native Hawaiian Advisory Council 2003, WEC 2003).

Despite recent advances in computer technology, ecology, or fisheries science, it is still impractical (fiscally or in terms of data requirements) for any agency (state, federal, international) to scientifically manage fisheries from a broad ecosystems perspective (Laevastu and Larkins 1981). The feasible alternative is usually optimization of bioeconomic models based on surplus production, which carried to their economic limits result in the overexploitation and localized extinction of stocks (Clark 1973). Examples of fisheries management that works place complicated ecological processes into a simple, applied framework to allow monitoring, modeling, conflict resolution, decisionmaking, and management action to take place in a time frame relevant to biological change (Johannes 1981b, 1996, and 1997; Johannes et al. 1993; Pauly 1994; Hui Mālama o Mo‘omomi 1996; Pacific American Foundation and Hui Mālama o Mo‘omomi 2001). The most intuitive and practical such models include the ancient methods developed and utilized by *kanaka maoli* and other indigenous people. However, such methods have always been replaced by something more complicated and “scientific,” which usually doesn’t work.

In addition to the fact that economic optimization alone is not a sustainable management strategy for marine fisheries or renewable natural resources in general, tropical marine fisheries may be especially susceptible to random ecological stresses because they are dominated by more specialized species that rely upon a relatively stabile marine environment. Adding to these concerns, the unique biogeographic status of remote Pacific islands in general and Hawai‘i specifically, places Hawai‘i’s inshore fisheries in a position where occasional catastrophic events

[53] Madam Pele is the ancient volcano goddess whose name, synonymous with lava flows and volcanic eruptions, symbolizes the creation of land (a base for life) through dynamic natural processes. Characterized by it glasslike hardness and fragility, “Pele’s tears” is the geologists’ name for the teardrop-shaped rock created when hot lava is thrown into cold air under considerable pressure, the epitome of the status of modern Hawaiian culture.

can seriously impact fragile ecosystems with only remote sources of recruitment. This status is worthy of precaution, bet-hedging, and judicious conservation to provide leeway to survive those inevitable "rainy days".

Because of the relative isolation and uniqueness of Pacific island fisheries, fishing culture in this region represents a pinnacle of learning with regard to what can and cannot work to maintain fisheries and coastal ecosystems. The large land base of the continents allows continental people the luxury of time to test the limits of sustainable resource management, but island societies must rise to the challenge of sustainable management more rapidly. If we can learn from generations of experience, perhaps Hawaiʻi's inshore fisheries can become whole again. Because of its status as the only Pacific island that is also an entire U.S. state, and since Hawaiʻi has also suffered the most extreme cultural and environmental devastation, we may be in a unique position to find pioneering modern solutions that remain rooted in ancient knowledge. The delicate balance of inshore production based on stocks with a high degree of endemism that rely on nutrients and freshwater effluents from land make learning these lessons even more crucial and place conserving Hawaiʻi's natural gifts among the most important challenges facing our culture at the dawn of the millennium.

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[60] This name was spelled "Mondsarrat" on a previous map (see Mondsarrat, 1886)

Catch, Effort, and Yields for Coral Reef Fisheries in Kāneʻohe Bay, Oʻahu and Hanalei Bay, Kauaʻi: Comparisons between a Large Urban and a Small Rural Embayment

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Abstract

Two separate studies utilizing similar methodologies were conducted between December 1990 and December 1993 as part of the Main Hawaiian Islands Marine Resources Investigation. The fisheries of Kāneʻohe Bay on Oʻahu and Hanalei on Kauaʻi are multispecies, multigear with relatively low yields. Both surveys found that fishing effort (number of fishers per day) increased dramatically on weekends vs. weekdays. Seasonal effort peaked in summer and was generally lowest during winter months. This was particularly pronounced in Hanalei Bay, which was exposed to large oceanic swells and heavy rainfall during winter months. Inshore effort was dominated by pole-and-line fishing at both locations. Gill and surround nets accounted for the majority of the fish catch in Kāneʻohe Bay by weight while surround netting for akule was the dominant fishery by weight in Hanalei Bay. A high percentage of the participants in both inshore fisheries are considered recreational and are not required to report their catch. Expanded catch data derived from the Hanalei Bay creel survey was substantially greater than the state's commercial catch data for the entire north shore of Kauaʻi for the same time period. Results from these studies demonstrated that inshore creel surveys are a viable method for obtaining recreational catch and effort data for Hawaiʻi's inshore fisheries. Since State landings data only includes commercial landings, the results of both surveys reiterated the need for an accurate method of estimating total statewide fishery landings in Hawaiʻi.

Introduction

Coral reef fishes are vital components of reef communities and are important for recreational, commercial, and artisanal purposes. Interest has grown in recent years in assessing the available stocks of fishes, the actual catches, and the potential sustainable yields from shallow tropical waters that contain coral reefs (Marten and Polovina 1982, Munro and Williams 1985, Russ 1991, Wright

1993, Dalzell 1996). The potential sustainable global harvest from coral reef fisheries could amount to 9 x 10^6 t yr^{-1} (Medley et al. 1993) yet this represents less than 7% of the total global fish catch (FAO 2002). Although the economic value of the catch might be low compared with large continental-shelf-based commercial fisheries, coral reefs provide sustenance for innumerable developing countries and island communities. Coral reef fisheries also provide a vital source of income (monetary or barter) and cultural expression to its many participants and also as an important outlet for recreation. In developed island states such as Hawaiʻi, the recreational catch and artisanal catch combined may exceed the commercial catches (Friedlander et al. 1995, Friedlander and Parrish 1997). Income derived from recreational use of the fishery through the sale of fishing tackle, bait, license fees, fuel, etc. is also an important component of the local economy in many of these areas.

Coral reefs have always been an important component of human existence in Hawaiʻi. These reefs once provided the majority of the protein for the Hawaiian people, and today consumptive uses of reef resources include subsistence, commercial, and recreational activities. Contemporary management of coral reef fisheries is often a difficult task, due to a variety of factors. The multi-species, multi-gear nature of the fishery does not lend itself well to the classic methods of stock assessment and community modeling. Coral reefs are spatially heterogeneous, accounting for extremes in catch rates from area to area. One of the foremost problems in Hawaiʻi (and other areas as well) is the lack of reliable catch data. These characteristics usually cause difficulty in assessing such fisheries, particularly because effort is diffused over such a large base of small producers, and reporting mechanisms are usually crude or nonexistent (Munr, 1980, Acosta and Recksiek 1989, Russ 1991, Medley et al. 1993). The only consistent long-term source of data of Hawaiʻi's fisheries is the commercial landings database maintained by the State Division of Aquatic Resources (DAR) (Smith 1993). Hawaiʻi has no recreational saltwater fishing license or reporting requirements, making it difficult to estimate the recreational effort or catch. In an island state such as Hawaiʻi, where as much as 35% of the resident population fishes (Hoffman and Yamauchi 1972, USFWS 1988), the recreational/subsistence catch may have a large impact on the nearshore marine resources.

This paper will attempt to compare and contrast two studies that took place under the Main Hawaiian Island Marine Resources Investigation (MHI-MRI) from 1990-1993 to characterize the fishery resources of two embayments in Hawaiʻi – Kāneʻohe Bay on the island of Oʻahu and Hanalei Bay on Kauaʻi. The Main Hawaiian Island Marine Resources Investigation was initiated in 1990 to evaluate the status of near-shore marine resources in the high Hawaiian Islands through a cooperative effort of participants from a diverse group of State, Federal, and private fishery research organizations. The Kāneʻohe Bay portion of the study was conducted from spring 1991 to spring 1992 as a pilot project to establish standard methodology for estimating current catch and effort in the MHI fisheries. Similarly, the Hanalei Bay study was conducted from summer 1992 to winter 1993 using a similar methodology to assess fishery resources both inside and offshore of the bay.

Study area

The Kāneʻohe Bay study area on Oʻahu's windward coast extends from Pyramid Rock on the Mōkapu Peninsula to Kualoa Point in the north (Figure 1). The area runs from the shore to the barrier reef and includes the leeward shore of Kapapa Island. Fishing activity that occurred on the Kapapa side of the barrier reef to a depth of about 10 m was also included. Kāne‘ohe Bay is approximately 12.8 km long by 4.3 km broad and is the largest sheltered body of water in the Hawaiian Islands (Smith et al. 1973). Kāne‘ohe Bay encompasses approximately 56.7 km^2 (measured to the 90' isobar) of habitat (Hunter and Evans 1995).

Hanalei Bay is a crescent shaped bay, framed by two rocky points ~ 2 km apart, on the north shore of the island of Kaua‘i (Fig. 1). The bay is characterized by well-developed fringing reefs bordering an extensive area of unvegetated carbonate sediments in the center that stretches from beyond the mouth of the bay to the shoreline in the southeast quadrant. The areas of mostly hard substrate cover approximately 0.75 km^2 of the west side of the bay and 2.89 km^2 of the northeast side (Friedlander et al. 1997). The total area of Hanalei Bay, including soft sediment habitats is ca. 4.6 km^2.

METHODS

For both studies, a dual approach was used to collect effort and catch information. The basic design utilized variations of two major creel survey techniques (the roving creel, access point survey) used successfully in a number of fisheries (Malvestuto 1983, Hayne 1991, Everson 1994, Friedlander et. al. 1995, Friedlander and Parrish 1997)

At Kāne‘ohe Bay participation (fishing effort) data were gathered at various vantage points located in shoreline areas throughout the Bay using the roving creel survey technique. The primary vantage point used to obtain fisher counts was at He‘eia Kea State Park (Figure 1). It was possible to view most of the Bay and discern method used per fisher from this vantage point with the aid of binoculars or a high-powered spotting telescope. In this manner an instantaneous estimate of participation rates (fishing effort) by method was obtained. Fishing activities in Hanalei Bay were monitored by remote visual surveillance and creel census of fishers intercepted at shore. From a single vantage point above Pu‘upōā Point, an observer scanned the bay waters and shoreline frequently on a systematic schedule using binoculars and/or a high-power spotting telescope. The configuration and dimensions of the bay are such that this approach permitted detection of fishing vessels and individual fishers almost anywhere in the bay.

At Kāne‘ohe it was not possible to estimate fishing effort in gear or fisher hours for all gear types. Passive methods (nets, traps) were analyzed differently from active fishing methods (pole-and-line, spear). Any passive activity observed during a sample day was designated as a passive-effort-day, whether a method was viewed during one or more hours. Each passive fishing party was considered a unique observation counted only once during a sample day. Active methods that could be viewed the entire time that the activity was occurring were measured in angler-hours.

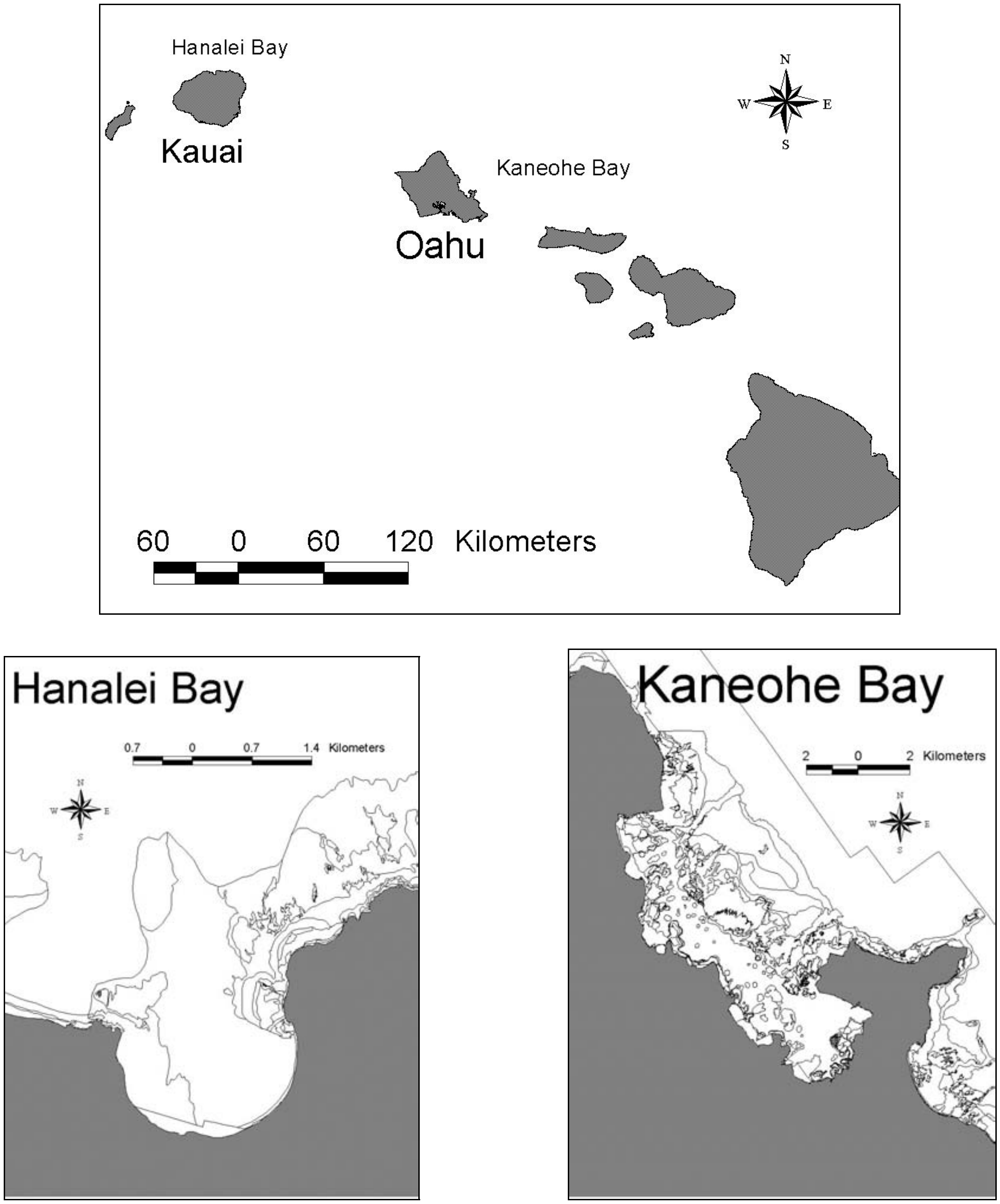

Figure 1. Map of the main Hawaiian Islands including Kāne‘ohe Bay, O‘ahu and Hanalei Bay, Kaua‘i. NOAA/NOS benthic habitat maps (Coyne et al. 2003).

At Hanalei it was possible to ascertain the total amount of hours a net was actually fished, so consequently all effort was measured in gear hours. For any fisher(s) who intended to fish throughout the night, a specific effort was made to interview the fisher(s) the following morning. Similarly, any fishers observed in the bay at the beginning of a survey day were interviewed to determine whether they had fished the previous night. Because of the small size of the bay and the small number of potential night fishing locations, this procedure seemed to produce results for effort and catch from the nighttime fishery nearly as accurate as those obtained from the diurnal fishing activities within the bay.

Catch and catch per unit of effort (CPUE) data were collected during access point surveys. Access surveys were designed to take place at various landing areas within the sample area. The majority of interviews at Kāne‘ohe Bay were conducted at He‘eia Kea Harbor, since it was the most heavily used boat launching facility in the area. Interviews were conducted at the launch ramp and various shoreline locations along Hanalei Bay.

Recreational fishing effort was considerably greater on weekend days and holidays compared to weekdays. To reduce variability associated with estimates of fishing effort, days within a survey period were grouped into sampling strata as (1) weekdays (WD) and (2) weekend days and holidays (WE/H) (Malvestuto 1983). Sampling dates were randomized within each stratum to minimize bias. Participation (effort) and access point (catch) data were collected on separate days during alternate weeks in the case of Kāne‘ohe Bay owing to the large size of the bay and limited personnel. Effort and catch data were collected during the same time period in Hanalei Bay.

Date analysis and expansion methods

Both surveys utilized the basic data expansion technique described by Malvestuto et al. (1978) to estimate total catch and effort. The entire survey day was sampled equally, to detect the amount of fishing activity that occurred at various times throughout the day. A total of at least 24 days (12 WD and 12 WE/H) were sampled each quarter for Kāne‘ohe Bay and 21 days on average (11 WD and 10 WE/H) were sampled each quarter in Hanalei Bay. Data expansions were calculated by quarters of the year for each fishing gear to evaluate seasonal differences in estimates of total catch, effort, and CPUE.

Estimated effort rates were calculated in fisher-hours for active methods and in effort-days (trips) for passive methods. Variance was measured as the relative standard error (RSE), defined as standard error divided by the estimate and expressed as a percentage (Malvestuto 1983) for Kāne‘ohe or coefficient of variation (standard deviation divided by mean) for Hanalei.

Effort

An estimate of total effort for each gear type, E, was obtained by calculating a mean daily effort (gear-hours for Hanalei and active gear in Kāne‘ohe Bay, gear-days for passive gear in Kāne‘ohe Bay) by all fishers in the stratum combined (using observed effort on each day and the number of observation days) and expanding by the total number of days available for fishing in the stratum, i.e.,

$$E = \bar{E} \times D = \frac{\sum_{i=1}^{d}\sum_{j=1}^{N_i} E_{ij}}{d} \times D.$$

where E = Total effort by gear type, $\bar{E}$ = Mean daily effort, D = Total number of WD or WE/H days in that quarter, d = Number of days fishery was observed, N_i = Number of fishers observed on day i, and E_{ij} = Observed effort of fisher j on day i, where i = 1....d, j = 1....N_i.

Catch per Unit Effort (CPUE)

A mean CPUE, U, over all fishers in a stratum was estimated by obtaining an individual CPUE for each interview, summing over all interviews, and dividing by the number of interviews, i.e.,

$$U = \frac{\sum_{i=1}^{d}\sum_{j=1}^{n_i} \frac{c_{ij}}{E_{ij}}}{\sum_{i=1}^{d} n_i}.$$

where U = Mean CPUE over all fishers, c_{ij} = Catch of fisher j on day i, where i = 1....d, j = 1....n_i, E_{ij} = Observed effort of fisher j on day i, where i = 1....d, j = 1....N_i, and n_i = Number of fishers interviewed on day i.

Total Catch

An approach to estimating total catch calculated the catch, C_u, as a product of the mean CPUE, mean daily effort, and total number of days in the stratum, i.e.,

$$C_u = U \times \bar{E} \times D.$$

A detailed description of the expansion techniques and algorithms used in each study is contained in Everson (1994) and Friedlander et al. (1995).

Results

Fishing Effort

It was not possible to compare total fishing effort between Kāne‘ohe and Hanalei because fishing effort for passive gears in Kāne‘ohe Bay was estimated on a daily rather than hourly basis as was the case in Hanalei. For active gear types, total fishing effort for Kāne‘ohe Bay in 1991 (65,162 hrs) was 2.5 times greater than that observed in Hanalei Bay in 1993 (25,725 hrs) (Figure 2). Hook and line fishing was the dominant method at both locations, accounting for 55% of the active fishing effort in Kāne‘ohe Bay and 72% of the active effort in Hanalei Bay. Spear fishing was the second most common fishing method in Kāne‘ohe Bay (26% of total active fishing hours) while crab nets were the second most important method by effort in Hanalei Bay accounting for 21% of the total active fishing effort. Invertebrate collecting, primarily featherduster worms (mainly *Sebellastarte sanctijosephi*), accounted for 3% of the total active gear effort in Kāne‘ohe and was the only fishing method in either location which exhibited greater mean daily fishing effort during the weekdays rather than weekends or holidays. Gill nets were the dominant passive fishing method in Kāne‘ohe Bay with effort ranging from 438 effort-days in fall 1991 to 146 in winter 1991. In contrast, gill net effort in Hanalei ranged from a high of only 35 effort-days in winter 1992 to a low of 0 in winter 1993.

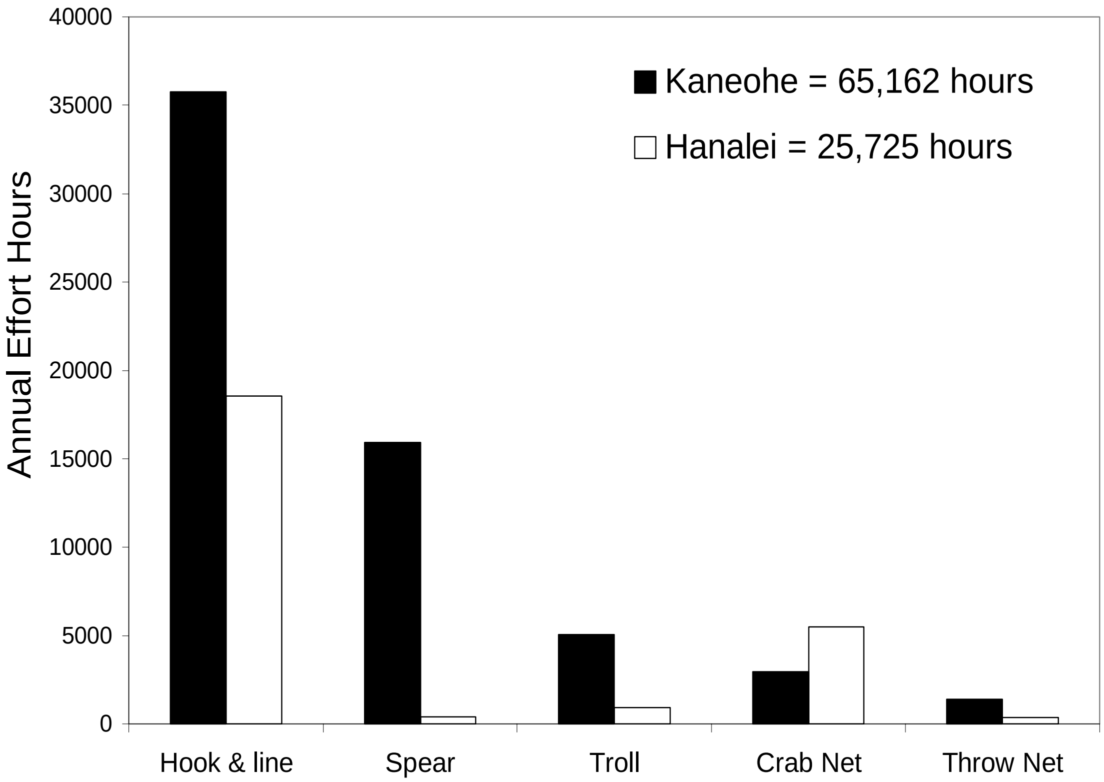

Figure 2. Expanded annual fishing effort (gear-hours) for major active fishing gears in Kāne‘ohe and Hanalei bays.

Seasonally, most gear types showed their lowest levels of effort during the winter quarters. Estimated effort over all active methods in Kāne‘ohe Bay peaked in summer 1991 and was lowest during winter of both years (Table 1). Similarly, in Hanalei effort was lowest during both winter quarters but highest during spring 1993 (Table 2). Most gear types followed a somewhat similar trend except crab netting in Hanalei where effort washighest in winter 1992. Effort in this fishery is correlated with rainfall events. High rainfall events increase the discharge of nutrient-rich material into the bay that in turn results in high concentrations of the kuhonu or white crab (*Portunus sanguinolentus*) that feed on this material. Surround netting was seasonally variable depending on the presence of large schools of akule (*Selar crumennopthalmus*) and opelu (*Decapterus* spp.), but accounted for a small proportion of the passive gear fishing effort in both bays.

Table 1. Quarterly estimates of mean daily effort-hours or effort-days* by weekday (WD) and weekend/holiday (WE/H) for various methods observed in Kāne'ohe Bay during 1991. Standard error in parentheses. Asterisks denote passive gear effort calculated in effort-days.

	Spring 1991		Summer 1991		Fall 1991		Winter 1991	
GEAR	WD	WE/H	WD	WE/H	WD	WE/H	WD	WE/H
Troll	630.0	1284.3	847.3	1040.0	447.3	557.1	61.0	193.3
	(40.2)	(23.9)	(22.0)	(19.9)	(36.4)	(23.7)	(61.0)	(32.9)
Spear	1344.0	1193.1	1529.3	2050.0	3253.3	3274.3	1769.0	1513.3
	(44.1)	(16.7)	(33.3)	(27.0)	(17.0)	(15.6)	(33.5)	(12.8)
Pole–and-line	3696.0	4250.6	6262.0	7220.0	3395.7	6197.1	1433.5	3293.3
	(17.6)	(18.3)	(19.1)	(14.4)	(17.0)	(15.9)	(32.7)	(11.1)
Invert. Collectors	189.0	16.6	434.0	-	894.7	68.6	427.0	40.0
	(35.7)	(87.1)	(25.0)-	-	(18.2)	(75.6)	(31.8)	(41.8)
Crab Net	546.0	273.4	640.7	310.0	386.3	188.6	396.5	200.0
	(17.6)	(20.0)	(36.6)	(32.1)	(34.1)	(22.3)	(22.8)	(20.1)
Throw Net	441.0	82.9	206.7	90.0	305.0	120.0	61.0	73.3
	(31.2)	-	(19.0)	(50.5)	(58.6)	(23.4)	(70.5)	(37.5)
Aquarium Net	-	16.6	-	-	-	-		6.7
	-	(87.1)	-	-	-	-		(83.7)
Dip Net	252.0	145.0	-	210.0	-	120.0	162.7	180.0
	-	(19.3)	-	(13.8)	-	-	(24.4)	-
Fence Net	-	116.0	165.3	15.0	-	-	-	-
	-	-	(24.4)	(61.1)	-	-	-	-
Limu picking	168.0	165.7	124.0	100.0	-	60.0	15.3	13.3
	(57.3)	(10.4)	(42.5)	(33.0)	-	(74.0)	(93.2)	(83.7)
Gill Net*	210.0	70.4	155.0	140.0	254.0	184.0	76.2	70.0
	(23.0)	(28.1)	(29.0)	(23.0)	(19.0)	(14.7)	(30.7)	(24.6)
Surround Net*	-	4.1	10.3	-	-	-	-	16.7
	-	(87.1)	(95.0)	-	-	-	-	(26.4)
Traps*	52.5	16.6	51.7	120.0	71.2	8.6	15.3	10.0
	(54.5)	(45.3)	(35.0)	-	(32.7)	(56.5)	(61.0)	(59.2)

Table 2. Expanded quarterly inshore fishing effort (gear-hours) by gear type. Coefficient of variation (CV) for each estimate is in parentheses. No data for Fall 92 because of Hurricane Iniki. WD - weekdays, WE/H - weekends and holidays.

	Summer 92		Winter 92		Spring 93		Summer 93		Fall 93		Winter 93	
GEAR	WD	WE/H	WD	WE/H	WD	WE/H	WD	WE/H	WD	WE/H	WD	WE/H
Cast net	62.15	35.11	-	54.00	56.11	41.36	50.45	34.78	95.48	8.74	78.00	-
	(0.26)	(0.18)	-	(0.91)	(0.50)	(0.69)	(0.22)	(0.33)	(0.34)	(0.43)	(0.96)	-
Crab net	129.62	296.30	350.20	1011.96	224.75	1210.61	964.97	112.65	578.27	1048.71	152.16	311.25
	(0.66)	(0.33)	(0.77)	(0.59)	(0.62)	(0.66)	(0.43)	(0.74)	(0.55)	(0.33)	(0.59)	(0.64)
Gill net	26.22	135.72	138.20	217.44	-	67.97	67.46	59.49	54.46	152.70	-	-
	(0.86)	(0.34)	(0.95)	(0.72)	-	(0.76)	(0.60)	(0.42)	(0.77)	(0.51)	-	-
Glean	12.48	-	-	-	-	-	-	-	-	-	-	-
	(0.69)	-	-	-	-	-	-	-	-	-	-	-
Hand net	-	6.53	-	-	-	-	-	-	-	-	-	-
	-	(0.81)	-	-	-	-	-	-	-	-	-	-
Line	322.97	437.70	55.00	12.00	145.31	650.04	669.21	513.57	73.11	409.95	44.04	35.70
	(0.16)	(0.16)	(0.85)	(0.91)	(0.40)	(0.24)	(0.32)	(0.20)	(0.59)	(0.39)	(0.90)	(0.57)
Longline	10.37	-	-	-	-	-	-	9.48	-	18.40	-	-
	(0.62)	-	-	-	-	-	-	(0.74)	-	(0.74)	-	-
Pole-and-line	1813.51	2272.48	1099.80	654.96	2462.41	3612.75	1072.02	2372.80	1734.76	3015.38	627.00	953.03
	(0.28)	(0.15)	(0.46)	(0.59)	(0.20)	(0.26)	(0.21)	(0.16)	(0.18)	(0.19)	(0.24)	(0.29)
Spear	217.78	268.97	-	-	11.63	103.60	30.29	205.43	-	38.48	7.08	-
	(0.25)	(0.34)	-	-	(0.93)	(0.55)	(0.85)	(0.31)	-	(0.47)	(0.96)	-
Small surround	33.51	33.87	-	-	372.62	5.44	24.23	4.82	-	15.06	-	-
net	(0.46)	(0.44)	-	-	(0.78)	(0.85)	(0.62)	(0.74)	-	(0.74)	-	-
Trap	-	16.43	-	-	-	-	130.85	-	-	11.71	-	-
	-	(0.81)	-	-	-	-	(0.89)	-	-	(0.74)	-	-
Troll	304.09	241.79	91.80	46.02	131.05	145.87	206.88	197.85	44.88	47.63	-	22.50
	(0.24)	(0.24)	(0.87)	(0.62)	(0.81)	(0.44)	(0.47)	(0.37)	(0.51)	(0.34)	-	(0.93)

CPUE

Mean catch per unit of effort (CPUE in number per hour for invertebrate collectors and kg/hr for all other methods) was calculated for the major active fishing methods observed (Table 3). Spear fishers had the highest average CPUE of all active methods in Kāne‘ohe and ranked second in Hanalei. Similar catch rates were observed for both fisheries with ranges from ~0.8 to 1.0 kg/gear-hour. Crab netting followed by trolling and line fishing had the next highest CPUE for active gear in Kāne‘ohe while trolling, line fishing, and crab netting had the next highest catch rates, respectively, in Hanalei. CPUE for trolling was more than twice as great in Hanalei (0.64 kg/line-hr) as in Kāne‘ohe (0.30 kg/hr). Pole-and-line fishing, i.e. from shore and boat, were combined in the Kāne‘ohe Bay study, with an annual CPUE of 0.27 kg/hr compared to a combined CPUE of 0.17 kg/hr in Hanalei. While line fishing from boats in Hanalei Bay produced a similar CPUE (0.26 kg/line-hr), CPUE with pole from shore was substantially lower (0.07 kg/pole-hr), and lower than any other major gear in the Hanalei Bay fishery.

Table 3. Catch per unit effort for active (kg/effort-hour) and passive gear (kg/effort-day) in Kaneohe and Hanalei bays. For passive gear in Hanalei, mean CPUE was multiplied by mean daily effort-hours for each gear to obtain an estimate of mean daily effort-days comparable to Kaneohe.

	Kaneohe Bay			Hanalei Bay
Method	1991	1992	Average 91-92	92-93
Passive Gear				
Spear	0.83	1.02	0.93	0.87
Line fishing	0.31	0.23	0.27	0.17
Troll	0.35	0.25	0.30	0.64
Throw net				1.60
Crab nets		0.87	0.87	0.10
Invert collectors*		20.08	20.08	
Passive Gear				
Gill nets	15.80	19.08	17.44	9.00
Surround Nets	198.85	112.41	155.63	213.38
Traps	4.09		4.09	

Invert collectors* = number per hour

For both fisheries, surround nets provided the highest CPUE, followed by gill nets. Catch rates for passive fishing methods were measured in catch per net or trap day in Kāne‘ohe Bay. In Hanalei, mean CPUE was multiplied by mean daily effort-hours for each passive gear type to obtain an estimate of mean daily effort-days comparable to Kāne‘ohe. Gill net catch rates were 17.4 kg/effort-day is Kāne‘ohe and 9.0 kg/effort-day in Hanalei. Surround net catch rates were highly variable with a mean of over 213 kg/effort-day in Hanalei and nearly 155 kg/effort-day in Kaneohe.

Expanded Catch Estimates

For all gear types combined, total annual harvest was 63,958 kg in Kāne‘ohe Bay and 15,801 kg in Hanalei (Figure 3), a difference of more than 300%. A total of 65 taxa from 40 families were captured in Kāne‘ohe while 85 taxa from 43 families comprised the inshore catch composition in Hanalei. Gill nets accounted for 39% of the total catch in Kāne‘ohe followed by spear (23%), surround nets (19%), and line fishing (13%). In Hanalei, surround nets comprised the majority (69.1%) of the catch followed by line fishing (13.2%) and gill netting (5.3%). In Kaneohe, annual invertebrate collector catch was estimated at nearly 100,000 individuals per year with featherduster worms (*Sebellastarte sanctijosephi*) accounting for over 89% of the total catch.

For passive fishing methods in Kāne‘ohe, gill net catches averaged 25,000 kg per year, followed by surround nets with 12,500 kg. The annual surround net catch in Hanalei (8,741 kg) was comparable to that observed in Kāne‘ohe. Catches for all other gears were substantially lower in Hanalei compared with Kāne‘ohe. Passive gear accounted for 59% of the total catch in Kaneohe and greater than 83% of the total catch in Hanalei.

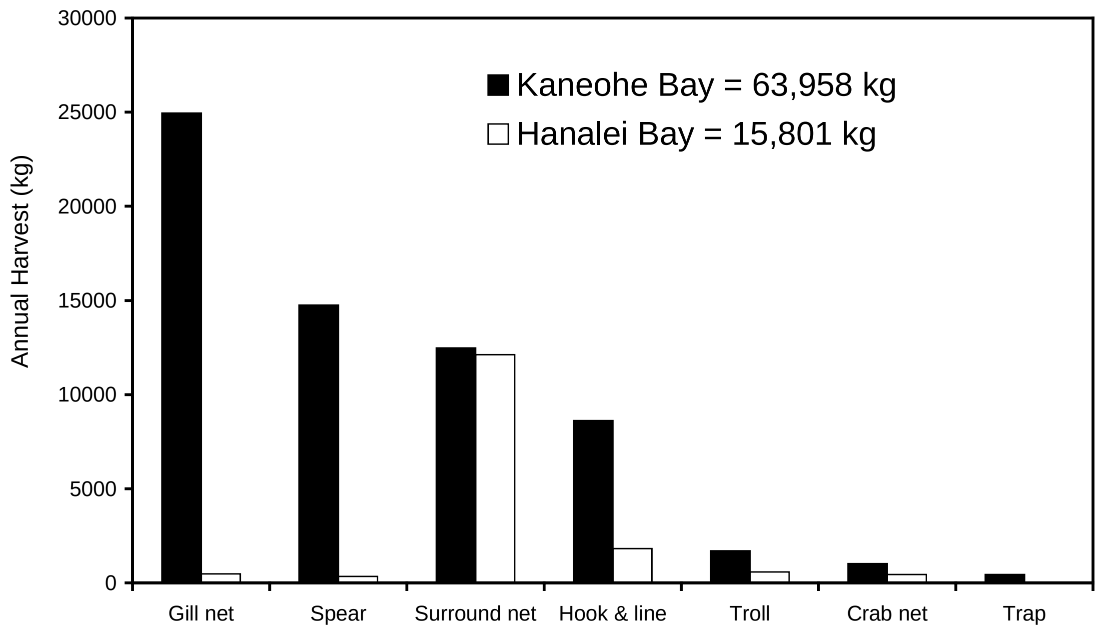

Figure 3. Annual fisheries harvest (kg) in Kāne‘ohe and Hanalei Bays by gear type.

Expanded catch estimates by species were calculated for active fishing methods only in Kāne‘ohe (Table 4). He‘e or octopus (primarily *Octopus cyanea*) accounted for 52% of the total annual active gear catch, followed by jacks (8.9%), crabs (6.6%), goatfishes (6.4%), and akule (4%). Annually, 88% (11,692 kg) and 89% (15,485 kg) of the 1991, 1992 spear catch consisted of he‘e, respectively. The primary species caught using pole-and-line were goatfishes (Mullidae), and pāpio, (juvenile jacks, Carangidae). Troll catches consisted primarily of pāpio and ‘awa‘awa (*Elops hawaiiensis*).

Catch by species was not calculated for passive methods in Kāne‘ohe, although common species could be identified using interview catch data. Gill net catches consisted of various reef species, including goatfishes, pāpio, palani (*Acanthurus dussumieri*), ta‘ape (*Lutjanus kasmira*), and nenue (*Kyphosus* spp.), while surround nets primarily caught weke, ‘ama‘ama or mullet (*Mugil cephalus*), ‘o‘io (*Albula* spp.), and pāpio. Trap catches consisted of many of the above reef species, and in addition included pualu (*Acanthurus blochii*), crabs, and spiny lobsters (*Panulirus* spp.).

Table 4. Annual harvest (kg) in Kāne‘ohe Bay for active gear only.

Taxa	1991	1992	Average 1991-92	Percentage of total
he‘e (Octopus)	11750.4	15485.4	13617.9	52.10
Jacks (pāpio, ōmilu, ulua, Carangidae)	2059.1	2580.0	2319.5	8.87
Crabs (mainly kuhonu, *Portunus sanguinolentus)*	2036.8	1425.0	1730.9	6.62
Goatfishes (Mullidae)	2252.7	1084.1	1668.4	6.38
mano or sharks (mainly scalloped hammerheads, *Sphyrna lewini*)	697.7	1498.2	1098.0	4.20
akule (*Selar crumenopthalmus*)	347.3	670.9	1009.1	3.86
‘awa‘awa (*Elops hawaiiensis*)	814.5	997.3	905.9	3.47
uhu (Scaridae)	713.6	1091.4	902.5	3.45
ta‘ape (*Lutjanis kasmira*)	966.4	43.2	504.8	1.93
awa (*Chanos chanos*)	714.1	0.0	357.0	1.37

In Hanalei, two small coastal pelagic jacks, akule (*Selar crumenophthalmus*) and ōpelu (*Decapterus* spp.), accounted for more than 70% of the total catch (Table 5) with the majority of this catch (97%) taken using large surround nets. Jacks accounted for 14.8% (534 kg) of the total catch in Hanalei excluding akule and ōpelu. Pāpio (small jacks, primarily *Caranx melampygus*) provided an annual catch of 346 kg taken mostly by line fishing and trolling while the larger ulua aukea (*Caranx ignobilis*) contributed an additional 188 kg to the total catch.

Crabs, mainly kuhonu (*Portunus sanguinolentus*), were a major contributor to the annual catch (350 kg) in Hanalei excluding coastal pelagics (9.7%). Sharks (mostly scalloped hammerheads *Sphyrna lewini*) comprised 9.5% of this catch, followed by nenue (*Kyphosus* spp., 8.9%), manini (*Acanthurus triostegus*, 8.1%), ‘o‘io (*Albula* spp., 7.2%), and goatfishes, mainly small juveniles or oama (family Mullidae).

<u>Yield per unit area</u>

Kāne‘ohe Bay encompasses approximately 56.7 km^2 (measured to the 90' isobar) of habitat (Hunter and Evans 1995). Total (all active and passive methods combined) catches for 1991 and 1992 were 52.2 and 79.8 t respectively and yield per unit area ranged from 0.92 - 1.4 t km^{-2} yr^{-1} during the study period. The total area of Hanalei Bay is ca. 4.6 km^2 with an annual catch of 12.6 t (3.6 t excluding akule and ōpelu). Total annual yield for Hanalei using these numbers is 2.7 t km^{-2} yr^{-1} for the entire catch and 0.8 t km^{-2} yr^{-1} excluding small coastal pelagics.

Table 5. Annual harvest (kg) in Hanalei for both active and passive gears.

Taxa	Annual Total (Dec. '92 to Nov. '93)	Percentage of total catch	Percentage of catch excluding coastal pelagics
akule (*Selar crumenophthalmus*)	6231.00	49.28	-
opelu (*Decapterus* species)	2810.46	22.23	-
Jacks	703.68	5.56	19.53
papio (*Caranx melampygus* and other juvenile Carangids)	(345.54)	(2.73)	(9.59)
ulua aukea (*Caranx ignobilis*)	(188.52)	(1.49)	(5.23)
Goatfishes (Mullidae)	439.87	3.48	12.21
oama (*Mulloidichthys* spp.)	(236.39)	(1.87)	(6.56)
kumu (*Parupeneus porphyreus*)	(53.54)	(0.42)	(1.49)
kuhonu or white crab(*Portunus sanguinolentus*)	350.64	2.77	9.73
mano kihikihi or scalloped hammerhead (*Sphyrna lewini*)	342.01	2.70	9.49
nenue (*Kyphosus* species)	319.13	2.52	8.86
manini (*Acanthurus triostegus*)	293.54	2.32	8.15
‘o ‘io (*Albula* spp.)	259.88	2.06	7.21

Discussion

Expanded catch and effort information, along with ancillary information gleaned from fishers during the interview process, facilitated formulation of a more complete picture of the current status of fishery resources in both Kāne‘ohe and Hanalei bays than were previously available. Using similar sampling methodologies, we were able to compare the catch, effort, and yields for two coastal fisheries with different natural and human influences. Kaneohe Bay is the largest shelter embayment in Hawai‘i and is one of the most urbanized watersheds in the state (Hunter and Evans 1995). In contrast, Hanalei Bay is a relatively small bay, exposed to large winter swells and located in a more rural area.

Total catch in Kāne‘ohe Bay was more than 5 times that recorded in Hanalei. In additional to the 64.1 t of catch recorded in the Kāne‘ohe study, 44.5 t of baitfish, primarily nehu (*Encrasicolina purpurea*) were reported in the State commercial landings data for Kāne‘ohe Bay during the same time period. Gill and surround nets were used to harvest the major portion of the catch at both locations. High catch rates were obtained using surround nets (Hanalei – 213 kg/effort-day; Kāne‘ohe – 157 kg/effort-day) and gill nets (Kāne‘ohe – 17.4 kg/effort-day; Hanalei – 9.0 kg/effort-day). This compares to an island wide annual mean CPUE (1990) for gill and surround nets at 38 kg/trip and 143 kg/trip, respectively (Hamm and Lum 1992). Reported commercial landings for inshore gill net (89.3 kg/trip) and surround net (246.7 kg/trip) fishery in Hawai‘i indicated even higher catch rates (Smith 1992).

Pole-and-line fishers were responsible for more than half (55%) of the total active fishing effort in Kaneohe and greater than 72% in all fishing effort in Hanalei. These fishers had among the lowest CPUE of all active methods at both locations. Despite the low catch rates, pole-and-line fishing ranked first in total annual catch among active gears in Hanalei and second in Kāneʻohe. These low CPUE values may reflect the concern of pole-and-line fishers that the catch rate for this method has declined in recent years. A DLNR creel survey conducted in 1958-61 revealed that Kaneohe Bay had the highest catch rates of all areas surveyed on Oʻahu, due in large part to the high pole-and-line catches of ōmaka (*Atule mate*) (Hawaiʻi DLNR 1959). Expanded ōmaka catches in Kāneʻohe during 1991 and 1992 amounted to between 200 and 260 kg per year.

In Kāneʻohe, spear fishers had the highest annual catch rate of any active fishing method with the vast majority (88-89%) of the catch consisted of heʻe. Despite relatively heavy fishing pressure, the fishery continues to yield CPUEs around 1 kg per hour and estimates of 13-17 tons annually in Kāneʻohe. Although spear catch rates in Hanalei were also high, the low spear fishing effort in Hanalei contributed little to the overall catch (<3%). The large size and protection from large oceanic swells in Kāneʻohe may account for the large catch and lack of seasonality in this fishery compared to spear fisheries in Hanalei and many other exposed locations throughout the state.

A substantial number of feather duster worms (over 740,000 since 1976) and other invertebrates are harvested commercially from Kāneʻohe Bay (Walsh et al. this volume). Legislation was enacted in 1993 making it "unlawful to intentionally take, break or damage, with crowbar, chisel or any other implement, any rock or coral to which marine life is visibly attached or affixed". Despite these new regulations, the commercial harvest for featherduster worms in 2003 was still more than 50,000 individuals. The other type of commercial activity regularly observed in Kāneʻohe Bay was surround netting for baitfish that yielded 42.0 t in 1991 and 47.0 t in 1992. Landings for this fishery peaked in 1977 at 111.3 t and declined steadily until 1982, remaining fairly stable thereafter (DLNR unpublished data).

Catch composition

As is the case with most coral reef ecosystems, the Kāneʻohe and Hanalei fisheries exploited a diverse group of fish and invertebrate species. However, the bulk of the active gear catch was dominated by relatively few genera and species, most of which are higher-level carnivores. Planktivorous akule and opelu were mostly targeted using surround nets and these species provided the majority of the catch in Hanalei. Fishers using other passive methods such as gill nets or traps often pooled their catch together as 'reef fish', making species identifications difficult. Similar results for the coral reef fishery at Apo Island in the Philippines reported a catch composed of species from 38 families and three classes of cephalopods, but nine families comprised over 93% of the annual yield (Bellwood 1988).

Comparison of yields

Yield per area figures for Kāneʻohe (0.92 - 1.4 t km^{-2} yr^{-1}) and Hanalei (2.7 t km^{-2} yr^{-1} for the entire catch and 0.8 t km^{-2} yr^{-1} excluding small coastal pelagics) are similar but lower compared with estimates from other coral reef habitats throughout the Indo-Pacific. Expanded catch estimates for baitfish could not be calculated in the Kāne‘ohe study, but if the commercial baitfish landings data for 1991 and 1992 were included, the yield per area estimates for Kaneohe Bay would be 1.7 - 2.2 t km^{-2} yr^{-1}. During the peak year of 1977, baitfish yield alone amounted to 2.0 t km^{-2} yr^{-1}. Estimates of yields for shallow coralline shelves with good coral cover ranges from 3 - 5 t km^{-2} yr^{-1} at select locations in the 1970s (Marshall 1985). A study of a number of Pacific Island reef fisheries in the late 1980s (Russ 1991) found that eight out of ten locations had yields exceeding 5 t km^{-2} yr^{-1}. Both Russ (1991) and Munro and Williams (1985) noted that areas reporting yields in excess of 20 t km^{-2} yr^{-1} have high proportions of small, planktivorous fishes in the catch.

Comparison with DAR commercial catch data

The only other fishery data available comes from the commercial catch data reported to Hawai‘i DLNR, Division of Aquatic Resources (DAR). The DAR commercial catch data from reporting areas 502, 503, 522, and 523 covers the entire marine area of northern Kau‘ai from Anahola to Ha‘ena and includes offshore as well as inshore fishing activities. The total catch from the Hanalei creel survey (46,822 kg) is more than eight times that reported to DAR (5490 kg) for the same time period despite a much smaller fishing area surveyed (Figure 4). The overall catch from the DAR catch reports contained only 28 taxa while the catch from the Hanalei creel survey included 95 taxa, although the catches of many taxa were trivial. For taxa that occurred in both the creel survey and the DAR catch reports, the catch estimates from the creel survey were higher in 17 of 21 such comparisons (81%), despite the larger areal coverage of the four DAR reporting areas. The differences ranged from a factor less than two to more than 100; typically the creel catch estimate was at least twice or three times the size of the DAR value.

Generally, few fishers reported selling any portion of their catch in Kāne‘ohe. Gill netters and surround netters had the highest percentage (12%) of interviews in which any part of the catch was reported as sold (Table 6). Only one percent or less of the interviewees for all other methods reported selling any of their catch. Thirty-two percent of the pole-and-line fishers interviewed reported the disposition of their catch as “other,” which indicates that part of the catch was either given away or used as bait. Average annual catch of he‘e (octopus) in Kaneohe Bay from the creel survey was 13,618 kg while the average annual statewide reported he‘e landings during 1980-90 were only 5,818 kg (Smith 1992).

Differences between these values may consist of at least two components: (1) under-reporting by commercial fishers on catch reports, and (2) large non-commercial catches contained in the creel survey. Underreporting is a common problem with unmonitored catch reports generally and is widely believed to be substantial in Hawai‘i. Most fishers, most trips, and most fishing effort units were observed to be noncommercial - not made by commercially licensed fishers who report through the HDAR commercial catch report system. This probably accounts for a good deal of the difference between catch values from the two sources but the differences from this cause cannot be separated from differences caused by underreporting or other influences, but the unlicensed commercial catch of most species is likely large.

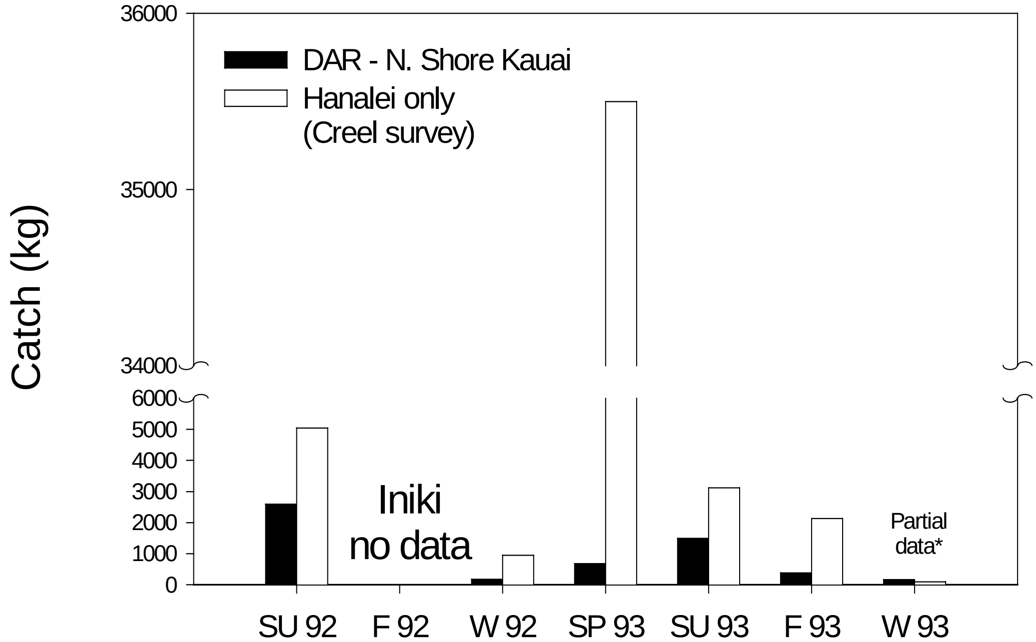

Figure 4. Quarterly comparisons of commercial landings at Hanalei Port from commercial catch records and estimates of total catches inside the bay from the Hanalei creel survey. Data from commercial fishers supplied by Hawai‘i Division of Aquatic Resources (DAR) and include statistical fishing areas 502 and 503. Catches for fall 1992 are reduced or missing because of effects of Hurricane Iniki.

Table 6. Annual (March 1991-February 1992) disposition of catch for major fishing methods observed in Kaneohe Bay. “Other” indicates that part of the catch that was either given away or used as bait.

Method	% kept	% sold	% other
Troll	89	<1	11
Pole-and-line	67	1	32
Spear	89	<1	11
Gill net	85	12	4
Trap	100	0	0
Crab net	86	0	14

Assessment of fisheries resources

The high effort and low CPUE for pole-and-line fishers may indicate that species targeted by this method are being over fished. These fishers were the most vocal in proclaiming that the fishery resources of the Bay were in serious decline. Many of the species targeted by pole-and-line fishers are also caught by gill netters. It is clear from the Kāne‘ohe data that nets are responsible for the majority of the catch of these species. The netters on the other hand were most hesitant to admit that there may be a problem. This reiterates the need for more accurate time-series data that includes a substantial amount of catch and effort information that is currently not being collected.

For most species in Hanalei, the general impression from this study is that the rate of exploitation *per se* is not extremely high. However, reef species do not appear to be unusually abundant or large in size (Friedlander et al. 1997) possibly suggesting higher exploitation rates at scales larger than just Hanalei Bay. The most common complaints from fishers are that large jacks and moi (*Polydactylus sexfilis*) are no longer commonly caught in the bay.

The large annual harvest of he‘e in Kaneohe should be monitored to ensure stock health. If reductions in fishing effort are warranted, the best strategy might be to prohibit or restrict fishing from spring through summer when the smallest animals are caught. The ancient Hawaiians adopted similar restrictions on harvest, in which the fishery was closed from January or February for 4 to 6 months (Buck 1964).

Enhanced nutrient inputs and reduced herbivory have both been suggested as probable mechanisms driving phase shifts from coral to algal dominance on coral reefs (Smith et al. 2001). In Kāne‘ohe Bay, macroalgae has overgrown many of the reefs, resulting in loss of live coral cover (Hunter and Evans 1995) and it has been suggested that the continued abundance of an invasive macroalga *Dictyosphaeria cavernosa* in Kaneohe Bay is the result of a reduction in grazing intensity (Stimson et al. 2001). Gill nets catch large quantities of herbivorous fishes in Kāne‘ohe and the reduced abundance of this feeding guild may be contributing to the current observed dominance of macroalgae in the bay.

The small sizes at which some fishes are being caught and retained is a matter of concern for management of the stocks. Of a sample of 1270 omilu/papio (*Caranx melampygus*/ Carangidae) examined in Hanalei; less than 30% were of legal size (>7 in. TL = 139 mm SL, 1994 State regulations) even for home consumption; and not more than about 30 individuals had reached the size (350 mm SL) for first reproduction (SFR). Less than 9% of all specimens measured would have been legal for catch by spear or for sale (1 lb ≈ 263 mm SL).

For moi, almost 70% of all specimens measured in the catch in Hanalei were below the minimum legal size for retention (7 in. TL = 162 mm SL; 1994 state regulations) and only two of 29 specimens in this sample had reached size at first reproduction (250 mm SL), and most were much smaller. Despite the small sample size, it seems clear that here (as in most of the main Hawaiian Islands) moi experiences heavy growth overfishing, and recruitment overfishing may be responsible for the apparent decline in stocks in recent decades statewide (Friedlander and Ziemann 2003).

The largest portion of the annual catch of goatfishes at both locations consisted of oama (juvenile goatfishes). This fishery operated on the so-called “oama run,” a phenomenon in which large numbers of a cohort of mullid species at a relatively young juvenile stage move inshore to adult demersal habitat (Harrison et al. 1991, Friedlander and Parrish 1997). The relatively large catches from heavily concentrated effort at this small size (much below SFR) contribute to growth overfishing and may reduce recruitment of valuable adults.

Conclusions

The low yields and small sizes of fisheries taxa at both Kāneʻohe and Hanalei support the need for better management of coral reef fisheries resources statewide. Commercial catch data alone provides an incomplete assessment of the resources harvested at most locations in Hawaiʻi. In addition, commercial fishers report the catches aggregated into standardized geographical areas, which are large compared to the traditional ahupuaʻa management unit and may not be commensurate with the spatial patters of the species being harvested. The greater weight and diversity of taxa included in the creel surveys highlight the need for better catch estimates of coastal fisheries in Hawaiʻi, especially in terms of managing the complete fish assemblage from an ecosystem perspective.

Hawaiʻi is one of the few coastal states that do not require a saltwater recreational fishing license, meaning that a large percentage of the catch goes undocumented. In addition, the poor compliance and lack of enforcement of existing fisheries regulations have all contributed to the decline in fisheries resources and ecosystem health observed statewide. The Hawaiʻi Department of Land and Natural Resources is currently expanding its creel program to sample the recreational catch and have recently revised existing fishing regulations in response to concerns about the continued decline in marine resources.

The resources of Hawaiʻi have been fished since prehistoric times, first for subsistence by native Hawaiians, and more recently for recreational, subsistence, and commercial purposes. The traditional system in Hawaiʻi emphasized social and cultural controls on fishing with a code of conduct that was strictly enforced (Poepoe et al. 2003, Friedlander et al. 2002). Harvest management was not based on a specific amount of fish but on identifying the specific times and places that fishing could occur so it would not disrupt basic processes and habitats of important food resources. The Hawaiʻi State Legislature created a process in 1994 to designate community-based subsistence fishing areas and these are currently being implemented on Molokaʻi, Kauaʻi, Mauʻi and Hawaiʻi.

Traditional management regimes have largely broken down in Hawaiʻi, and the western common property philosophy has led to a much wider participation by a variety of users with far fewer restrictions. In addition, the introduction of technology (motorized vessels, GPS, depth finders, etc.) has greatly increased fishing power, especially over the last several decades. What is most needed in Hawaiʻi today is a better understanding of how to best interact with our marine resources in a sustainable manner. This will require a diverse approach that includes public education, enforcement of existing regulations, marine protected areas, stock enhancement, artificial reefs, and more management at the local level. Current behaviors have established themselves over a relatively few number of generations but it will take several generations using a more sustainable approach to revitalize our coastal marine resources.

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The Commercial Marine Aquarium Fishery in Hawai‘i 1976-2003

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Abstract

The commercial aquarium fishery in Hawai‘i has developed over the last 50 years into one of the state’s major inshore fisheries, with landings of over 708,000 specimens with a reported value of $1.06 million. The true economic value of this fishery is substantially underestimated. The catch is diverse, with a total of over 200 different fish and invertebrates collected. The top 10 species constitute 73% of the entire catch. In the early days of the fishery, most collecting activity was centered on the island of O‘ahu. This fishery has declined over the years due to hurricane impacts and localized overfishing. Low-value invertebrates are increasingly replacing previously caught fishes. In contrast to O‘ahu, the aquarium fishery on the island of Hawai‘i is expanding and now accounts for 55% of the catch and 68% of the total state value. Recent research shows that collecting activities can significantly affect targeted species. A network of Fish Replenishment Areas (FRAs) has been established on the island of Hawai‘i to ensure sustainability of the aquarium fishery and to reduce user conflicts. Three years after implementation of the FRAs there are significant increases in several targeted species, and the overall value of the fishery is at an all-time high. Catch report compliance is low on this island and likely elsewhere within the state. Actual aquarium catch is underreported. Specific management actions increase reporting compliance by collectors.

Introduction

The marine aquarium fish trade has expanded into a multi-million dollar industry in fisheries throughout the tropical world. Total annual catch may exceed 30 million fish (Wood, 2001). Many of the marine ornamentals originating from the U.S. are caught in Hawai‘i, which is known for its high-quality fishes and rare endemics of high value. Here fish are collected without the use of chemicals or explosives; instead small-mesh fence and hand nets are used, resulting in a high survival rate of collected animals.

Background

Commercial aquarium collectors have been working Hawaiian waters for at least 50 years. The early collectors operated almost exclusively in the nearshore waters along the leeward coast of the island of O‘ahu. These collectors were usually experienced watermen skilled at spearing fish for food, and many of the same skills proved useful in collecting aquarium animals. Their equipment was rudimentary and included primitive goggles (bone and glass), pole spears, and cotton or linen nets. To collect specimens they practiced breath-hold diving. (DAR, undated a).

SCUBA gradually became more commonplace among collectors in the years following World War II. Synthetic nets were also introduced, which greatly increased the efficiency of collecting. In 1953 the territorial government of Hawaiʻi enacted Act 154, which authorized the Board of Agriculture and Forestry to establish a permit system for the use of fine-mesh nets and traps for the taking of aquarium fish. The law permitted the use of such otherwise-prohibited gear to take small fish that were not considered to be of food value. In creating the permit system, the legislature apparently anticipated that the aquarium fishery would grow over time and ultimately prove to be a substantial source of employment and export revenue (DAR, undated b).

The early growth of the aquarium fishery was constrained by the lack of airline connections and slow overseas flight times. With the arrival of commercial jet service to Hawaiʻi in 1959, exporters could now ship expeditiously to the U.S. mainland. Beginning in 1969 there was a rapid increase in the number of aquarium permittees, especially non-commercial ones collecting for their own aquaria. The number of commercial collectors began to increase substantially after 1971. (Table 1).

Table 1. Number of aquarium permits issued statewide for Fiscal Years 1969-1975.

Fiscal Year	Non-Commercial	Commercial
1975	218	78
1974	230	82
1973	360	36
1972	238	28
1971	144	6
1970	42	7
1969	55	4

Commercial aquarium collecting was well established on Oʻahu by 1973, when public concern about the fishery prompted the Division of Fish and Game (precursor to DAR) to place a moratorium on aquarium collecting and to suspend the issuance of aquarium fishing permits. This moratorium was to commence July 1, 1973, the start of the fiscal year, but was rescinded two days prior to its start. After the suspension was lifted, the ten-member State Animal Species Advisory Commission recommended restricting the issuance of aquarium fishing permits pending "full and extensive study." At a September 1973, meeting called by Fish and Game, a number of university marine scientists recommended the establishment of sanctuary areas and the prohibition of collecting within their confines (Walsh 1999).

Prior to 1973, commercial aquarium collectors reported their catches on the same forms (C-3) as those used by all other commercial fishermen. These forms proved unsuitable for the multi-species aquarium catch, and the resulting data is considered unreliable. As part of the lifting of the 1973 moratorium, collectors were now required to report their monthly catch on a separate, more detailed aquarium fish catch report (C-6). The penalty for failing to submit timely catch reports is revocation of the aquarium permit and prosecution of an enforcement action.

Much of the data provided in this report are from monthly catch reports. In 1989 the aquarium permit statue (HRS §188-31) was amended to require a report to the Board of Land and Natural Resources (BLNR) of the monthly catch of each species of aquarium fish. Annual summaries were reported by DAR until 1994. The last catch report was a five-year summary for FY 1995-1999 (Miyasaka 2000).

As has been noted, the reliability of this data is dependent upon the sincerity (and integrity) of the permittees (Katekaru, 1978). At present there is no provision for verification of submitted reports. Given that there are indications of underreporting (see Kona section), catch numbers and dollar amounts should be regarded as minimum and not absolute values. Data from FY 74 and FY75 are not included in this analysis due to problems with early C-6 versions, which produced data not comparable with that of subsequent years. Only commercial data are presented, as non-commercial permit holders are not required to submit monthly catch reports. Non-commercial permit holders are also limited to a total take of five fish or aquatic specimens per person per day, so their overall potential catch is considerably less than that of commercial collectors. In FY 2003, 108 non-commercial permits were issued in comparison to 116 commercial ones.

Statewide Perspective

The Hawaiʻi aquarium fishery developed at an extraordinary rate in the early 1970s. During FY 1973, 36 commercial permit holders reported a catch of 35,556 animals, which sold for a value of $74,100 (Ego, 1973). Five years later in 1978 the catch had increased 500% (179,900 specimens) and the value of the fishery had increased 400% to $296,850 ($812,900 adjusted value) (Figure 1). There were now 138 commercial collectors. This period of expansion ended at the end of the decade as a recession took hold in Hawaiʻi and the United States. The recession was closely tied to a substantial cutback in production by oil-producing nations, resulting in worldwide oil and fuel shortages. Inflation during 1978 to 1981 averaged over 10%, further eroding the real value of the catch. The number of commercial collectors fell to 42, the lowest number recorded since reporting began.

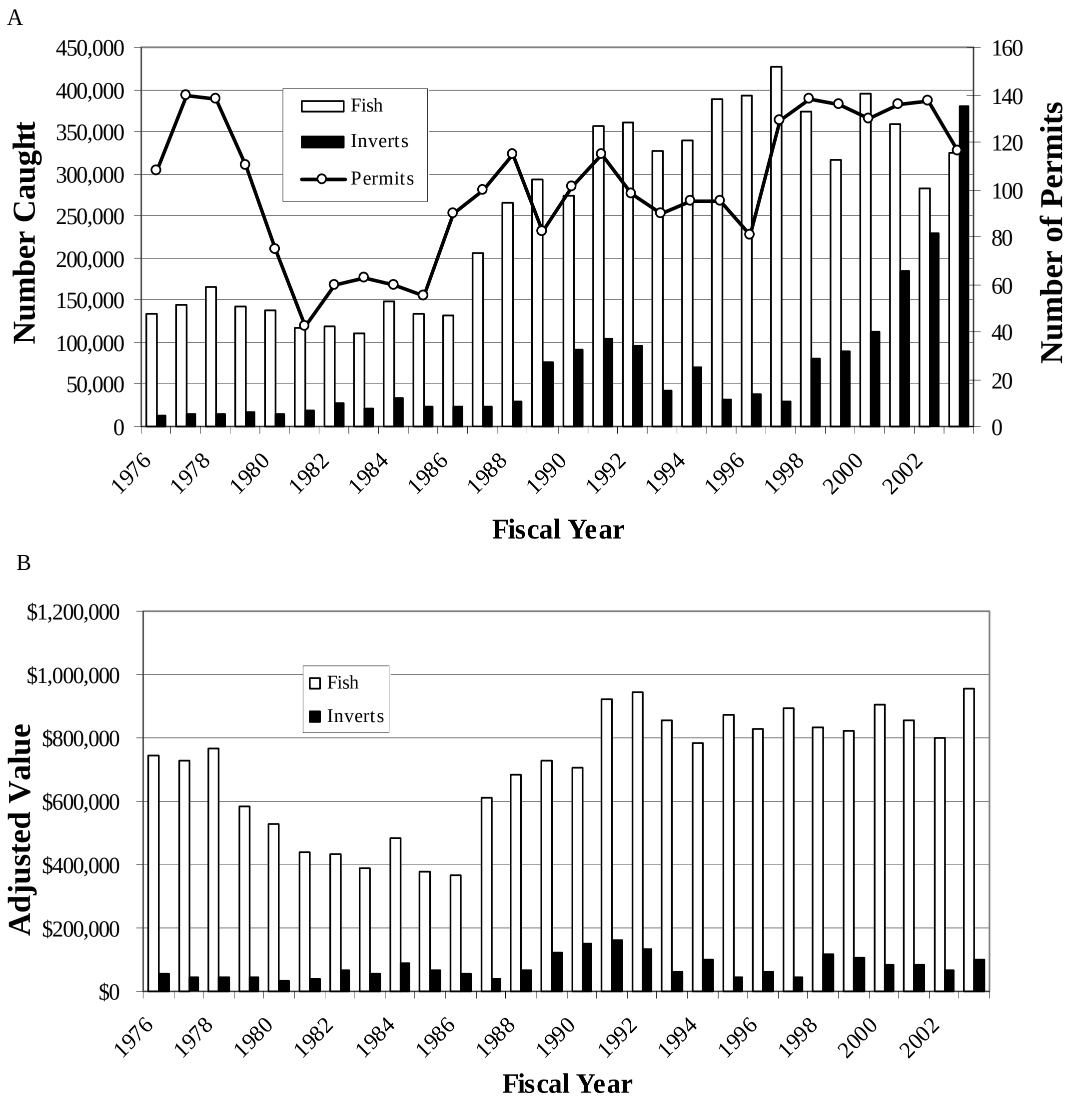

Figure 1. A. Number of commercial aquarium permits issued statewide and the numbers of fish and invertebrates reported caught. B. Dollar value of commercially caught fish and invertebrate aquarium specimens. Value is adjusted for inflation by means of Honolulu Consumer Price Index (Dept. of Labor and Industrial Relations, State of Hawai‘i).

The overall aquarium catch has been diverse, comprised of a total of 235 taxa of fish and 37 of invertebrates (Appendix A). A relatively small number of species dominates the catch; the top 10 species constitutes 73.3% of the total historical catch (Table 2). Surgeonfishes, butterflyfishes, and wrasses are the most commonly caught fish species, while feather duster worms, hermit crabs, and shrimp predominate among the invertebrates. Particularly noteworthy is the substantial increase in invertebrate catch over the last several years (see Island section).

Based upon catch report data (DAR 2001), the value of the aquarium fishery is among the highest of all inshore fisheries in Hawai‘i, exceeded only by the akule (bigeye scad - *Selar crumenopthalmus*) hook and line/net fishery (Figure 2).

Table 2. Top ten taxa of collected animals over the period FY 1976-2003.

Taxa	Common Name	Total Caught	% of Total
Zebrasoma flavescens	Yellow Tang	3,386,860	37.2
Sabellastarte sanctijosephi	Feather Duster Worm	741,949	8.1
Hermit Crabs	Hermit Crabs	707,654	7.8
Ctenochaetus strigosus	Goldring Surgeonfish	346,944	3.8
Acanthurus achilles	Achilles Tang	337,781	3.7
Naso lituratus	Orangespine Unicornfish	298,884	3.3
Centropyge potteri	Potter's Angelfish	287,668	3.2
Forcipiger flavissimus	Forcepsfish	251,523	2.8
Zanclus cornutus	Moorish Idol	187,662	2.1
Halichoeres ornatissimus	Ornate Wrasse	121,766	1.3

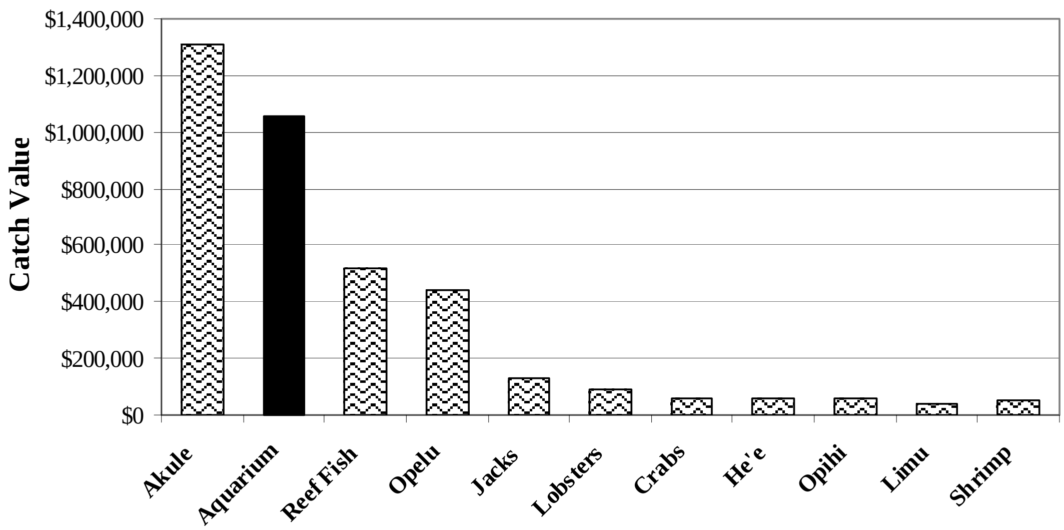

Figure 2. Value of Hawai'i commercial marine landings for FY 2001.

Due to the fact that the aquarium industry is composed of both independent contractors (collectors) and wholesalers, who may or may not be collectors themselves, the overall economic value of the aquarium fishery is estimated to be substantially higher than shown in Figure 2. Cesar et al. (2002) estimated industry gross sales at $3.2 million and industry profits at $1.2 million. A 1993 analysis based on export figures by an aquarium trade group (Hawai'i Tropical Fish Association 1993) pegged total sales of Hawaiian fish (inclusive of freight and packing) at $4,909,654. DAR reported total average value for FY 1993 /FY 1994 as only $819,957 (Miyasaka 1994a, 1994b).

It is difficult to precisely compare the scale of the Hawai'i aquarium fishery with those of other countries around the world. The international distribution network for marine ornamentals is often complex, involving a number of intermediaries, and record keeping has not been standardized or centralized. Although it is clear that aquarium collecting is one of the most important inshore fisheries in Hawai'i, total catch is substantially less than that of the major exporting countries such as the Philippines and Indonesia. The Philippines exports 6 million aquarium fish a year (Wood, 2001). Aquarium fishery data from Indonesia is scarce, but its 40 exporters of marine ornamentals (NAFED 2002) and a 1999 export value of US$11.4 million (Suara Pembaruan 1998) attest to its international prominence. Hawai‘i nonetheless is one of the major exporters among the second-tier countries (Figure 3).

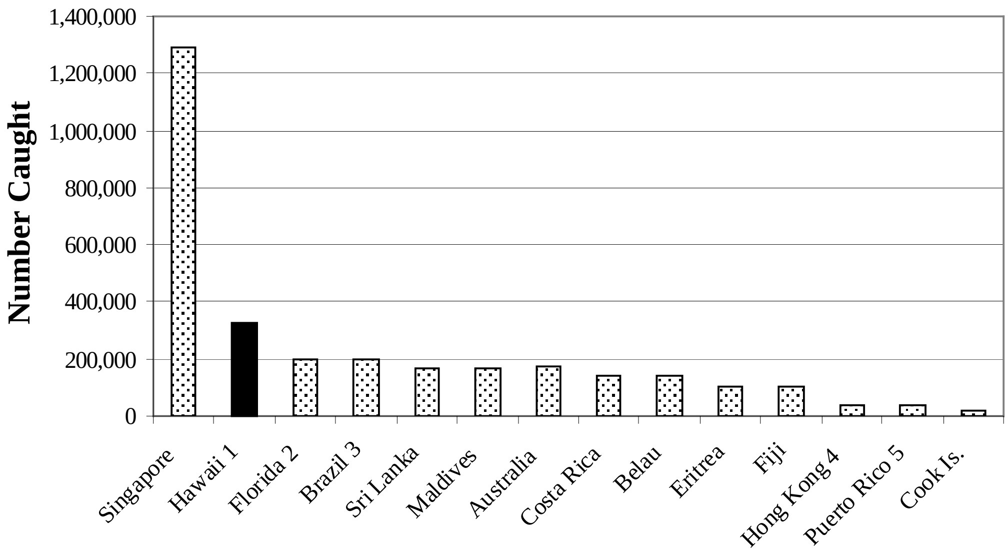

Figure 3. Number of marine aquarium fish caught or exported in recent years. All data from Wood 2001 except for 1-This study; 2- Adams et al. 2001; 3-Cassiano et al. 2003; 4-Chan and Sadovy 1998; 5-Mote 2002.

Island Comparison

Subsequent to the overall contraction of the aquarium fishery in the late 1970s and early 1980s, there has been a trend for an increasing number of commercial permits on all islands (Figure 4). The largest growth has occurred on the island of Hawai`i, which has experienced a 645% increase over the last two decades. The expansion on Hawai‘i was due to both an influx of new collectors and the relocation of collectors from O‘ahu.

In the early years of the aquarium fishery, O‘ahu was the most productive area, accounting for between 64% (1976) and 84% (1981) of the fish catch (Figure 5). The southern and leeward reefs of the island were prime collecting areas. While there is considerable between-year variability in the O‘ahu catch, there has been an overall decline in catch over time. This decline is in marked contrast to the catch of the island of Hawai‘i, which has increased dramatically since the 1980s.

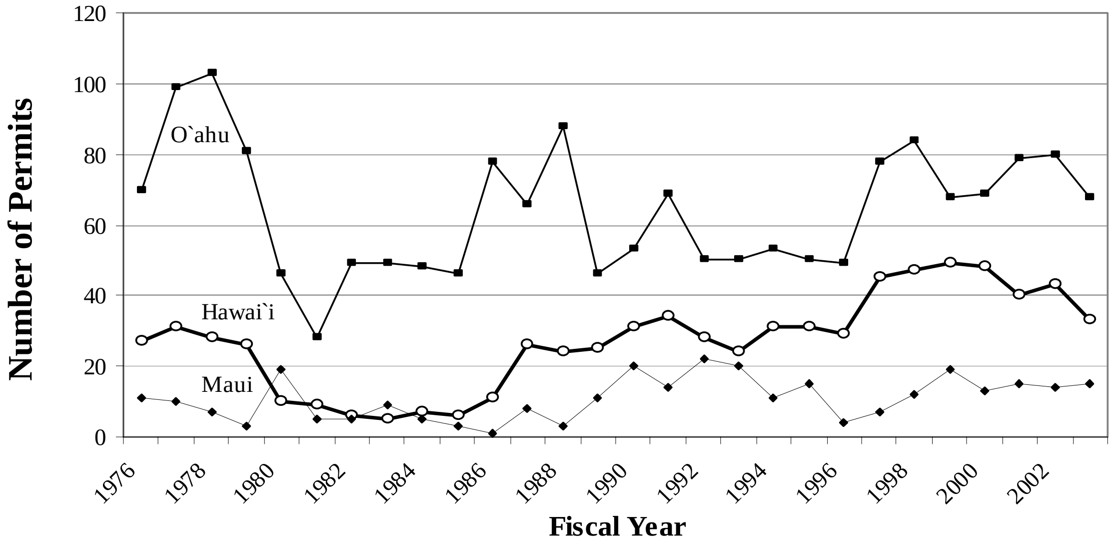

Figure 4. Number of commercial aquarium permits issued on each island per fiscal year. Maui refers to Maui county and includes the islands of Maui, Moloka`i and Lana`i. Kaua'i is not shown due to the low number of permits (mostly 0 and 2, 1 and 3 in the last three fiscal years).

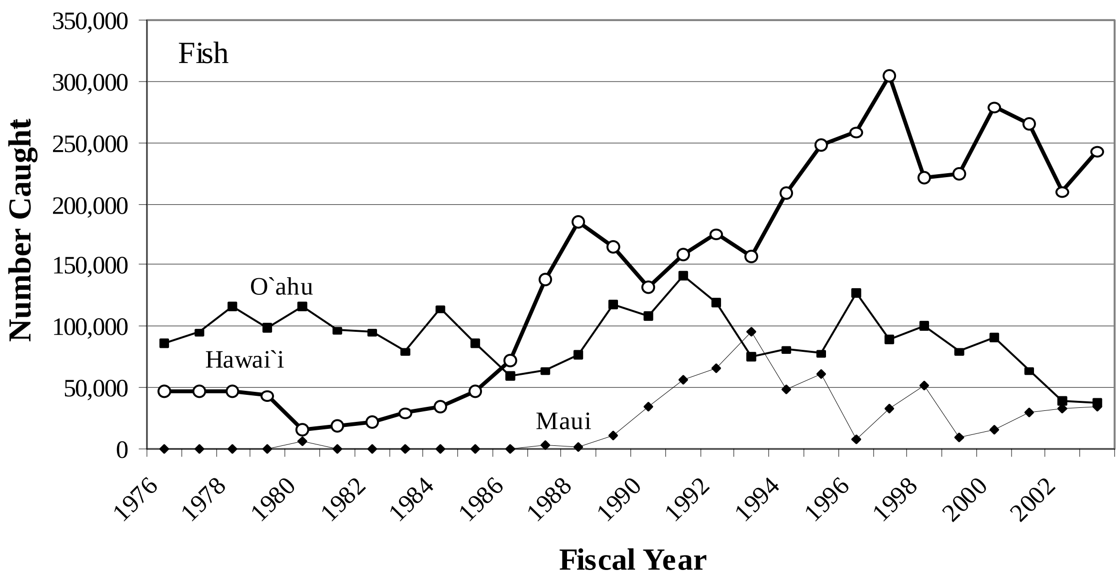

Figure 5. Number of aquarium fish caught on each island per fiscal year. Kaua'i's catch has been omitted due to low numbers.

At the present time, the O‘ahu catch represents only 12% of total aquarium fish catch in contrast to Hawai‘i’s 75%. The sharp decline in catch on Maui in FY 1996 may have been due to the temporary close of business by the primary exporter on the island (Miyasaka 2000).

While the overall economic value of the aquarium fishery in the state has been relatively stable over the last decade (Figure 2), as with total catch, there have also been substantial changes in value on each of the islands (Figure 6). The value (adjusted for inflation) of the O‘ahu aquarium fish catch in FY 2003 has declined by 76% while that of Hawai‘i island has increased 282%.

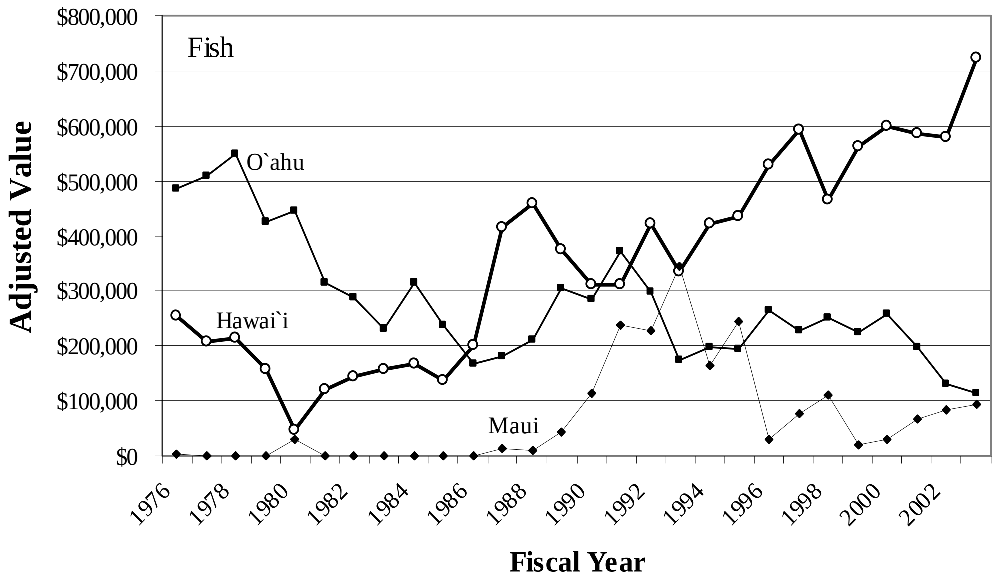

Figure 6. Dollar value (adjusted for inflation) of aquarium fish catch on each island per fiscal year. Kaua‘i omitted.

The catch of invertebrates is largely confined to O‘ahu. As the number of fish caught has dropped, the number of invertebrates has increased (Figure 7). Over the last 10 years 99% of all such animals were caught on O‘ahu. In 1997 and 1998, 5000-6000 invertebrates of 22 species were caught on Hawai‘i island but numbers dropped rapidly to just dozens in recent years. The majority of these animals were shrimps, especially the red striped shrimp *Saron marmoratus* (45% of catch). Similarly Maui had short-lived peaks of invertebrate catches around 1993, primarily echinoderms, hermit crabs, and pencil urchins, and then again in 2003 (hermit crabs collected on Moloka‘i).

The O‘ahu invertebrate catch has been dominated in recent years by a relatively few species. Over the past 10 years the top 10 species have accounted for 95% of the catch. Two groups in particular are the main target of collectors: feather duster worms (*Sabellastarte sanctijosephi*) and hermit crabs (species not specified) (Figure 8). The collection of hermit crabs has increased dramatically on O‘ahu and to a lesser extent on Maui. On O‘ahu alone over 291,000 hermits were caught last year. The unit value per crab over the last five years has been $.11 while feather dusters bring in $1.15. Feather dusters appear to be collected mostly from in and around Kāne`ohe Bay. It is unclear where on O‘ahu hermits are being collected because catch reports do not specify localities, but there is some indication that the Kāne`ohe Bay region is key.

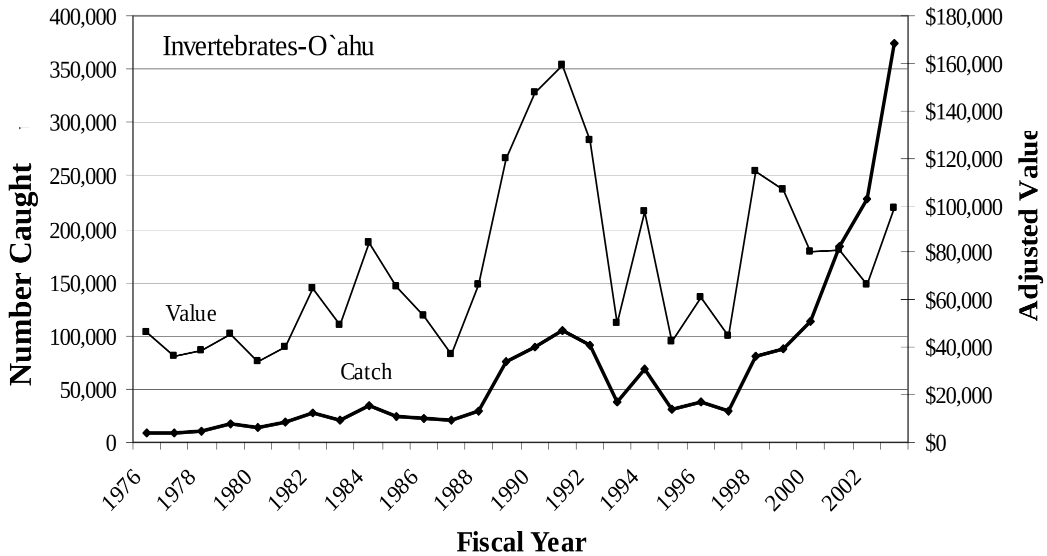

Figure 7. Number of invertebrates caught on O'ahu per fiscal year and dollar value (adjusted for inflation).

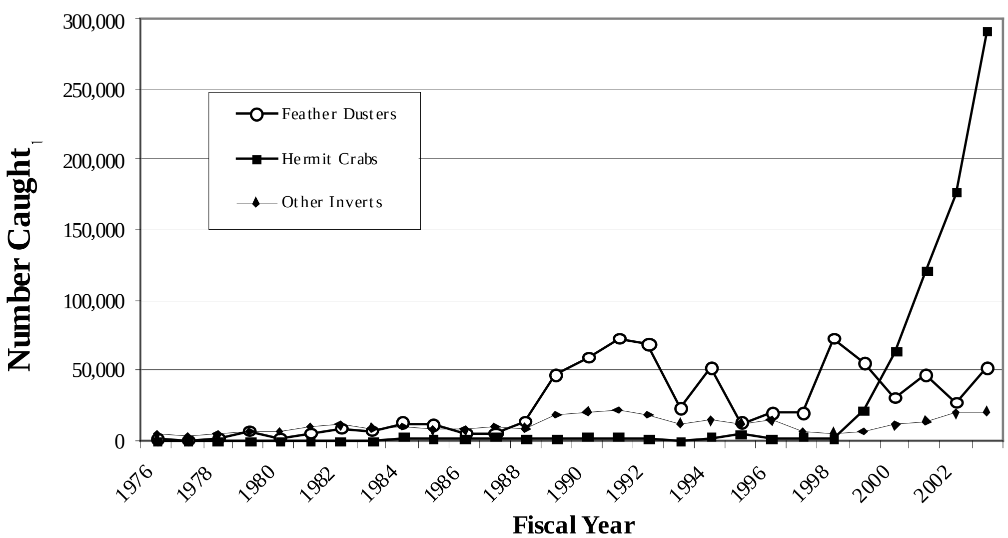

Figure 8. Number of invertebrates caught on O'ahu per fiscal year. "Other Inverts" refers to 3-10th most abundant species caught.

Hurricane Effects

Three major storms struck the Hawaiian Islands during the past twenty-five years. The earliest one was a large three-day "Kona" storm, which occurred during January, 1980. This storm was one of the most severe of its type in at least 20 years (Hawai'i County Civil Defense). The effects of this storm on the coral reefs of Hawai'i island were substantial (Dollar 1982, Dollar and Tribble 1993) but patchy. Effects on the fish community were ameliorated by the presence of deeper-water refuges and remaining undamaged areas (Walsh 1983). The effect of this storm on other islands remains unclear, although at least one area of leeward O'ahu (Kahe Pt.) suffered extensive coral damage. Thirty of 32 coral-monitoring stations at Kahe showed reductions in coral coverage up to 100% at some stations (Mean = 52±6.4% SE) (Coles and Brown, in prep.).

Subsequent to this storm, two major hurricanes struck the islands with substantial impacts on O‘ahu and Kaua‘i. On November 23, 1982 Hurricane ‘Iwa passed to the southwest of O‘ahu, striking Kaua‘i. The hurricane generated maximum waves of 9-14.8m (Dengler et al. 1984, Coles and Brown in prep). On September 11, 1992, Hurricane ‘Iniki passed to the west of O‘ahu, again striking Kaua‘i. ‘Iniki was the most powerful hurricane to strike the Hawaiian Islands in recent history. The areas most affected on O‘ahu were the leeward coast, with lesser damage along the south shore (Rosendale web site).

Coral and habitat damage as a result of ‘Iwa were substantial on Kaua‘i and parts of O‘ahu (W. Aila, pers. comm.). According to an undated, anonymous DAR report, ‘Iwa damaged “extensive inshore reef areas, especially the prime aquarium fishing grounds along O‘ahu’s western coast.” Pfeffer and Tribble (1985) similarly noted that ‘Iwa resulted in extensive subtidal damage along the west and south shores of O‘ahu. The majority of coral 30’ to 150’ deep were severely damaged and most small coral patch reefs were destroyed. ‘Iniki also impacted coral reef communities on O‘ahu (Brock 1996, Coles and Brown, in prep.) but limited evidence suggests the effects may have been less than with ‘Iwa (Miyasaka 1994).

With one notable exception, the overall effects of either of these two hurricanes on the O‘ahu aquarium fishery have not been well documented. The exception is the study done by two collectors (Pfeffer and Tribble 1985) on the effects of ‘Iwa on their collection efforts. The data in the study was based upon billing invoices compiled from collecting trips over several years before and after the hurricane. The area collected on the south shore of O‘ahu (‘Ewa) is termed Zone 401 on the monthly catch report forms.

Pfeffer and Tribble reported that their catch (and gross earnings) declined markedly after the storm. This was most apparent for yellow tangs (*Zebrasoma flavescens*), which was one of their primary targets. In the weeks following the storm, numerous dead and injured fish were observed and many appeared stunned and disoriented. Shortly after the storm, some fish could even be caught by just allowing them to swim into an open collection container. Observations also revealed that many fish had migrated to areas that escaped major damage. Catches at some of these sites increased and remained high after the hurricane. Subsequently, however, catches declined. The authors attribute this decline to increased fishing pressure in these areas. With the loss of collecting habitat, collectors concentrated their efforts in those sites still economically utilizable. In some cases the numbers of collectors working a particular area also increased. The net result was that storm effects combined with overfishing resulted in the collapse of the aquarium fishery along this portion of the O‘ahu coastline.

Catch report data was used to examine possible hurricane effects on the O‘ahu aquarium fishery. The first approach specifically examined those areas deemed to be most impacted by the storms (Figure 9). For presentation purposes, the west coast zones were combined into two sections.

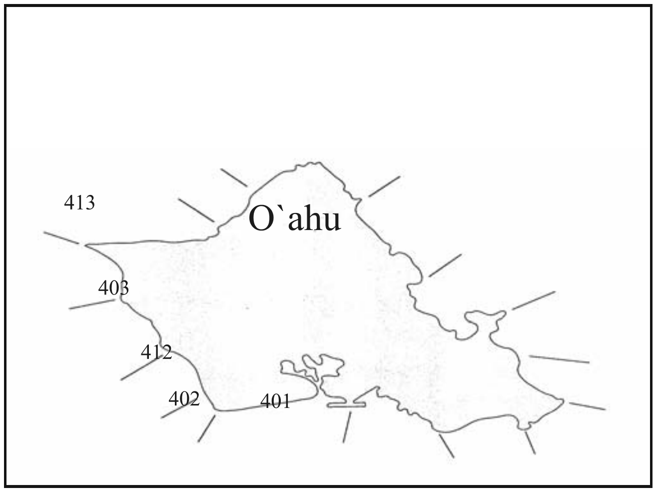

Figure 9. C-6 Aquarium Fish Catch Report zones for southwest O‘ahu.

The number of commercial permittees reporting catch in these areas is shown in Figure 10. These zones constituted the heart of the early O‘ahu fishery and to a large part determined the overall statewide patterns (e.g. Figure 1). It is clear that the number of collectors working all these areas had declined substantially prior to ‘Iwa. As noted before, this contraction may have been due to an economic recession. Subsequent to this period, the number of collectors working these areas was relatively stable. This is not to say that the same individual collectors were present during this time, however. Apparently, subsequent to ‘Iwa, several O‘ahu collectors relocated to Maui or Hawai‘i.

The number of fish caught in these zones varied widely over this time period (Figure 11). Zone 401, the area reported on by Pfeffer and Tribble, showed an overall increase in the year following the storm and then a pattern of valleys and peaks afterwards. Average fish catch in the years after ‘Iwa was quite comparable to the years prior to the storm. The maintenance of catch numbers may have been due to a compensatory shift of target species (e.g., *Thalassoma duperrey, Ctenochaetus strigosus*) after more desirable ones, such as yellow tangs, became less abundant (Figure 12). A declining trend was apparent after ‘Iniki and again in recent years. Invertebrates now make up the majority of collected animals in this zone.

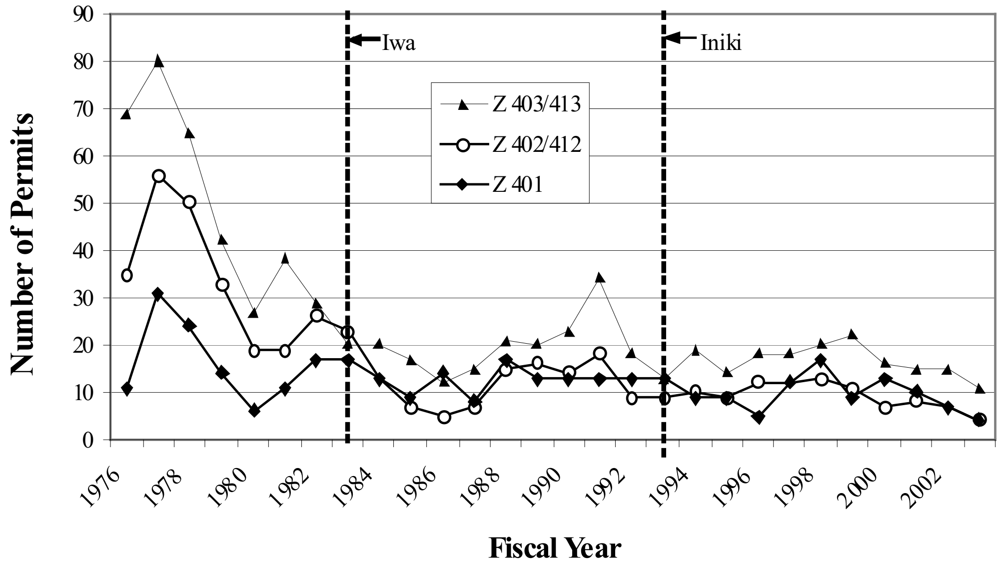

Figure 10. Number of aquarium permittees reporting catch from southwest O'ahu reporting zones.

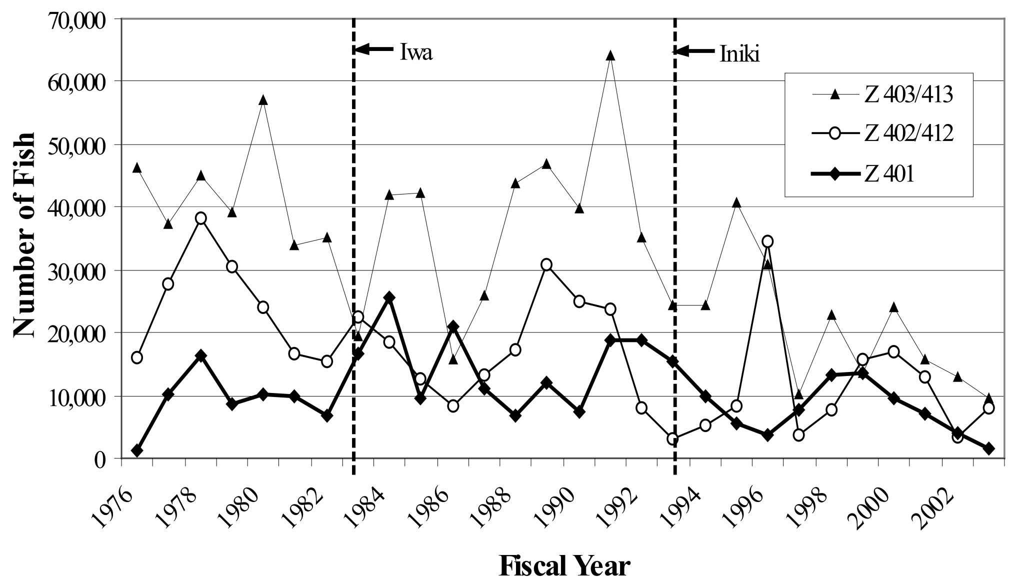

Figure 11. Number of fish caught of all species in southwest O'ahu reporting zones.

No consistent storm-related decreases are apparent in the other two zones. Both areas had markedly declining catches *prior* to the hurricanes and, in three out of the four cases, catch increased over the subsequent year or two. As with zone 401, recent fish catch in these areas is on a decidedly downward trend, and in zone 403/413 (Wai`anae), invertebrates now make up the majority of collected animals.

The temporal pattern of the yellow tang catch in the pre-‘Iwa period (Figure 12) closely tracks that of the total catch, highlighting the importance of this species in the fishery at that time. The highly variable but general decline in catch from the late 1970s and early 1980s may be due to the reduction in the number of commercial collectors. Although Pfeffer and Tribble reported that their catch of yellow tangs decreased markedly after ‘Iwa, in fact, the overall catch in the area increased both during the year of the storm (FY 1983) and the year after. This apparent contradiction may be due to an increase in the number of collectors working the zone in response to loss of their collecting areas elsewhere. This increase was relatively short-lived, however, as the number of collected tangs subsequently plummeted with only a single exception, FY 1992, the year before ‘Iniki.

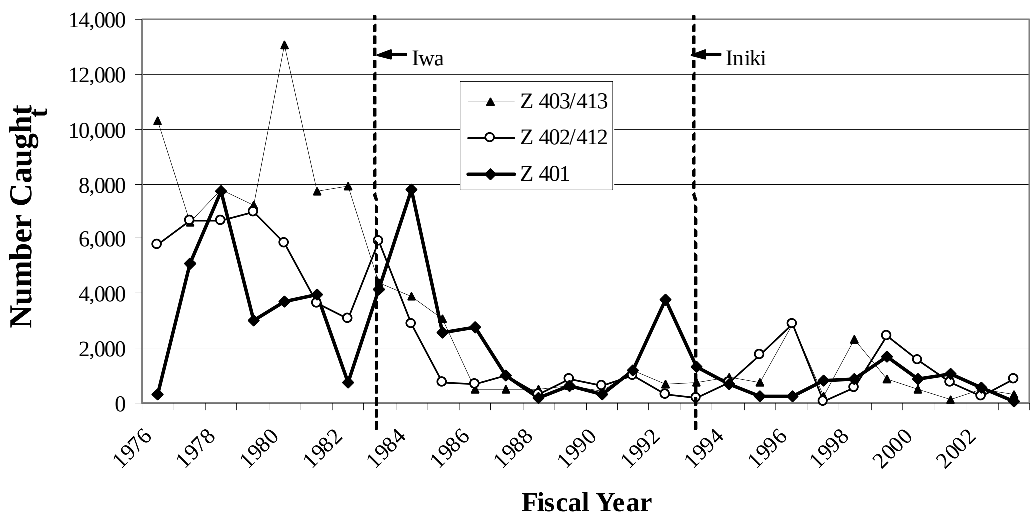

Figure 12. Number of yellow tangs caught in southwest O‘ahu reporting zones.

The two other areas along the west coast of the island also showed clear and persistent declines in yellow tang catch after ‘Iwa. Given the desirability of the species within the aquarium trade, these declines undoubtedly reflect low numbers of yellow tangs on the reefs, at least a decline in the number of small individuals. The aquarium fishery primarily targets young of the year and small, sexually-immature individuals. These size classes are strongly associated with a finger coral (*Porites compressa)* habitat (Walsh 1984) and may recruit preferentially to this habitat. This habitat is very vulnerable to destruction by unusually large storms such as ‘Iwa and ‘Iniki. It is not unreasonable that substantial reduction of suitable finger coral habitat will result in reduced recruitment and/or increased recruit mortality. Given that even very small (5 cm.) recently-recruited yellow tangs are marketable (D. Dart, pers. comm.), it is likely that the overall poor catch in recent years is due to low recruitment levels. The small peaks in the years after ‘Iwa likely reflect recruitment pulses of yellow tangs. It is interesting to note the yearly asynchrony of some of the peaks in these three geographically proximate locales.

Examination of changes in the effort involved in catching aquarium specimens over time would seem to be an appropriate method to assess the impacts of these hurricanes. Unfortunately Catch per Unit Effort (CPUE) data derived from the aquarium catch reports is fraught with uncertainties. Collectors use varying techniques, they often work in teams which change over time, and some target primarily invertebrates while others target fish and some target both. Varying interpretations of what constitutes actual (i.e., reported) collecting time further confounds the situation. Nevertheless, an attempt was made to pull together CPUE information for the three areas under consideration. In an effort to increase the reliability of the data, two separate CPUEs were calculated, one for fish and one for invertebrates. Only permittees reporting just fish or just invertebrates were included in the CPUE calculations. As the invertebrate fishery is largely a recent development, only fish CPUE data are presented.

Even with these adjustments, CPUE values often vary wildly from one year to the next (Figure 13), and clear and consistent hurricane effects are difficult to discern. In zone 401 and to a lesser extent in zone 403/413, an increase in CPUE the year of ‘Iwa then subsequently decreased. The CPUE was of a similar magnitude, however, as that which had occurred several years earlier in FY 1980, the year of the previously-mentioned “Kona” storm. It is possible that both these increases were directly related to storm effects on species catchability. In contrast to these two areas, 403/414 showed a slight decrease in CPUE the year of ‘Iwa and then an increase afterwards.

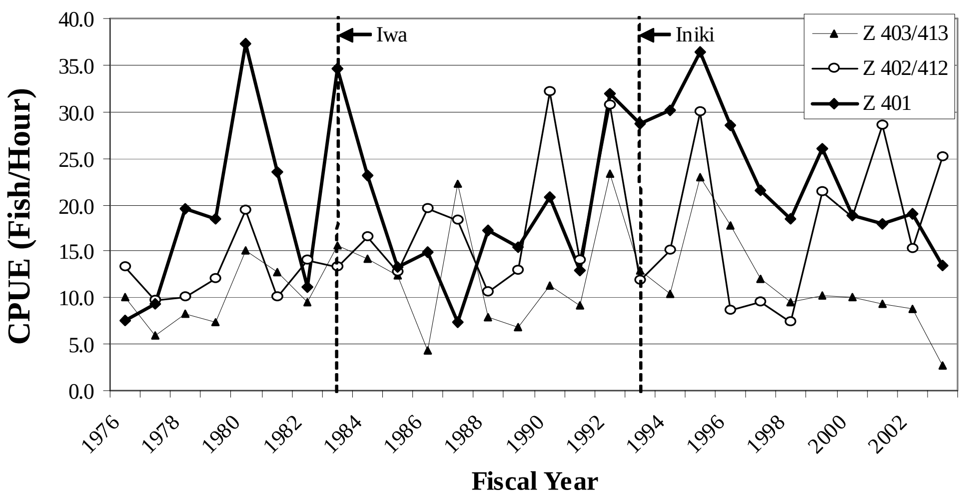

Figure 13. Catch per Unit Effort (CPUE) data for fish in southwest O‘ahu reporting zones. CPUE was calculated per permit per area per month, and fiscal year CPUE is the average of all these values.

The pattern during ‘Iniki is in marked contrast to the pattern during ‘Iwa in that all areas had a decline in CPUE followed by a peak two years later (FY 1995). Dramatic declines subsequently followed, and in two of the areas have continued to the present time. This pattern suggests that in recent years it is getting increasingly more difficult to collect aquarium fishes in these areas.

Although caution is called for in interpreting the CPUE findings, these, along with other indications, seem to clearly indicate the southwest O'ahu aquarium fishery is not what it once was. Indeed the O'ahu fishery as a whole is not static, but rather is a dynamic entity which has changed in response to physical, fishery, market, and economic factors. On a geographic basis there has been a major shift in the fishery from the west side to the east over the past 27 years (Figure 14). The proportion of fish and invertebrates caught along the west coast is significantly less in the present period (1994-2003) than it was in the years 1976-1982 (1 way ANOVA with Tukey's test P<0.001, P<0.012). Conversely, the east side has significantly increased its proportion of both fish and invertebrate catch during these periods (P=0.004, P<0.001). The north shore has also become a more important collection area for fish (P<0.001). The south shore has not changed significantly.

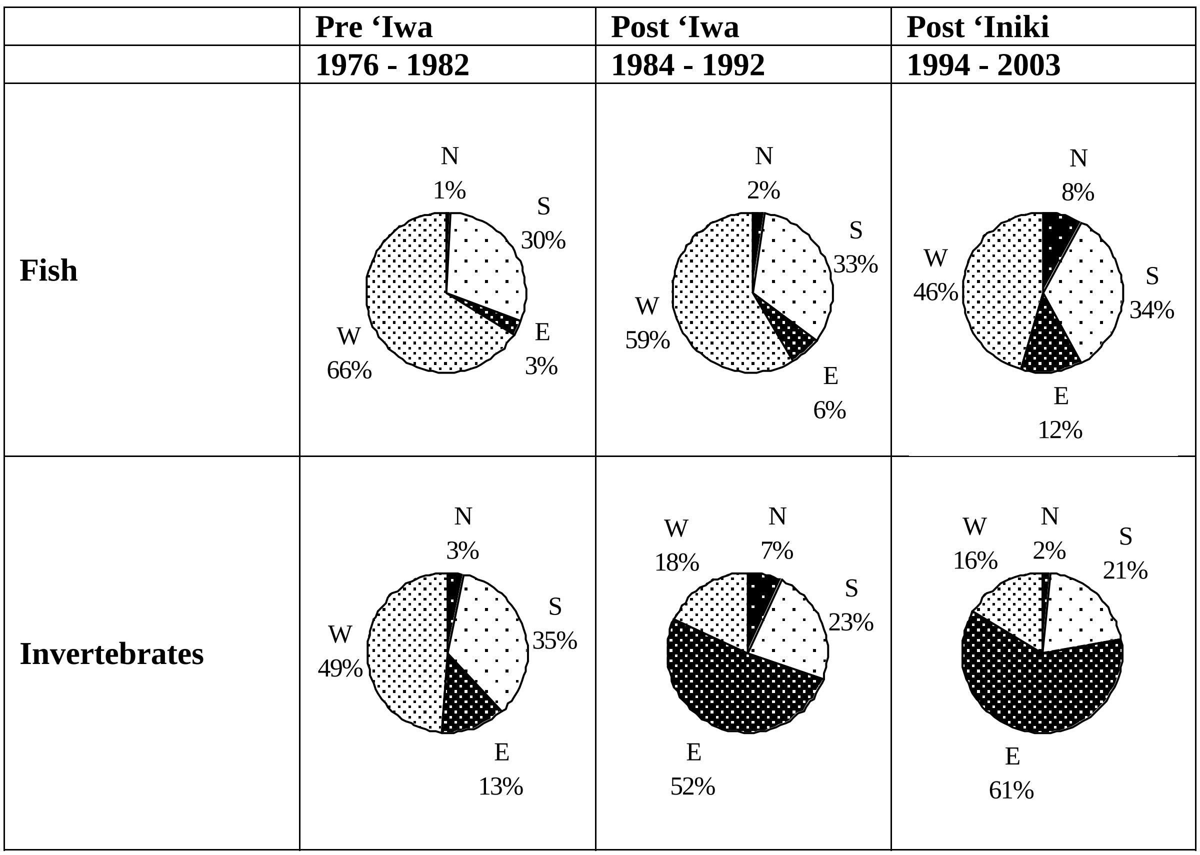

Figure 14. Average proportion of fish and invertebrate catch from four geographic sectors of O'ahu over three hurricane-related time periods. Data from the fiscal years of hurricane 'Iwa and 'Iniki are omitted.

The West Hawai'i Fishery

In contrast to O'ahu, the aquarium fishery in West Hawai'i has undergone dramatic expansion over the past twenty years (Table 3, Figs. 5 and 6). The majority of animals caught in the state and their resulting value now come from the Big Island, and almost all of that (98.6%) from

West Hawaiʻi. Invertebrates constitute a minor component of the West Hawaiʻi catch (.02% of catch and value).

Table 3. Changes in West Hawaiʻi aquarium fishery over last twenty years. Dollar Value is adjusted for inflation.

	FY 1983	FY 2003	Δ
No. Permits	5	33	660% ↑
Total Catch	30,000	243,908	813% ↑
Total Value	$159,756	$722,255	452% ↑
% of State Fish Catch	27%	75%	47%↑
% of State Total Catch	23%	55%	32% ↑
% of State Value	36%	68%	32% ↑

This growth has not come without controversy and conflict, however (Walsh 1978; Randall 1978; Taylor 1978; Walsh 1999). In response to growing public concern over the impacts of collecting on nearshore coral reef communities, a number of initiatives were developed to address the issue. An informal 'Gentlepersons' Agreement" was worked out among user groups in 1987 whereby collectors would refrain from collecting in certain areas. In 1991 these areas were incorporated into four no-collecting zones (Kona Coast Fishery Management Area) totaling approximately 4 miles of coastline. The next year, a Marine Life Conservation District (MLCD) of 1.3 mi. was established at the Old Kona Airport, where collecting was also precluded.

Public concern continued to escalate as the aquarium fishery further expanded. Despite widespread anecdotal reports of impacts, clear scientific evidence of overfishing was lacking. An early 1974 attempt to investigate the impact of aquarium collecting (Nolan 1978) reported that collecting had no significant effects. This study was fraught with methodological problems and the results are suspect (Tissot and Hallacher, in press). It was also conducted during a period of substantially less collection. (Figure 5). In the mid-1990s, DAR contracted with the University of Hawaiʻi Hilo to conduct research to assess impacts of aquarium collecting along the Kona Coast of Hawaiʻi. This paired control-impact study (Tissot and Hallacher 1999, in press) found that the numbers of 7 of 10 aquarium species surveyed were significantly reduced by collecting. The magnitude of the percent reduction in abundance at collection sites ranged from 38% (*Chaetodon multicinctus*) to 75% (*Chaetodon quadrimaculatus*). In contrast, only two non-aquarium species (*Stegastes fasciolatus* and *Paracirrhites arcatus*) exhibited a significant difference in numbers.

In response to a perceived lack of success in adequately dealing with aquarium collecting, a grassroots organization of citizens successfully lobbied for legislation to control collecting. In 1998, the state legislature passed Act 306, which established a West Hawaiʻi Regional Fisheries Management Area to provide for effective management of marine resources. Among a number of provisions was the requirement to establish Fish Replenishment Areas (FRAs) where aquarium collecting would be banned. The West Hawaiʻi Fisheries Council, composed of stakeholders and government representatives, developed a network of nine FRAs encompassing 35.2% (including existing protected areas) of the coastline (Walsh 1999; Capitini, in prep.).

Research is presently underway (WHAP-West Hawai‘i Aquarium Project) to evaluate the effectiveness of these reserves and to better understand the ecological dynamics of the nearshore reef environment. Preliminary analysis (Tissot et al., in press) indicates that three years after closure of the FRAs there have been significant increases in the overall abundance of fishes targeted by collectors. Two species, the yellow tang and Potter's angelfish (*Centropyge potteri*), showed significant (74-80%) increases in FRAs relative to previously protected reference areas. Furthermore, no aquarium fishes declined in abundance in open areas as might be expected if the intensity of harvesting increased outside of the FRAs. In fact, two species displayed significant increases in abundance in the open areas. Thus early results of this study demonstrate that MPAs can be a highly effective strategy for managing these resources (Friedlander, 2001).

After two years of declining yellow tang catch subsequent to the implementation of the FRAs, the numbers caught have increased in FY 2003 (Figure 15). This is due primarily to successful recruitment of this as well as several other species in the summer of 2002. Good recruitment was also apparent this past summer (2003). Of special note is the fact that the dollar value of each yellow tang has increased in the past two years. Indeed, the overall value of the West Hawai‘i aquarium fishery in FY 2003 is the highest it has ever been (Figure 6).

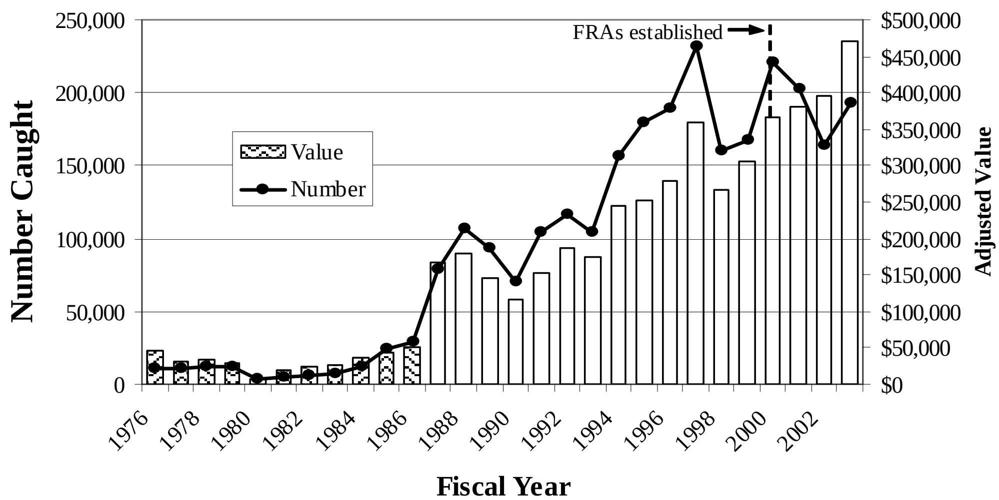

Figure 15. Number and value (adjusted for inflation) of yellow tangs caught in West Hawai‘i per fiscal year.

The trends for the four next most heavily collected species are shown below (Figure 16). Kole (*Ctenochaetus strigosus*) catch has been consistently increasing since the late 1980s and now ranks second in collected fishes both in West Hawai‘i and statewide. Catch in FY 2003 is the highest it has even been. In contrast, catch of the clown tang (*Acanthurus achilles*) has been in decline since FY 1990.

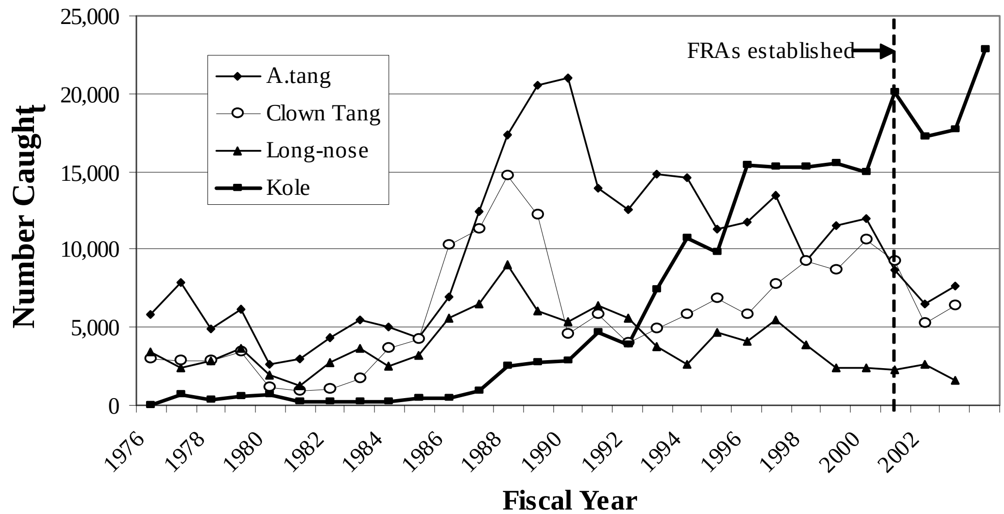

Figure 16. Number caught of top 2nd-5th West Hawai‘i species per fiscal year.

CPUE has historically been the highest in West Hawai‘i (Figure 17) due in large part to the abundance of and relative collecting ease of commonly targeted surgeonfishes. There appears to be a substantial decrease in CPUE in West Hawai‘i coincident with FRA establishment. This could possibly reflect an increase in travel and dive time as collectors work unfamiliar areas distant from their previous ones. The average CPUE for West Hawai‘i over the last ten years (37.7 ±16.8 SD fish/hour) is considerably higher than that reported for other areas such as Australia (20-45 fish/day), Cook Islands (24-36 fish/day), and Sri Lanka (30-50 fish/day) (Wood, 2001). As noted previously CPUE data is by far the weakest part of the aquarium catch report data, and these findings must be viewed cautiously.

One of the caveats implicit with catch report analyses is that catch report data accurately reflect what is being caught. At present there is no provision or means to verify this information. DAR is working to change this. In an effort to gain insight into the limitations of the catch report data, an analysis was done on the West Hawai‘i reports. For each month over two time periods, the required catch report was sorted as to whether it indicated catch, no catch, or had not been filed (i.e., no report) (Figure 18). The two time periods were demarcated by the date of a letter sent to all West Hawai‘i collectors from DAR reminding them of the requirement to file monthly catch reports. It is clear that a substantial number of collectors are not complying with the reporting requirement. Many of these delinquencies were from short-term and/or part-time collectors, but several of the more active collectors were delinquent as well. Of all 97 collectors who were active over these two periods, only 14% filed every required monthly catch report. It is likely that report compliance is as poor or worse on the other islands, where less attention is paid to the fishery. The mailing to the collectors did have a positive effect and significantly improved reporting compliance (X^2=30.18, P<0.001). With additional effort and appropriate enforcement this situation will improve.

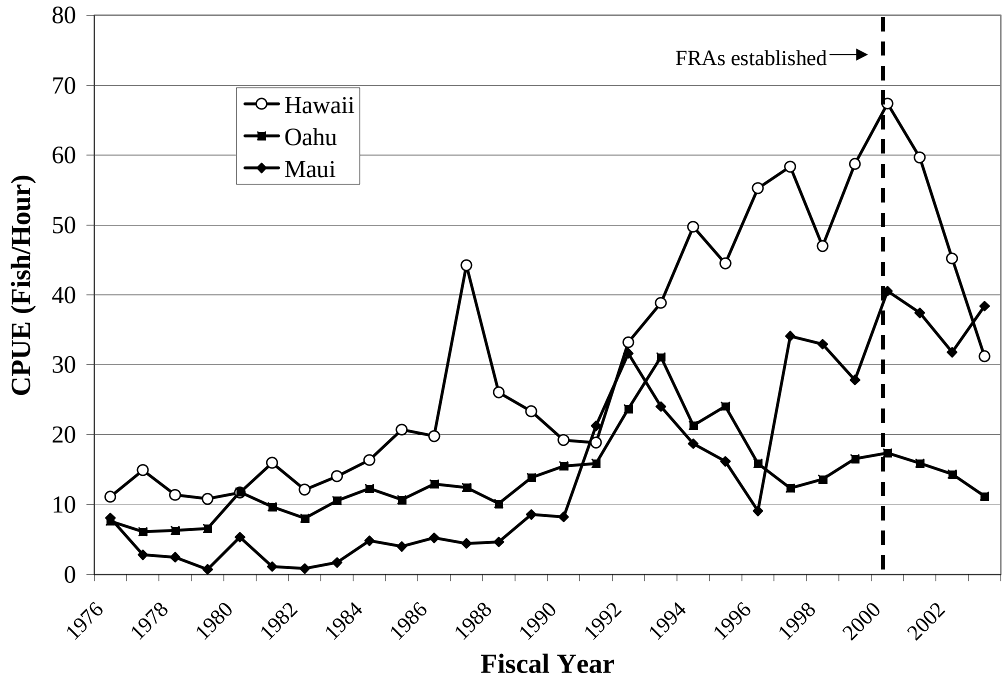

Figure 17. Catch per unit effort for Hawai'i collecting areas. Maui includes the islands of Maui, Moloka`i and Lana`i.

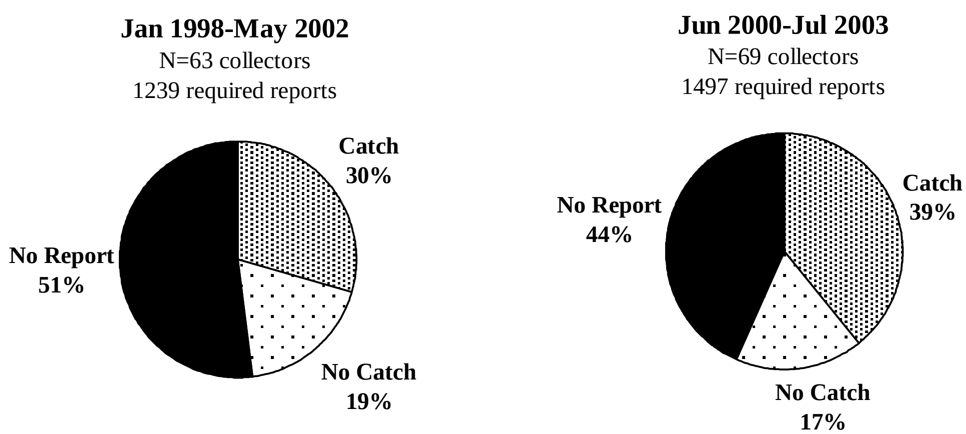

Figure 18. Aquarium catch report compliance for West Hawai'i collectors over two time periods.

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Appendix A. List of all taxa collected statewide for period FY 1967-2003 ranked by number caught. Total value is not adjusted for inflation.

Taxa	Common Name	Type	# Caught	Total Value
Zebrasoma flavescens	Yellow Tang	Fish	3,386,860	$ 5,567,252.60
Sabellastarte sanctijosephi	Feather Duster Worm	Invert	741,949	$ 860,362.09
Hermits Miscellaneous	Hermits Miscellaneous	Invert	707,654	$ 95,341.03
Ctenochaetus strigosus	Goldring Surgeonfish	Fish	346,944	$ 519,922.12
Acanthurus achilles	Achilles Tang	Fish	337,781	$ 1,197,423.19
Naso lituratus	Orangespine Unicornfish	Fish	298,884	$ 888,861.14
Centropyge potteri	Potter's Angelfish	Fish	287,668	$ 845,679.09
Forcipiger flavissimus	Forcepsfish	Fish	251,523	$ 537,155.00
Zanclus cornutus	Moorish idol	Fish	187,662	$ 445,958.61
Halichoeres ornatissimus	Ornate Wrasse	Fish	121,766	$ 190,280.77
Chaetodon multicinctus	Multiband Butterflyfish	Fish	111,454	$ 115,515.53
Chaetodon quadrimaculatus	Fourspot Butterflyfish	Fish	109,021	$ 226,275.92
Chaetodon miliaris	Milletseed Butterflyfish	Fish	105,411	$ 104,052.83
Lysmata amboinensis	Cleaner Shrimp	Invert	86,862	$ 178,283.07
Canthigaster jactator	HawaiianWhitespotted Toby	Fish	69,869	$ 66,760.97
Chaetodon unimaculatus	Teardrop Butterflyfish	Fish	69,033	$ 142,611.23
Ostracion meleagris	Spotted Boxfish	Fish	63,482	$ 149,856.61
Anampses chrysocephalus	Psychedelic Wrasse	Fish	62,481	$ 179,068.71
Thalassoma duperrey	Saddle Wrasse	Fish	53,220	$ 61,164.90
Labroides phthirophagus	Hawaiian Cleaner Wrasse	Fish	51,650	$ 158,839.06
Coris gaimard	Yellowtail Coris	Fish	51,052	$ 153,698.17
Chaetodon fremblii	Bluestripe Butterflyfish	Fish	50,280	$ 87,290.92
Dascyllus albisella	Hawaiian Dascyllus	Fish	49,930	$ 47,928.05
Crabs Miscellaneous	Crabs Miscellaneous	Invert	49,338	$ 53,798.20
Chaetodon kleinii	Blacklip Butterflyfish	Fish	47,397	$ 45,890.15
Stenopus hispidus	Coral-banded Shrimp	Invert	41,460	$ 45,529.24
Heniochus diphreutes	Pennantfish	Fish	41,320	$ 79,796.57
Forcipiger longirostris	Longnose Butterflyfish	Fish	40,630	$ 82,474.29
Anemones	Anemones	Invert	37,978	$ 57,830.55
Chaetodon lunula	Raccoon Butterflyfish	Fish	37,470	$ 104,793.79
Hippolytidae	Green Shrimp	Invert	34,740	$ 31,708.58
Cirrhitops fasciatus	Redbar Hawkfish	Fish	33,449	$ 47,173.50
Macropharyngodon geoffroy	Shortnose Wrasse	Fish	33,172	$ 44,841.15
Pseudocheilinus octotaenia	Eightline Wrasse	Fish	32,169	$ 56,630.63
Saron marmoratus	Marbled Shrimp	Invert	30,759	$ 37,481.20
Canthigaster coronata	Crown Toby	Fish	30,146	$ 33,046.50
Sea-Stars Miscellaneous	Sea-Stars Miscellaneous	Invert	29,020	$ 29,493.37
Sargocentron xantherythrum	Hawaiian squirrelfish	Fish	27,917	$ 25,988.55
Centropyge fisheri	Fisher's angel	Fish	26,947	$ 72,694.03
Chaetodon auriga	Threadfin Butterflyfish	Fish	25,640	$ 64,284.09
Sea Cucumbers	Sea Cucumbers	Invert	25,030	$ 21,673.05
Pervagor spilosoma	Fantail Filefish	Fish	25,007	$ 27,279.53
Gomphosus varius	Bird Wrasse	Fish	24,799	$ 86,095.56
Ctenochaetus Hawai'i ensis	Black Surgeonfish	Fish	24,600	$ 265,244.60
Acanthurus olivaceus	Orangeband Surgeonfish	Fish	22,107	$ 40,349.63
Shrimp Miscellaneous	Shrimp Miscellaneous	Invert	20,585	$ 27,297.45
Echinoderms	Echinoderms	Invert	18,845	$ 17,659.35
Pseudojuloides cerasinus	Smalltail Wrasse	Fish	18,807	$ 28,300.50

Taxa	**Common Name**	**Type**	**# Caught**	**Total Value**
Chaetodon ornatissimus	Ornate Wrasse	Fish	17,554	$ 31,931.97
Paracirrhites arcatus	Arc-eye Hawkfish	Fish	17,300	$ 21,502.04
Naso unicornis	Bluespine Unicornfish	Fish	17,193	$ 32,968.05
Pseudanthias bicolor	Bicolor Anthias	Fish	16,957	$ 49,190.25
Desmoholacanthus arcuatus	Bandit Angelfish	Fish	16,828	$ 171,041.24
Pseudanthias thompsoni	Thompson's Anthias	Fish	16,716	$ 46,005.55
Holocentridae	Squirrelfish/Soldierfish	Fish	16,109	$ 18,685.90
Taenianotus triacanthus	Leaf Scorpionfish	Fish	15,216	$ 31,089.84
Xanthichthys mento	Crosshatch triggerfish	Fish	15,193	$ 59,861.35
Cirrhilabrus jordani	Flame Wrasse	Fish	13,919	$ 133,166.40
Limu	Limu	Algae	13,483	$ 10,477.50
Heterocentrotus mammillatus	Red Pencil Urchin	Invert	13,310	$ 19,754.03
Labridae sp.	Wrasse	Fish	13,306	$ 22,144.00
Sufflamen bursa	Lei Triggerfish	Fish	12,920	$ 19,620.67
Bodianus bilunulatus	Hawaiian Hogfish	Fish	12,917	$ 22,659.00
Dardanus gemmatus	Jeweled Anemone Crab	Invert	12,878	$ 16,008.10
Hemitaurichthys polylepis	Pyramid Butterflyfish	Fish	11,685	$ 35,316.98
Priacanthus sp.	Bigeye	Fish	11,597	$ 15,829.25
Rhinecanthus rectangulus	Reef Triggerfish	Fish	11,369	$ 32,059.01
Acanthurus triostegus	Convict Tang	Fish	11,294	$ 11,255.65
Stethojulis balteata	Belted Wrasse	Fish	11,290	$ 20,316.37
Aulostomus chinensis	Trumpetfish	Fish	10,827	$ 22,032.55
Urchins Miscellaneous	Urchins Miscellaneous	Invert	10,631	$ 10,017.22
Cantherhines dumerilii	Barred Filefish	Fish	10,452	$ 9,705.10
Acanthurus nigricans	Goldrim Surgeonfish	Fish	9,747	$ 40,236.85
Melichthys niger	Black Durgon	Fish	9,605	$ 25,174.84
Cowries Misc.	Cowries Misc.	Invert	9,198	$ 6,874.40
Pseudocheilinus tetrataenia	Fourline Wrasse	Fish	8,978	$ 35,330.75
Naso sp.	Unicorn sp.	Fish	8,845	$ 31,386.70
Worm	Worm	Invert	8,710	$ 6,754.50
Acanthurus thompsoni	Thompson's Surgeonfish	Fish	8,642	$ 19,236.10
Nudibranchs Miscellaneous	Nudibranchs Miscellaneous	Invert	8,244	$ 8,713.00
Pseudocheilinus evanidus	Disappearing Wrasse	Fish	8,159	$ 10,784.15
Gymnothorax eurostus	Stout Moray	Fish	8,098	$ 23,630.05
Zebrasoma veliferum	Sailfin tang	Fish	7,863	$ 31,468.35
Novaculichthys taeniourus	Rockmover Wrasse	Fish	7,799	$ 27,968.10
Balistidae	Triggerfish Misc.	Fish	7,532	$ 17,089.30
Anampses cuvier	Pearl Wrasse	Fish	7,049	$ 20,579.55
Thalassoma trilobatum	Christmas Wrasse	Fish	6,716	$ 14,921.65
Melichthys vidua	Pinktail Durgon	Fish	6,635	$ 21,074.99
Worms Miscellaneous	Worms Miscellaneous	Invert	6,483	$ 4,654.40
Chromis ovalis	Oval Damselfish	Fish	6,385	$ 4,791.50
Gymnomuraena zebra	Zebra Moray	Fish	6,320	$ 35,248.65
Acanthurus nigrofuscus	Brown Surgeonfish	Fish	6,269	$ 10,468.22
Chaetodon tinkeri	Tinker's Butterflyfish	Fish	6,186	$ 353,240.45
Lactoria fornasini	Thornback Cowfish	Fish	6,165	$ 9,455.05
Molluscs Miscellaneous	Molluscs Miscellaneous	Invert	5,917	$ 1,802.55
Enoplometopus occidentalis	Red Reef Lobster	Invert	5,878	$ 21,028.95
Lutjanus kasmira	Bluestripe Snapper	Fish	5,615	$ 6,967.05
Exallias brevis	Shortbodied Blenny	Fish	5,090	$ 15,472.15
Paracirrhites forsteri	Blackside Hawkfish	Fish	4,999	$ 10,639.10
Acanthurus dussumieri	Eye-stripe Surgeonfish	Fish	4,981	$ 9,597.75

Taxa	**Common Name**	**Type**	**# Caught**	**Total Value**
Hymenocera picta	Harlequin Shrimp	Invert	4,731	$ 31,350.80
Centropyge loricula	Flame angelfish	Fish	4,707	$ 44,968.70
Dendrochirus barberi	Hawaiian Lionfish	Fish	4,643	$ 9,511.20
Sargocentron diadema	Crown Squirrelfish	Fish	4,624	$ 5,201.25
Hemitaurichthys thompsoni	Thompson's Butterfly	Fish	4,511	$ 7,237.25
Blenniidae	Blenny	Fish	4,107	$ 7,604.70
Coris venusta	Elegant Coris	Fish	4,009	$ 8,743.65
Echidna nebulosa	Snowflake Moray	Fish	3,982	$ 22,246.50
Coris ballieui	Lined Coris	Fish	3,919	$ 7,916.10
Arothron meleagris	Spotted Pufferfish	Fish	3,813	$ 8,069.70
Pterois sphex	Hawaiian Turkeyfish	Fish	3,680	$ 13,459.45
Medusa worms	Medusa Worms	Invert	3,586	$ 5,006.75
Panulirus marginatus	Spiny Lobster	Invert	3,484	$ 9,377.30
Parapercis schauinslandi	Sand Perch	Fish	3,416	$ 5,522.45
Coris flavovittata	Yellowstripe Coris	Fish	3,337	$ 8,529.20
Diodon holocanthus	Spiny Pufferfish	Fish	3,331	$ 9,868.25
Canthigaster amboinensis	Ambon Toby	Fish	3,271	$ 3,339.65
Cirrhitidae	Hawkfish	Fish	3,151	$ 5,134.50
Sea-Slugs Miscellaneous	Sea-Slugs Miscellaneous	Invert	3,094	$ 4,298.50
Damselfish	Damselfish	Fish	3,093	$ 2,523.20
Arothron hispidus	Stripebelly Pufferfish	Fish	3,048	$ 5,686.20
Antennarius sp.	Frogfish	Fish	3,043	$ 26,567.50
Pleuronectidae	Right-eye Flounders	Fish	2,878	$ 4,118.70
Acanthuridae sp.	Surgeonfish	Fish	2,710	$ 5,078.63
Myripristis berndti	Bigscale Soldierfish	Fish	2,485	$ 5,750.83
Bothus sp.	Lefteye Flounder	Fish	2,457	$ 3,737.30
Chromis vanderbilti	Blackfin Chromis	Fish	2,450	$ 1,828.00
Myripristis amaena	Brick Soldierfish	Fish	2,432	$ 2,842.25
Ostracion whitleyi	Whitley's Boxfish	Fish	2,408	$ 10,329.40
Cirrhitus pinnulatus	Stocky Hawkfish	Fish	2,358	$ 3,814.53
Aniculus maximus	Hairy Yellow Hermit Crab	Invert	2,273	$ 5,015.50
Mulloidichthys vanicolensis	Yellowfin Goatfish	Fish	2,236	$ 2,547.75
Parupeneus multifasciatus	Manybar Goatfish	Fish	2,204	$ 2,760.31
Chaetodon trifasciatus	Oval Butterflyfish	Fish	2,202	$ 4,425.30
Rhinecanthus aculeatus	Lagoon Triggerfish	Fish	2,190	$ 5,845.10
Chaetodontidae	Butterflyfish	Fish	2,149	$ 3,701.59
Diodon hystrix	Porcupinefish	Fish	2,050	$ 5,794.00
Canthigasteridae	Sharpnose Puffer	Fish	2,039	$ 2,537.00
Gymnothorax sp.	Moray eel	Fish	1,915	$ 8,742.75
Poecilidae	Mollies/Guppies	Fish	1,908	$ -
Thalassoma ballieui	Blacktail Wrasse	Fish	1,889	$ 3,097.85
Echidna polyzona	Barred Moray	Fish	1,864	$ 6,476.75
Scarus sp.	Parrotfish	Fish	1,747	$ 10,262.55
Chromis verater	Threespot Chromis	Fish	1,703	$ 1,529.87
Mullidae	Goatfishes	Fish	1,656	$ 2,136.30
Enchelycore pardalis	Dragon Moray	Fish	1,644	$ 73,544.00
Gymnothorax meleagris	Whitemouth Moray	Fish	1,636	$ 7,039.35
Abudefduf abdominalis	Sergeant Major	Fish	1,588	$ 1,420.25
Chaetodon reticulatus	Reticulated Butterflyfish	Fish	1,530	$ 3,945.72
Soft Coral Miscellaneous	Soft Coral Miscellaneous	Invert	1,500	$ -
Cones Misc.	Cones Misc.	Invert	1,492	$ 987.50
Hexabranchus sanguineus	Spanish Dancer	Invert	1,393	$ 3,005.50

Taxa	Common Name	Type	# Caught	Total Value
Iniistius pavo	Peacock Razorfish	Fish	1,317	$ 3,743.10
Lactoria diaphana	Spiny Cowfish	Fish	1,257	$ 2,457.50
Oxycirrhites typus	Longnose Hawkfish	Fish	1,241	$ 13,515.00
Parupeneus porphyreus	Whitesaddle Goatfish	Fish	1,164	$ 2,070.75
Canthigaster epilampra	Lantern Toby	Fish	1,142	$ 2,860.50
Canthigaster rivulata	Maze Toby	Fish	1,109	$ 1,196.95
Scorpaenopsis sp./ *Scorpaena* sp.	Scorpionfish	Fish	1,107	$ 1,608.26
Pseudanthias Hawai'i ensis	Hawaiian Longfin Anthias	Fish	1,080	$ 11,979.50
Snappers	Snappers	Fish	1,057	$ 2,136.25
Cheilio inermis	Cigar Wrasse	Fish	1,021	$ 1,693.50
Gymnothorax flavimarginatus	Yellowmargin Moray	Fish	991	$ 3,566.50
Uropterygius macrocephalus	Largehead Snake Moray	Fish	968	$ 3,885.40
Microcanthus strigatus	Stripey	Fish	930	$ 1,245.25
Scorpaenopsis diabolus	Devil Scorpionfish	Fish	928	$ 1,302.30
Xanthichthys auromarginatus	Gilded Triggerfish	Fish	902	$ 20,604.00
Kuhlia sandvicensis	Hawaiian Flagtail	Fish	876	$ 159.50
Cirripectes vanderbilti	Scarface Blenny	Fish	852	$ 2,379.25
Aluterus scriptus	Scrawled Filefish	Fish	832	$ 1,383.05
Chaetodon ephippium	Saddleback Butterflyfish	Fish	810	$ 2,919.65
Thalassoma lunare	Lyretail Wrasse	Fish	806	$ 1,188.85
Oxycheilinus bimaculatus	Twospot Wrasse	Fish	755	$ 989.20
Dactyloptena orientalis	Helmet Gurnard	Fish	752	$ 2,446.50
Acanthaster planci	Crown-of-thorns Seastar	Invert	746	$ 1,507.55
Scyllarides sp.	Slipper Lobster	Invert	734	$ 1,782.25
Sponges Miscellaneous	Sponges Miscellaneous	Invert	730	$ 1,920.90
Cephalopholis argus	Peacock Grouper	Fish	675	$ 3,874.50
Chaetodon lineolatus	Lined Butterflyfish	Fish	652	$ 3,590.75
Acanthurus blochii	Ringtail Surgeonfish	Fish	632	$ 2,012.55
Plectroglyphidodon imparipennis	Brighteye Damselfish	Fish	617	$ 560.50
Entomacrodus marmoratus	Marbled Blenny	Fish	611	$ 1,037.00
Istiblennius zebra	Zebra Blenny	Fish	607	$ 818.25
Cirripectes obscurus	Gargantuan Blenny	Fish	600	$ 1,392.05
Amblycirrhitus bimacula	Twospot Hawkfish	Fish	599	$ 962.00
Iniistius umbrilatus	Blackside Razorfish	Fish	526	$ 1,932.15
Cantherhines sandwichiensis	Squaretail Filefish	Fish	517	$ 569.75
Cosmocampus balli	Pipefish	Fish	494	$ 2,327.00
Chaetodon citrinellus	Speckled Butterflyfish	Fish	474	$ 693.25
Fistularia commersonii	Cornetfish	Fish	469	$ 61.41
Pervagor aspricaudus	Yellowtail Filefish	Fish	466	$ 882.25
Gymnothorax undulatus	Undulated Moray	Fish	449	$ 1,796.75
Parupeneus pleurostigma	Sidespot Goatfish	Fish	448	$ 537.70
Synodus sp.	Lizardfish	Fish	442	$ 544.00
Carangidae	Jack	Fish	430	$ 1,880.20
Myripristis kuntee	Epaulette Soldierfish	Fish	401	$ 711.50
Scutaria tigrinus	Tiger Moray	Fish	397	$ 1,804.75
Sebastapistes coniorta	Speckled Scorpionfish	Fish	394	$ 581.75
Stenopus pyrsonotus	Flameback Coral Shrimp	Invert	386	$ 1,584.50
Gobiidae sp.	Goby	Fish	382	$ 814.75
Chaetodon trifascialis	Chevron Butterfly	Fish	374	$ 1,054.40
Foa brachygramma	Bay Cardinalfish	Fish	370	$ 486.75
Abudefduf sordidus	Blackspot Sergeant	Fish	355	$ 101.50
Acanthurus thompsoni	Thompson's Surgeonfish	Fish	354	$ 367.50

Taxa	Common Name	Type	# Caught	Total Value
Crayfish	Crayfish	Invert	346	$ 0.01
Plectroglyphidodon johnstonianus	Blue-eye Damselfish	Fish	335	$ 327.25
Cheilodactylus vittatus	Hawaiian Morwong	Fish	329	$ 605.55
Apogon sp.	Cardinal fishes	Fish	293	$ 281.25
Jellyfish	Jellyfish	Invert	283	$ 273.25
Bubble Shells	Bubble Shells	Invert	240	$ 259.25
Myrichthys magnificus	Magnificent Snake Eel	Fish	223	$ 848.25
Conger cinereus	Mustache Conger	Fish	222	$ 711.50
Naso hexacanthus	Sleek Unicornfish	Fish	202	$ 311.50
Grammistidae	Soapfish	Fish	195	$ 473.00
Octopus cyanea	Day Octopus	Invert	187	$ 1,150.00
Thalassoma purpureum	Surge Wrasse	Fish	186	$ 540.00
Naso brevirostris	Paletail Unicornfish	Fish	173	$ 331.00
Chanos chanos	Milkfish	Fish	169	$ 1,171.00
Syngnathidae	Pipefish	Fish	167	$ 147.50
Malacanthus brevirostris	Flagtail Tilefish	Fish	160	$ 636.60
Sebastapistes coniorta	Speckled Scorpion	Fish	156	$ 236.15
Chromis leucura	Whitetail Chromis	Fish	151	$ 144.95
Plagiotremus ewaensis	Ewa Fangblenny	Fish	141	$ 261.00
Gymnothorax steindachneri	Steindachner’s Moray	Fish	124	$ 372.50
Gymnothorax rueppelliae	Banded Moray	Fish	123	$ 400.00
Monotaxis grandoculis	Bigeye Emperor	Fish	123	$ 330.25
Acanthurus leucopareius	Whitebar Surgeonfish	Fish	118	$ 172.90
Thalassoma lutescens	Sunset Wrasse	Fish	117	$ 344.95
Chromis hanui	Chocolate-Dip Chromis	Fish	109	$ 85.00
Stegastes fasciolatus	Pacific Gregory	Fish	100	$ 57.50
Ophichthidae	Snake Eel	Fish	97	$ 417.50
Iniistius sp.	Razor fish	Fish	97	$ 268.05
Acanthurus nigroris	Bluelined Surgeonfish	Fish	94	$ 392.00
Gymnothorax melatremus	Dwarf moray	Fish	93	$ 3,229.50
Brotulidae	Salt-water Cat	Fish	92	$ 197.25
Acanthurus xanthopterus	Yellowfin Surgeonfish	Fish	89	$ 200.00
Mulloidichthys flavolineatus	Yellowstripe Goatfish	Fish	86	$ 135.00
Blenniella gibbifrons	Bullethead Rockskipper	Fish	86	$ 114.50
Caracanthus typicus	HawaiianOrbicular Velvetfish	Fish	80	$ 95.75
Plagiotremus goslinei	Gosline’s Fangblenny	Fish	75	$ 149.50
Cymolutes lecluse	Hawaiian Knifefish	Fish	70	$ 211.50
Upeneus arge	Bandtail Goatfish	Fish	65	$ 86.20
Apogon kallopterus	Iridescent Cardinalfish	Fish	63	$ 42.50
Doryrhamphus excisus	Blue-stripe Pipefish	Fish	61	$ 129.25
Apogon maculiferus	Spotted Cardinalfish	Fish	61	$ 23.50
Acanthurus guttatus	Whitespotted Surgeonfish	Fish	60	$ 829.50
Parupeneus cyclostomus	Blue Goatfish	Fish	49	$ 74.25
Uropterygius sp.	Snake Moray	Fish	47	$ 195.00
Istiblennius sp.	Blenny	Fish	44	$ 65.50
Spratelloides delicatulus	Delicate Roundherring	Fish	41	$ 109.00
Genicanthus personatus	Masked Angelfish	Fish	39	$ 2,829.50
Elagatis bipinnulata	Rainbow Runner	Fish	31	$ 26.00
Sargocentron punctatissimum	Peppered Squirrelfish	Fish	27	$ 15.25
Oxycheilinus unifasciatus	Ringtail Wrasse	Fish	26	$ 43.50
Apogon erythrinus	Hawaiian Ruby Cardinalfish	Fish	26	$ 32.50
Apogon menesemus	Bandfin Cardinalfish	Fish	26	$ 4.00

Taxa	Common Name	Type	# Caught	Total Value
Cantherhines verecundus	Shy Filefish	Fish	25	$ 53.75
Epinephelus quernus	Hawaiian Grouper	Fish	16	$ 49.00
Kyphosus sp.	Sea Chub	Fish	12	$ 36.00
Parupeneus bifasciatus	Doublebar Goatfish	Fish	12	$ 16.00
Decapterus macarellus	Mackerel Scad	Fish	12	$ 12.00
Scarus rubroviolaceus	Redlip Parrotfish	Fish	10	$ 51.00
Neomyxus leuciscus	Sharpnose Mullet	Fish	5	$ -
Mugil cephalus	Striped Mullet	Fish	4	$ 4.50
Hemiramphus sp.	Halfbeaks	Fish	2	$ 80.00
Lutjanus fulvus	Golden Perch	Fish	2	$ -
Plectroglyphidodon sindonis	Rock damselfish	Fish	2	$ -
Polydactylus sexfilis	Six-fingered Threadfin	Fish	2	$ -
Tetraodontidae	Pufferfish	Fish	1	$ 8.95
Elops hawaiensis	Hawaiian Tenpounder	Fish	1	$ 2.00
Pseudocaranx dentex	Thicklipped Jack	Fish	1	$ 2.00
Ranina ranina	Kona Crab	Invert	1	$ 2.00
Baitfish	Baitfish	Fish	1	$ -
Unknown Fish spp.	Unknown Fish spp.	Fish	7,655	$ 17,557.30
Unknown spp.	Unknown spp.	Unknown	5,318	$ 5,739.65
Unknown Invert spp.	Unknown Invert spp.	Invert	876	$ 953.00

Commercial Marine Landings from Fisheries on the Coral Reef Ecosystem of the Hawaiian Archipelago

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Abstract

Hawai‘i has the largest coral reef fishery in the Western Pacific Regional Fishery Management Council's jurisdiction. In 2002, the Council contracted a project to look at the State of Hawai‘i commercial catch data in relation to the Council's Coral Reef Ecosystem Fishery Management Plan, Management Unit Species. On average, a total of 1,352,269 lbs. of coral reef fish are landed annually in Hawai‘i, comprised mainly of goatfishes, soldierfishes, surgeonfishes, parrotfishes, and octopus. However, coral reef landings in Hawai‘i also include the small coastal pelagics, *akule* (Bigeye Scad, *Selar crumenophthalmus*) and ‘*ōpelu* (Mackerel Scad, *Decapterus* spp.), which together comprise 79 % of the catch for 2001. Catches have continued to increase from 1985 to the present, as the population of Hawai‘i has increased. Catch rates are variable, with little evidence of noticeable trends, except for shoreline manual harvests for sea foods such as *limu* (various seaweed) and ‘*opihi* (limpet), which have declined markedly since 1978.

Introduction and Background

The largest of the coral reef fisheries in the Western Pacific is in Hawai‘i. In the recent past, many fishermen have noticed a decline in the coral reef resources. This decline may be due to sedimentation, runoff, pollution, urbanization, habitat degradation and destruction, and overfishing. The latter reason, overfishing, has been suspected as having the greatest effect on the coral reef resources, though the fishery data has never been looked at in great detail.

The extensive commercial fisheries database on Hawai‘i's coral reef fisheries remains largely unexplored. This database, maintained and managed by State of Hawai‘i Department of Land and Natural Resources (DLNR), Division of Aquatic Resources (DAR), contains records as far back as 1948, but data earlier than Fiscal Year 1966 are questionable due to inaccuracies in reporting and problems with licensing. Further, the licenses given to commercial fishermen were recycled every year up until 1992, when a permanent license was implemented.

Currently, commercial catch data are the only available data in Hawai‘i for coral reef fisheries resources. However, recreational and subsistence coral reef fisheries in Hawai‘i may play a bigger role in the overall fishery of Hawai‘i. The Hawai‘i Marine Recreational Fisheries Survey (HMRFS), a partnership between the National Marine Fisheries Service (NMFS) and DAR to collect marine recreational fishery data in Hawaii is currently underway.

Methods

The data used comprised the monthly commercial landings reports from 1966-2001 that were submitted to DAR by fishermen and input into a database. Landings and gear data for the different coral reef fishes in Hawaiʻi were requested from DAR. The data encompasses the entire Hawaiian archipelago, which includes both the Main Hawaiian Islands and Northwestern Hawaiian Islands. A crude estimate of effort, in terms of trips and catch per unit of effort (CPUE) in lbs./trip was also generated. Data from the year 2001 were used when comparing gear methods and species groups in some cases.

Results and Discussion

The number of fishers in Hawaiʻi participating in the coral reef fishery has risen from a little over 200 fishers in 1966 to a peak of nearly 1200 fishers in 1996. Since then, the number of fishers has slowly declined to over 800 fishers in 2001. We see an increase in fishermen from 1966 up until the mid to late 1980s, when the number of fishermen levels off (Figure 1).

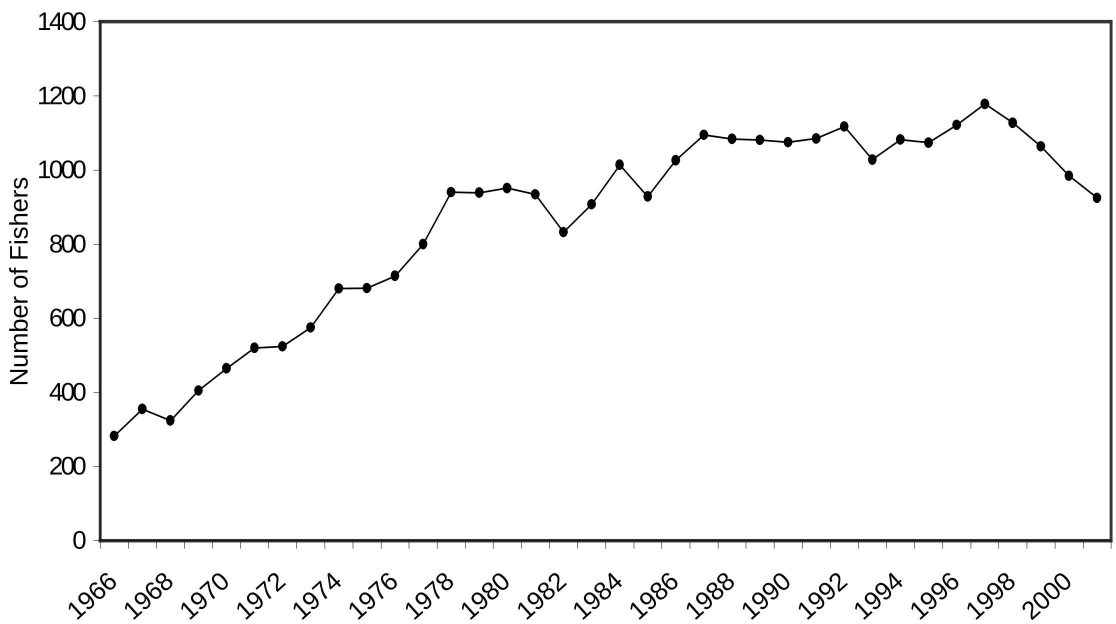

Figure 1. Number of commercial coral reef fishers in the Hawaiian Archipelago from 1966-2001.

Total weight landed and ex-vessel values of the coral reef fishery in Hawaiʻi from 1966-2001 appear in Figure 2. Landings have remained relatively constant, ranging from 1-2 million lbs. per year. On average, nearly 7% of the weight landed was not sold. The value of the fishery, inflated for 2001 values, ranged from a high of $3.5 million in 1977 to a low of a little over $2 million in 1985.

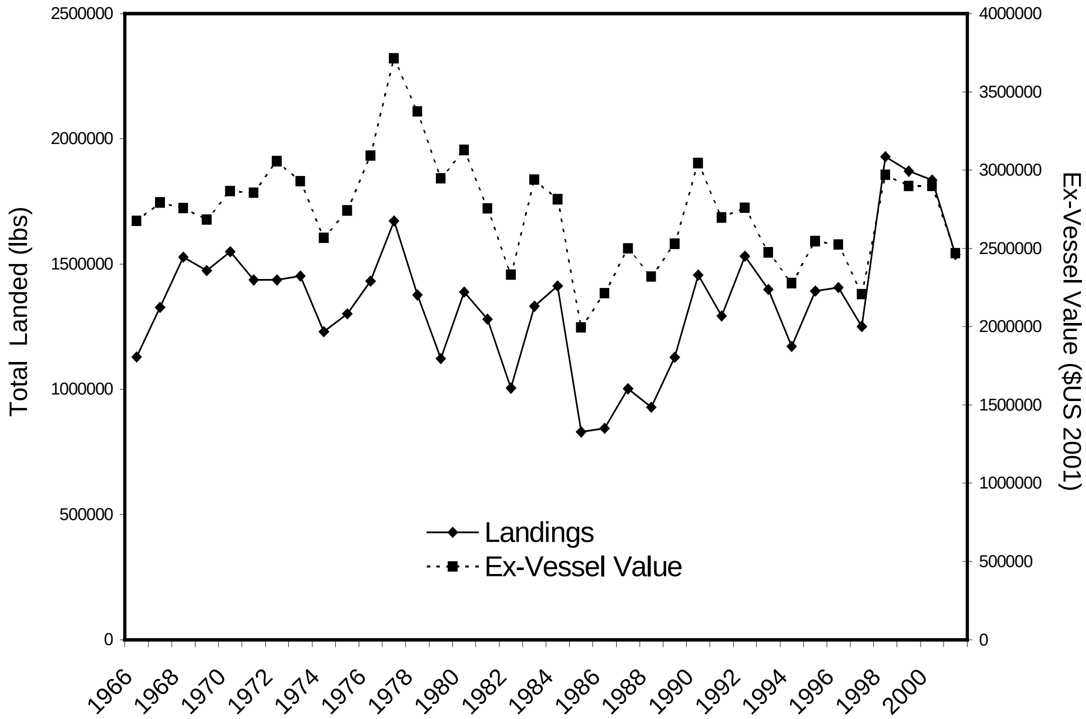

Figure 2. Total commercial landings of coral reef fishes and ex-vessel value in the Hawaiian Archipelago from 1966-2001.

Akule (Bigeye Scad, *Selar crumenophthalmus*) and *'ōpelu* (Mackerel Scad, *Decapterus* spp.), more commonly referred to as "coastal pelagic" species, are the top species caught in Hawai'i's coral reef fishery. According to 2001 commercial catch data (Figure 3), *akule* and *'ōpelu* accounted for nearly 80% of the 2001 coral reef catch. Of the coral reef species groups proper, surgeonfishes (Acanthuridae) had the highest catch, followed by goatfishes (Mullidae), squirrelfishes and soldierfishes (Holocentridae), unicornfishes (*Naso* spp.), and parrotfishes (Scaridae). The "other" category is comprised of 27 other species groups.

When *akule* and *'ōpelu* are excluded (Figure 4), the top species group in the coral reef fishery, according to the 2001 commercial catch data, is the surgeonfishes. The next species that dominated the 2001 commercial catch in Hawai'i's coral reef fishery include goatfishes, squirrelfishes and soldierfishes, unicornfishes, parrotfishes, octopus, seaweed, filefishes (Monacanthidae), '*opihi*, and crab. The "other" category includes 22 different species groups, each comprising less than 1% of the 2001 catch. Non-fish species groups, which include seaweed, octopus, '*opihi*, and crabs, made up over 18% of the catch.

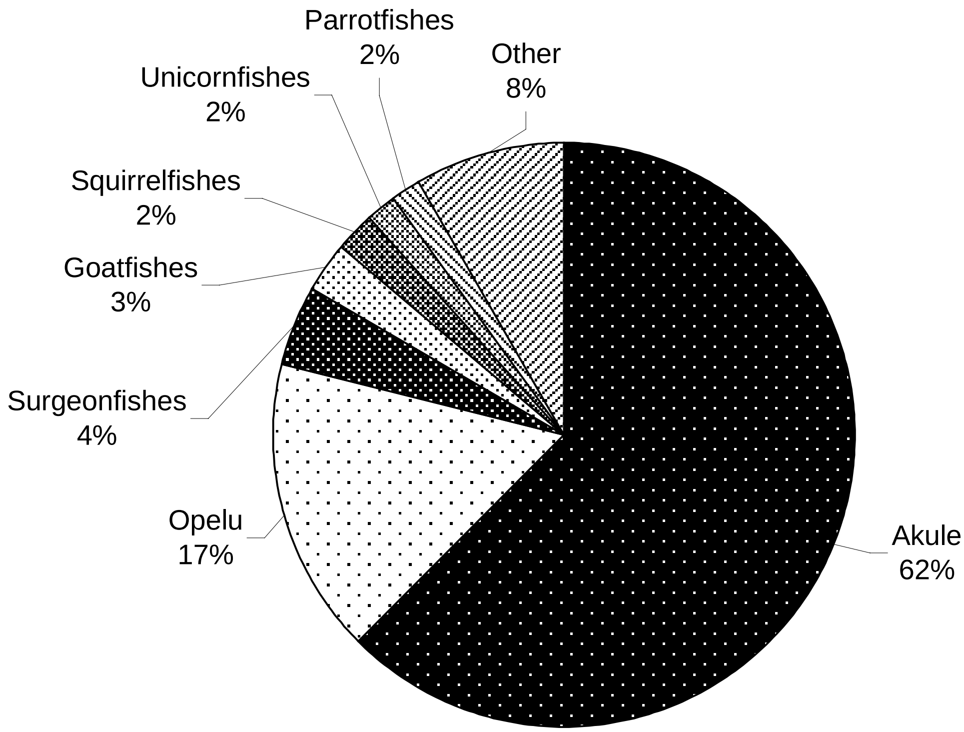

Figure 3. Top taxa in the Hawai‘i coral reef fishery based on 2001 commercial catch data.

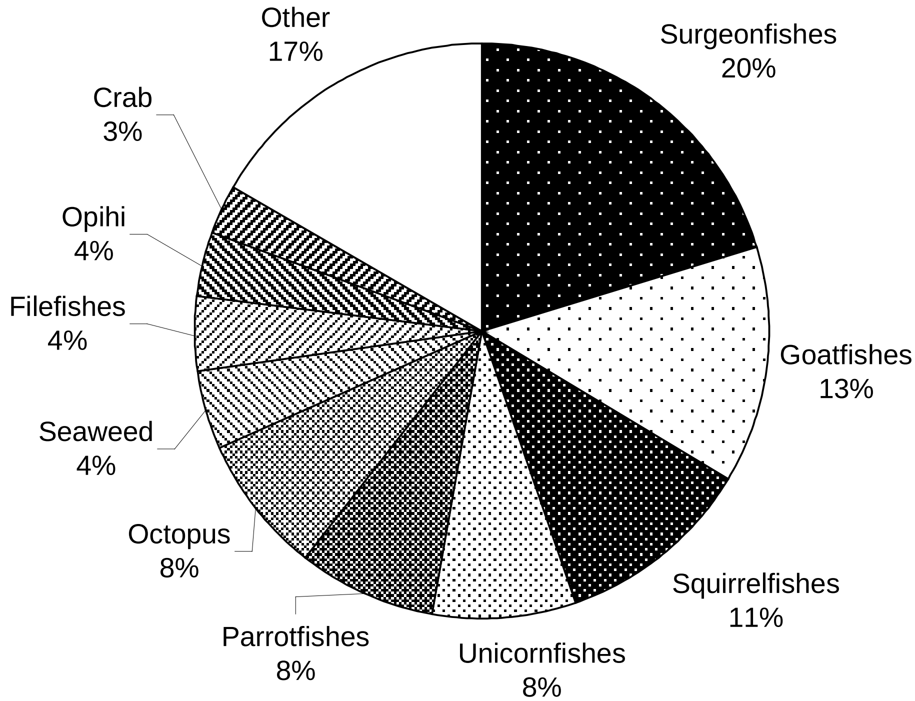

Figure 4. Top 10 species groups excluding *akule* and *‘ōpelu* according to the 2001 commercial catch data.

Three of the top four species groupings (surgeonfishes, squirrelfishes, and parrotfishes) all showed increases in landings since the 1960s, while goatfishes' landing decreased during this time period. All four species groups showed an increase in landings towards the end of the 1970s. The landings of surgeonfishes have remained relatively constant at about 50,000 lbs. per year up until the early 1990s (Figure 5a). After that, landings have doubled from nearly 50,000 lbs. in 1990 to over 10,000 lbs. in 2001. Soldierfishes and squirrelfishes landings have continually increased since 1966 (Figure 5b). The landings for this species group were over 10,000 lbs. in 1966, increasing to over 30,000. lbs. in 2001. More than 50,000 lbs. were landed in 1978 and in several other years in the mid to late 1990s. Figure 5c shows the only decline in landings of Mullidae, or goatfishes, the single top species groups that showed declines through the time period. The landings of goatfish started near the 100,000 lbs. mark in 1966 and has declined since then to a little over 40,000 lbs. in 2001. Landings did increase from the late 1960s until the late 1970s where they peaked at near 120,000 lbs., but they have declined since then. Landings of the Scaridae or parrotfishes species group have increased since 1966. Landings were consistently below 10,000 lbs. per year from 1966 up until the mid 1970s, where landings would increase and peak at over 50,000 lbs. in 1988. The mid 1990s showed relatively consistent landings above 30,000 lbs. per year, but these have declined to a little over 20,000 lbs. landed in 2001.

Commercial landings of octopus or *he'e* in1966 were a little over 5000 lbs. and have since increased to over 20,000 lbs. in 2001 (Figure 6a). The octopus catch had a high of over 40,000 lbs. in 1986 and has never dropped below 5000 lbs. since that time. Seaweed, or *limu*, commercial landings were nearly non-existent in 1966 but increased to over 60,000 lbs. a few years later and continued to rise to over 50,000 lbs. per year up until the late 1970s (Figure 6b). Since then, the landings of seaweed have remained below 20,000 lbs. per year, except for two times, in 1996 and 1997, when they exceeded 20,000 lbs. *'Ōpihi*, or limpet, landings have never returned to the landings they experienced in 1966-1968, when over 25,000 lbs. were landed (Figure 6c). The decline in landings continued from 1966 to 1984, when landings were lowest at 5,000 lbs. In the mid 1980s, the landings increased sharply, only to decrease again after 1987. Since 1990, the 'ō*pihi* landings have increased a little, but the 2001 landings are still less than half the landings of 1966.

According to the 2001 commercial catch data for coral reef fisheries in Hawai'i (Figure 7a), nets comprise the greatest percentage of the 2001 catch. These data also include the harvest of the coastal pelagic species *akule* and *'ōpelu*. The net gear method includes the gear types: akule net, *'ō*p*elu* net, gill net, throw net, surround net, and miscellaneous nets. Hook and line fishing, which includes the inshore hand line and rod and reel gear types, also provided a high percentage of the catch. Other gear methods used in this fishery include dive (which includes the gear type spearing), traps (including the gear types crab traps, fish traps, and bullpen traps), and hand harvest (including the gear types handpick and knife).

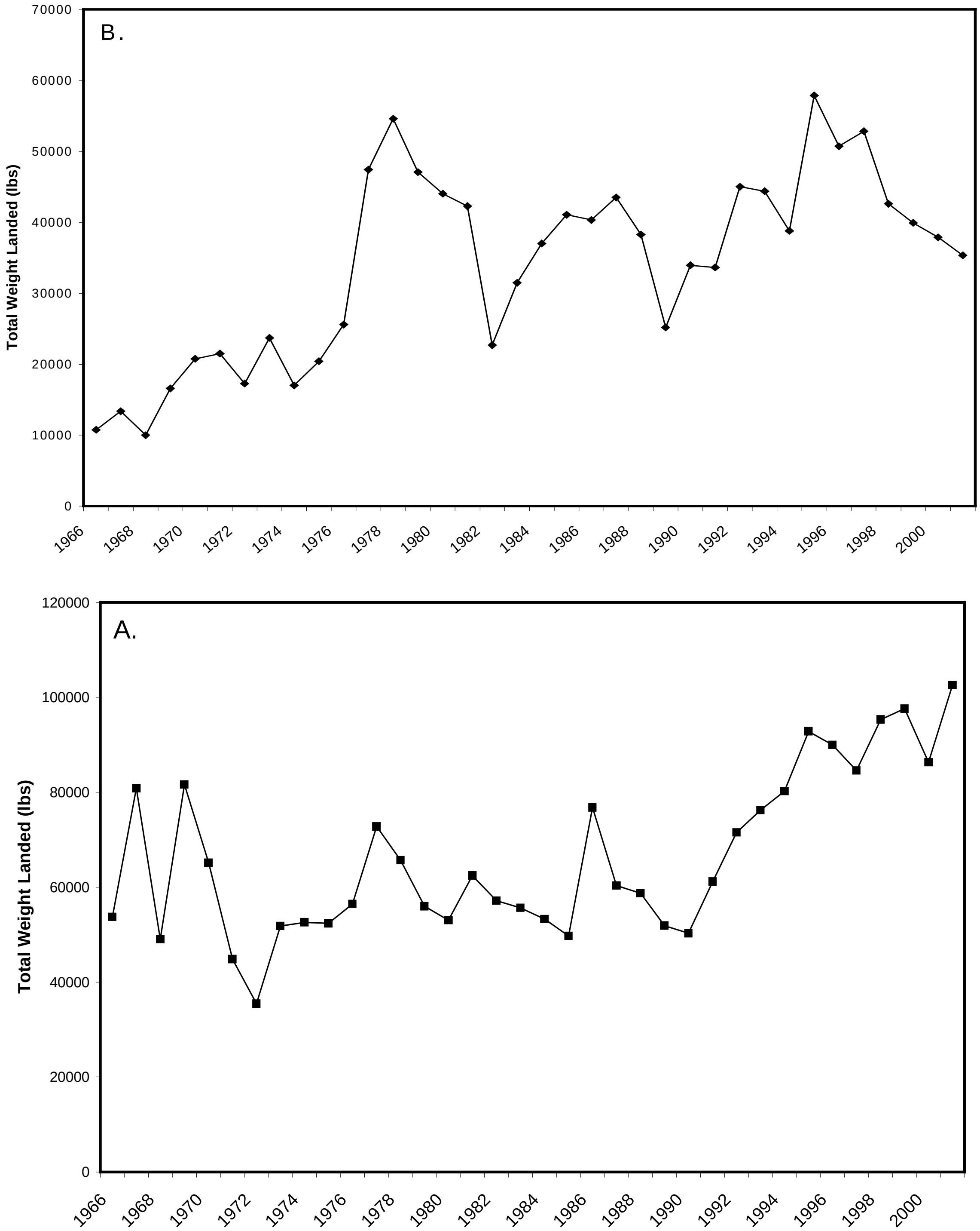

Figure 5a,b. Total commercial landings from 1966-2001 in the Hawaiian Archipelago of a) Acanthuridae (surgeonfishes and unicornfishes) and b) Holocentridae (squirrelfishes and soldierfishes).

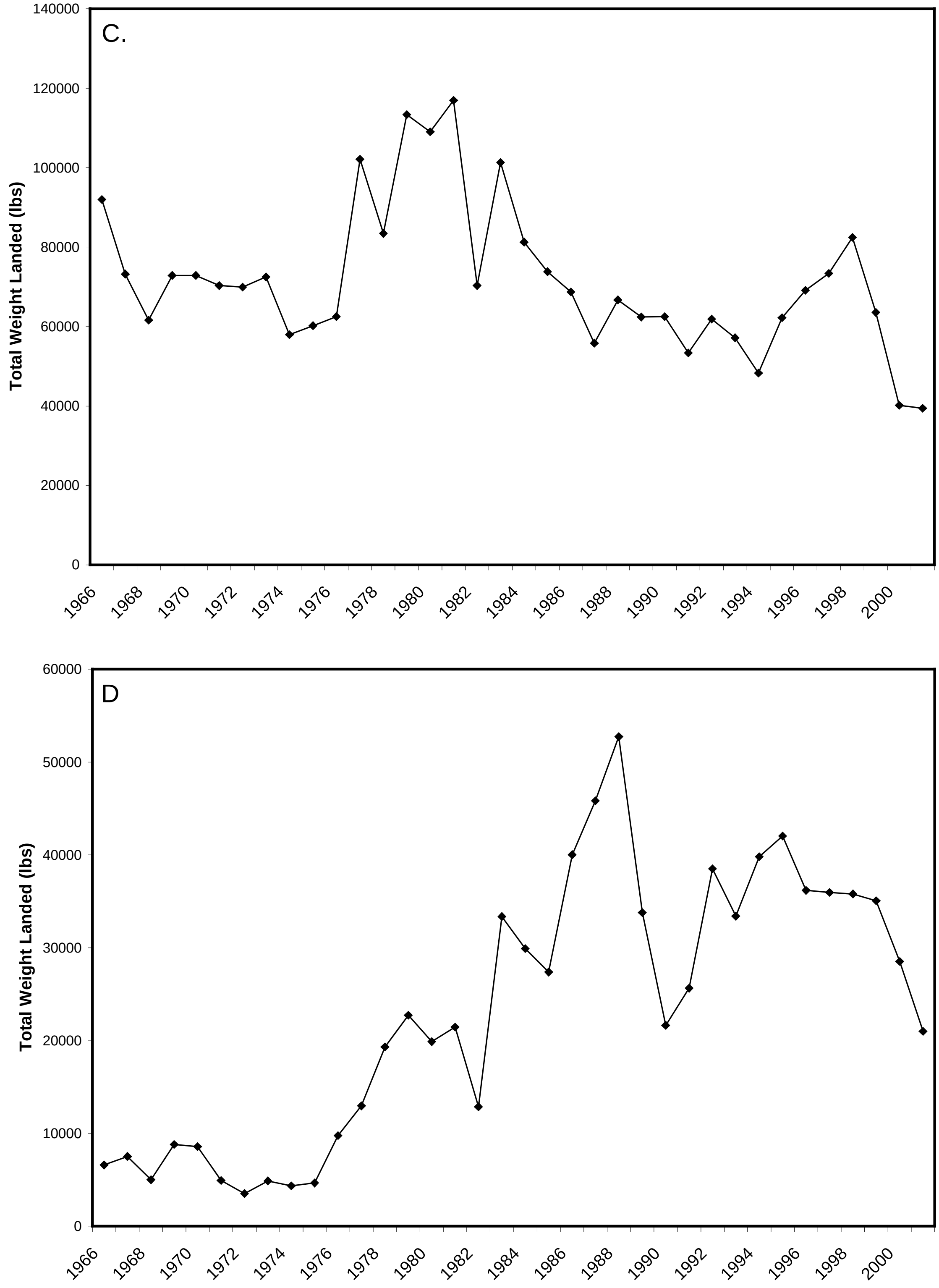

Figure 5c,d. Total commercial landings from 1966-2001 in the Hawaiian Archipelago of c) Mullidae (goatfishes); and d) Scaridae (parrotfishes).

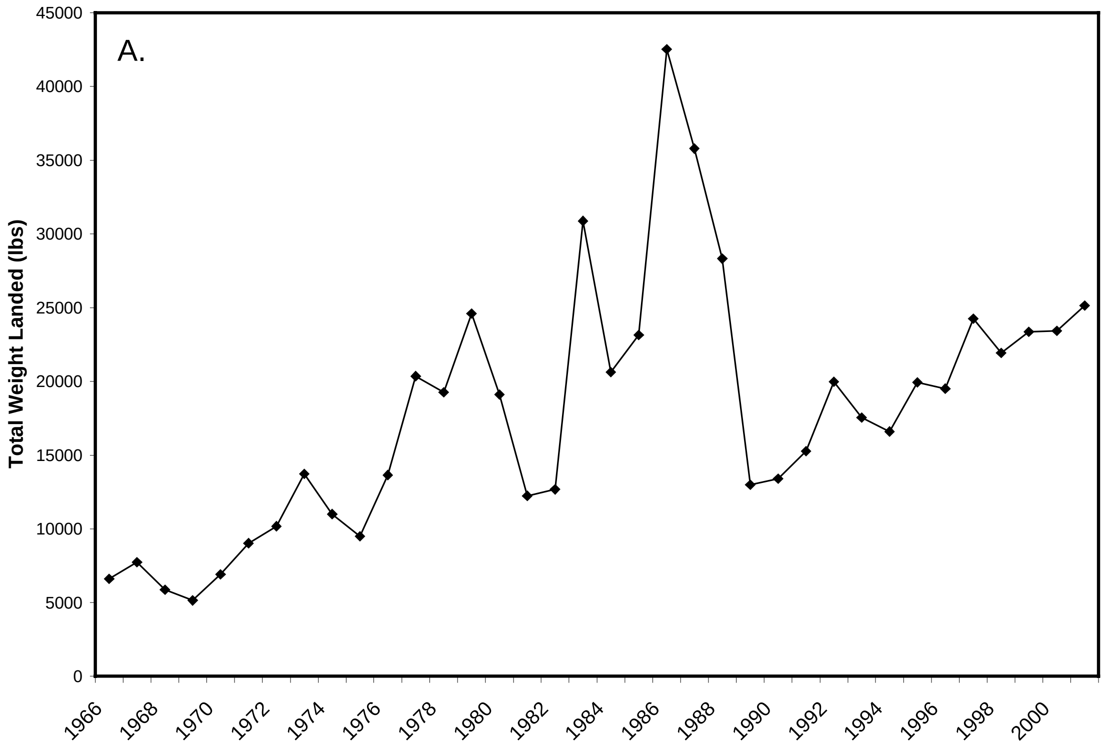

Figure 6a. Total commercial landings from 1966-2001 in the Hawaiian Archipelago of Octopus (*he'e* or *tako*)

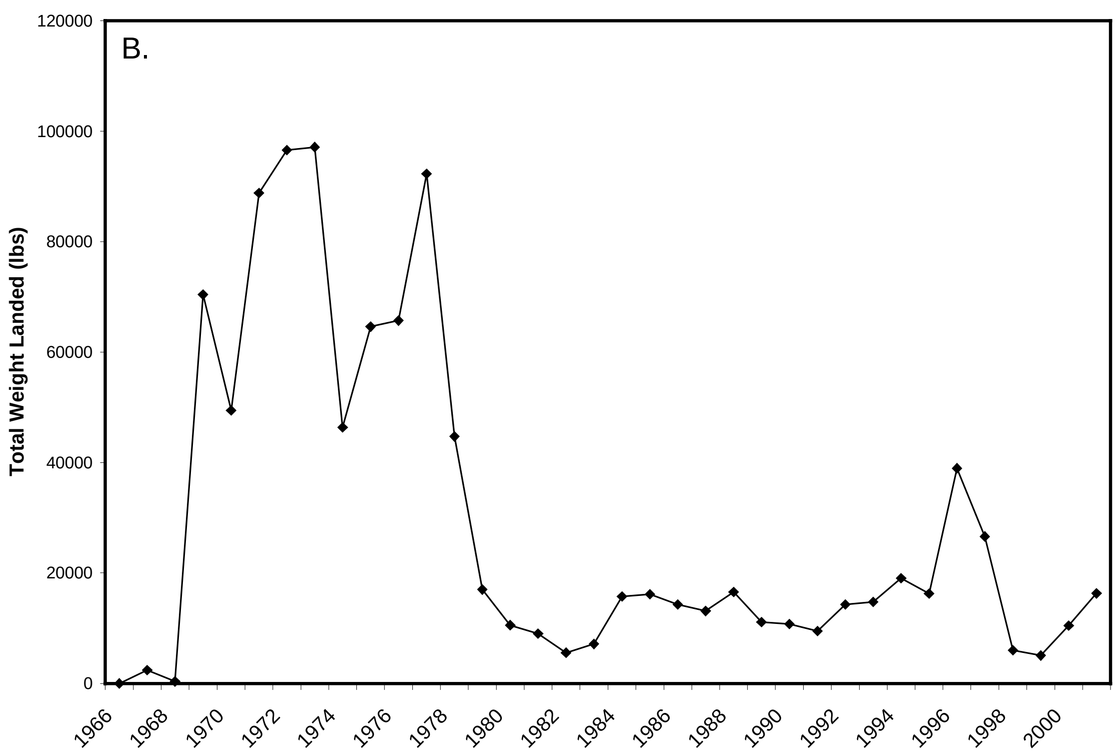

Figure 6b. Total commercial landings from 1966-2001 in the Hawaiian Archipelago of Seaweed (*limu*).

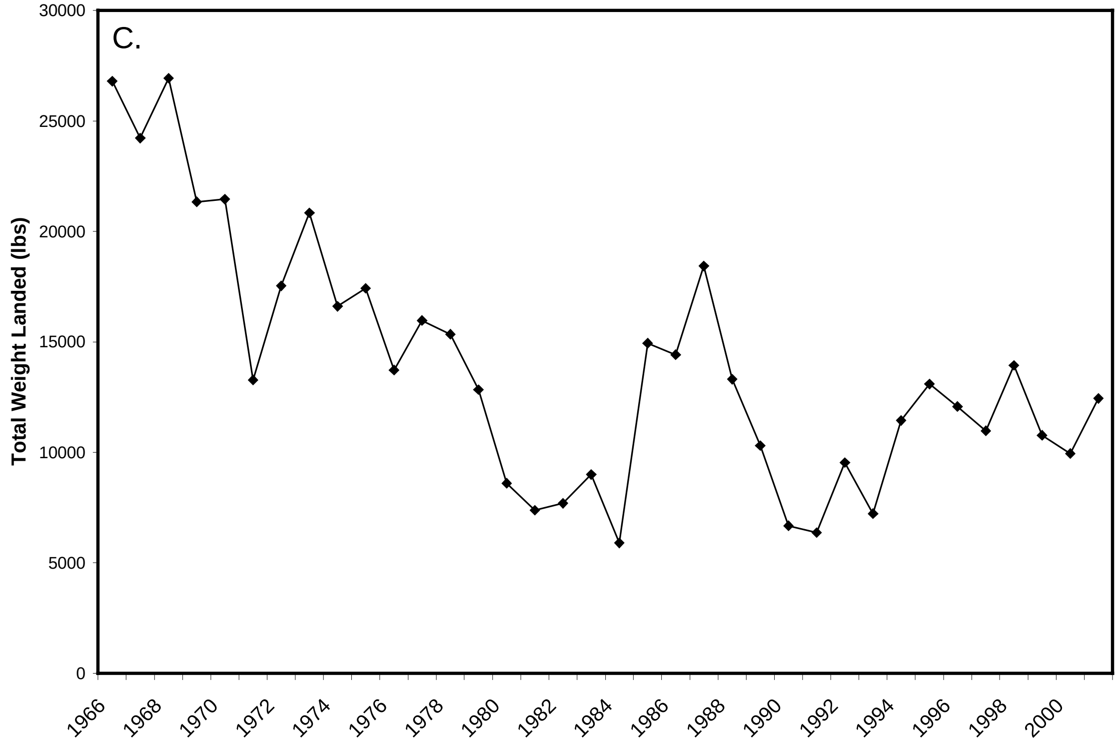

Figure 6c. Total commercial landings from 1966-2001 in the Hawaiian Archipelago of ‘*opihi* (limpet).

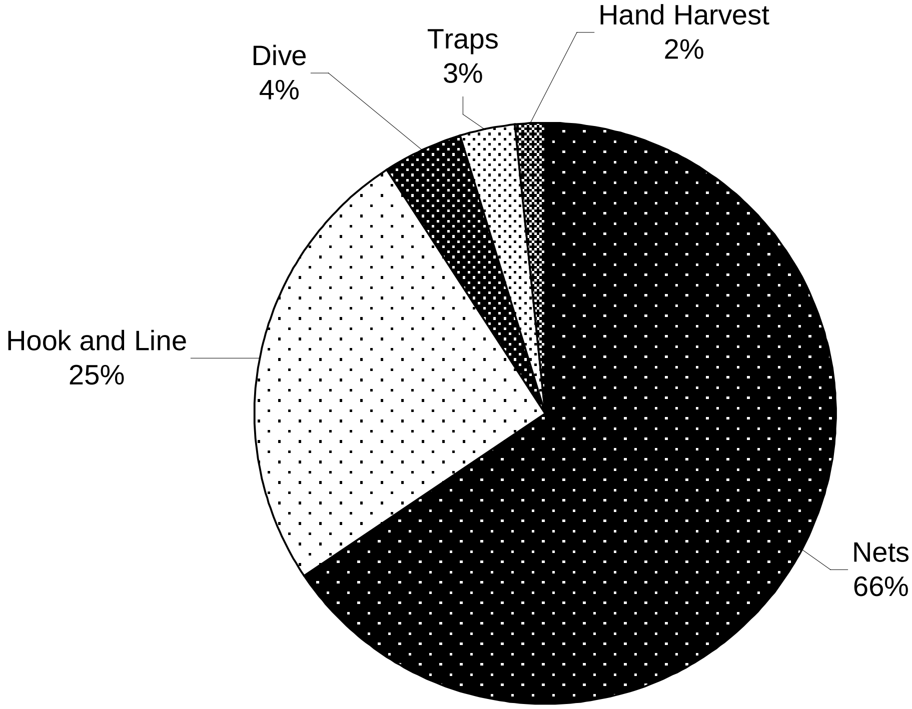

Figure 7a. Composition of 2001 commercial coral reef fishery catch by gear type.

When nets are targeting *akule* and/or *'ōpelu*, the catch was almost completely comprised of (98-99%) the coastal pelagic species. The 2001 commercial catch data for surround nets not targeting *akule* and/or *'ōpelu* harvested mainly surgeonfishes, goatfishes, and parrotfishes (Figure 7b). Other fish groups caught included rudderfishes, damselfishes, squirrelfishes, bonefishes, and barracuda. A group labeled "miscellaneous fish" is comprised of fish that were not identified in the catch reports. A large component of the catch (approx. 30%) was a group of species that are part of the Western Pacific Regional Fisheries Management Council's Bottomfish and Seamount Groundfish Fishery Management Plan Management Unit Species (BMUS) and were not considered to be coral reef fishes in this project (Table 1).

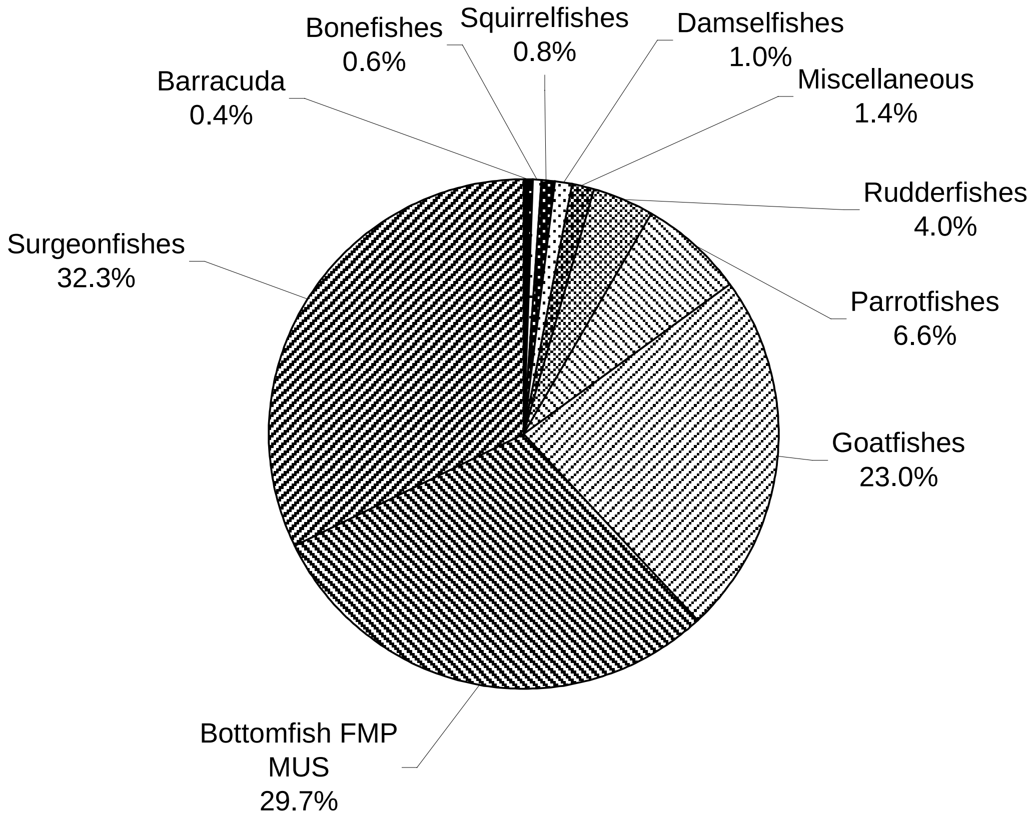

Figure 7b. Average composition of 1995-1999 commercial coral reef fishery catch in Hawai'i using the Surround Net gear type not targeting *akule* and/or *'ōpelu*.

Table 1. BMUS Species Groups as a percentage of BMUS total according to the total of the 1995-1999 commercial catch data, using surround nets not targeting *akule* and/or *'ōpelu*.

BMUS Species Group	% of BMUS Total
Snappers	94.8 %
Jacks	3.5 %
Emperorfish	1.7 %

Gill nets are another gear type of the net gear method that is used in Hawai‘i’s coral reef fishery. Figure 7c shows the gill net catch by species group composition of the 2001 commercial catch data. As with surround nets, surgeonfishes were the top species group caught using gill nets, followed by goatfishes and squirrelfishes. The BMUS (Table 2) again makes up a substantial portion of the catch (approx. 17%). Other species groups caught using gill nets included mullet, rudderfishes (Kyphosidae), parrotfishes, the endemic Hawaiian flagtail (*Kuhlia sandvicensis*), bonefishes (*Albula* spp.), and glasseyes (Pricanthidae).

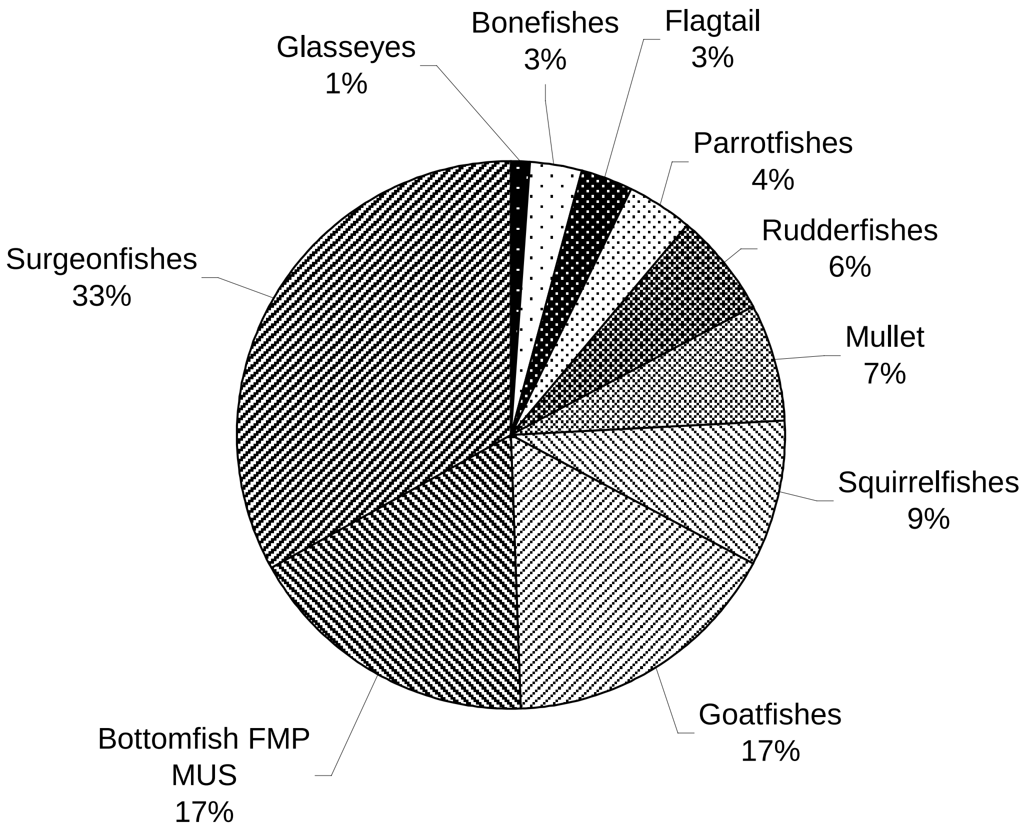

Figure 7c. Average composition of 1995-1999 commercial coral reef fishery catch in Hawai‘i using the gill nets not targeting *akule* and/or *‘ōpelu*.

Table 2. BMUS Species Groups as a percentage of BMUS total according to the total of the 1995-1999 commercial catch data, using gill nets not targeting *akule* and/or *‘ōpelu*.

BMUS Species Group	% of BMUS Total
Snappers	87.14 %
Jacks	9.05 %
Emperorfish	3.79 %
Grouper	0.02 %

The catch rates (lbs./trip) of differ amongst the top coral reef species groups, yet all have a sharp increase in catch rate in the period between 1977 and 1980. For Acanthuridae (surgeonfishes and unicornfishes) the catch rate decreased from 1966 till the mid to late 1980s, where it began to increase till 2001 (Figure 8a). The Scaridae (parrotfishes) saw catch rates increase from 1966 up until the mid 1980s where it peaked at 60 lbs. per trip (Figure 8b). Since then, the catch rates have leveled off at around 35 lbs. per trip, having declined to less than 30 lbs. per trip in 2001. Catch rates for Holocentridae (squirrelfishes and soldierfishes) have remained relatively constant from 1966-2001 at around 20-30 lbs. per trip (Figure 8c). Between 1977 and 1981, the catch rates rose above 30 lbs. per trip with a peak of over 50 lbs. per trip in 1978. Mullidae (goatfishes) catch rates have seen an overall decline since 1966, with an exception of a dramatic increase of 35 pounds per trip between 1976 and 1979 (Figure 8d).

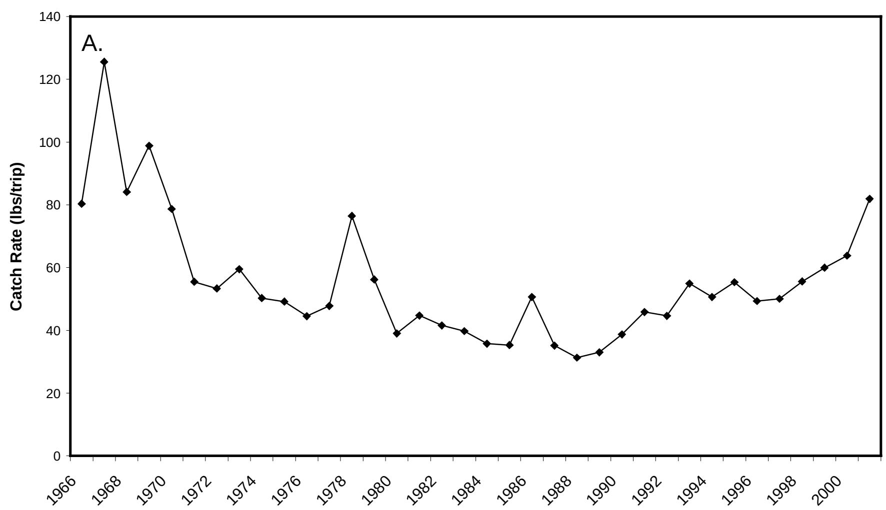

Figure 8a. Catch rates in lbs./trip of top coral reef species groups from 1966-2001 for Acanthuridae (surgeonfishes and unicornfishes).

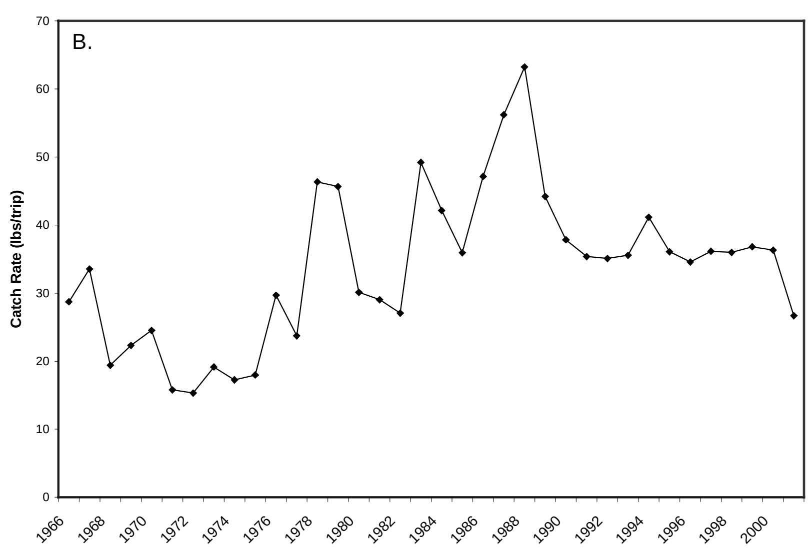

Figure 8b. Catch rates in lbs./trip of top coral reef species groups from 1966-2001 for Scaridae (parrotfishes).

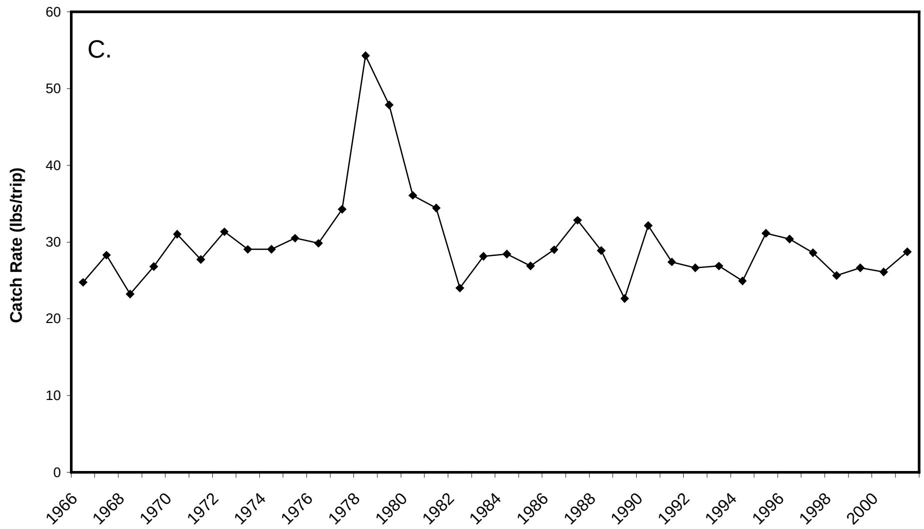

Figure 8c. Catch rates in lbs./trip of top coral reef species groups from 1966-2001 for Holocentridae (squirrelfishes and soldierfishes).

Figure 8d. Catch rates in lbs./trip of top coral reef species groups from 1966-2001 for Mullidae (goatfishes).

Conclusion

On average, a total of 1,352,269 lbs. of coral reef fish are landed annually in Hawai'i. This is comprised mainly of goatfishes, soldierfishes, surgeonfishes, octopus, and parrotfishes. However, coral reef landings in Hawai'i include the small coastal pelagics, Bigeye Scad (*akule*), and Mackerel Scad (*'ōpelu)*, which together comprise 79 % of the catch for 2001. For the reef fish proper, the dominant species groups in the catch are Mullidae (goatfishes*)*, Acanthuridae (surgeonfishes*)*, Holocentridae (soldierfishes and squirrelfishes*)*, Scaridae (parrotfishes, or *uhu*), and octopus (he'e or *tako*). Catches for some species groups have continued to increase from

1985 to the present, as the population of Hawaii has increased. Catch rates are variable, with little evidence of noticeable trends.

Non-fish species groups that make up a significant portion of the catch are also cultural resources. Landings for cultural use may not be captured in the commercial data. Recreational and subsistence data may be able to validate or vacate trends that are shown by the commercial data, since the number of recreational and subsistence fishermen are estimated to be greater than commercial fishermen.

Along with the fishing data, other effects on the fishery should be looked at to determine the cause of trends in coral reef fishery landings. Effects on habitat such as pollution, urbanization of coastlines, and natural disasters may have a greater effect on coral reef resources than fishing.

Overall, the commercial coral reef fishery has remained relatively constant in terms of landings. The top species groups show different trends in landings and catch rates, making it difficult to conclude that the commercial coral reef fishery in Hawaii in general is in a decline. Future studies into specific species groups, using recreational, subsistence, and aquarium collecting data, and non-fishing effects on coral reef fisheries would be good to determine the status of the complete coral reef fishery in the Hawaiian archipelago.

A review of the biology and fisheries of two large jacks, ulua (*Caranx ignobilis*) and omilu (*Caranx melampygus*), in the Hawaiian Archipelago.

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Abstract

Ulua and their relatives are the most important predators on Hawaiian coral reefs and are also the most highly sought after shoreline sport fish in Hawai‘i. Ulua played an important role in ancient Hawaiian culture and were often fished for sport by the chiefs or ali‘i. Commercial landings of coastal jacks, excluding akule and opelu, have declined by as much as 84% since the early 1900s, however, the average size of ulua aukea (*Caranx ignobilis*) and omilu (*C. melampygus*) landed in the commercial fishery has increased since the 1970s likely owing to the increase in the number of boats which now exploit previously unfished areas. Despite this increase in the size of commercially caught ulua and omilu, anglers on all islands reported declines in the average size and number of ulua taken in the recreational fishery. The catch per unit effort of 100+ lb ulua recorded on each of the main islands in the 1990s was inversely related to the island population density suggesting that over-harvest of large individuals is occurring near large population centers. However, the overall volume of large 100+ lb ulua aukea has increased markedly since the mid-1970s. Unlike the Main Hawaiian Islands, the populations of large jacks in the Northwestern Hawaiian Islands are presently very healthy and represent one of the few remaining large-scale, intact, predator-dominated reef ecosystems left in the world. Within the Northwestern Hawaiian Islands, the frequency of occurrence of omilu and ulua aukea are 3- to 5-fold higher at French Frigate Shoals compared to Midway Atoll, where they have been fished by US military personnel for nearly a century and since 1996 where they have been the target of a catch-and-release fishery since Midway was transferred to the US Fish and Wildlife Service. A tagging study currently being conducted by the Hawai‘i Division of Aquatic Resources will supplement management information for ulua, omilu and other carangids in the Main Hawaiian Islands by providing a direct measure of fishing mortality. This plus the other data presented in this paper will be needed to assess the potential of marine protected areas (MPAs) as a fishery management tool for jacks and other coastal fish in Hawai‘i, an issue which has become a topic of vigorous debate in Hawai‘i.

Introduction

Jacks (family Carangidae), along with sharks, comprise the most important nearshore predators on Hawaiian coral reefs (Friedlander and DeMartini 2002). On most other Indo-Pacific coral reefs the predator biomass is dominated by a mix of snappers (Lutjanidae), groupers (Serranidae) and emperors (Lethrinidae), however nearshore groupers, snappers, and emperors are almost entirely absent in Hawai‘i, apart from a few species introduced during the mid-1950s (Oda and Parrish 1982, Maciolek 1984 Randall 1987, Friedlander et al. 2002).

Not surprisingly, jacks as a group have assumed a pivotal role in ancient and contemporary Hawaiian culture. Gaffney (2000) notes that the strength of the ulua, particularly large species such as the ulua aukea (*Caranx ignobilis*) were greatly admired by ancient Hawaiians, and that they were used as a substitute in Hawaiian religious rites, when a human sacrifice was unavailable. More recently, jacks have become an important target for shoreline recreational fishermen, and was the driving force behind the founding of several sports fishing clubs in Hawai‘i in the early part of the 20th century (Gaffney 2000). Commercial landings of jacks higher than 600,000 lbs at the beginning of the 20th Century, but have declined considerably since then (Shomura 1987). Part of this decline might be attributed to overfishing as the population of the Hawaiian Islands has increased over the past century, but other factors such as contamination of fish by ciguatera poison, substantially reduced the demand for ulua as a commercial species in the latter part of the 20th century. In addition, habitat loss, particularly nearshore nursery habitats, may also be responsible for these observed declines.

Two of the commonest jacks caught in Hawai‘i are ulua aukea and the omilu (*Caranx melampygus*). Both species are a favored target of shore casting recreational fishermen, with a specific type of shore casting, known as slide bait fishing, being employed to catch ulua aukea. Both species are still caught in relatively small amounts by commercial fishermen to satisfy local demand, but are no longer caught in the large quantities taken previously, due to health fears over the risk of ciguatera.

In this paper, we look at the biology of both the ulua aukea and omilu, and the impacts of fishing on these populations within the Hawaiian Islands. The Hawaiian archipelago offers some interesting possibilities for examining the impact of fishing on jacks. Most of the human population is clustered on Oahu (72%), with over 880,000 residents (plus up to 6 million transient visitors), with smaller populations on other Main Hawaiian Islands (MHI). The 1200-mile Northwestern Hawaiian Islands (NWHI) is essentially uninhabited for most of its length. The majority of the islets and shoals remain uninhabited, although Midway, Kure, Laysan, and French Frigate Shoals have all been occupied for extended periods by various government agencies over portions of the last century. Midway was previously a US Navy base and currently a National Wildlife Refuge that until recently was an eco-tourism destination that offered sport fishing, including fishing for large ulua aukea, as an attraction.

Data sources

The sources of data we used for this paper are included in Table 1. The biology of ulua aukea and omilu has been studied in some detail in Hawaiʻi. A recent review of the biology of carangids found in Hawaiian waters is given in Honebrink (2000). Commercial fishing records for Hawaiʻi extend from 1948 to the present. These data are monthly catch reports submitted by commercial fishermen as required by the Hawaiʻi Division of Aquatic Resources (DAR) commercial fishing permit. Fishermen are required to list the number and weight of fish caught on each day of fishing during a given month. Detailed information on fishing effort is not recorded, permitting only a crude index of catch per unit of effort as catch per trip. Fishing data prior to 1948 has been summarized by Shomura (1987), which includes the survey of Hawaiʻi's fisheries conducted by the US Government in 1900 (Cobb 1903).

Recreational fishery data is far less complete for Hawaiʻi. Information on recreational boat-based catches of jacks are reported in the National Marine Fisheries Service (NMFS) 1979/80 survey of recreational fishing in the Hawaiian Islands, while more recently, shore-casting for jacks is one of the fishing activities captured by the joint Hawaiʻi Division of Aquatic Resources (DAR)/NMFS Hawaiʻi Marine Recreational Fishery Survey, which commenced in 2000 in Hawaiʻi. The US Fish and Wildlife Service (USFWS) conducts a nation-wide survey of recreational and hunting activities every 5 years, including Hawaiʻi. Other sources for the MHI include Hawaiʻi Fishing News which publishes details of large 100+ lb ulua aukea caught by rod and line, with records extending back to the 1950s.

Table 1. Data sources on ulua aukea and omilu biology, and on fisheries for these species in Hawaiʻi.

Topic	Data source
Biology	Sudekum et al.. (1991), Holland et al. (1996), Honebrink (2000) Meyer et al. (2001)
Fishery data	Cobb (1903), Shomura (1987) Division of Aquatic Resources fisheries database, Gaffney (2000), Hawaiʻi Marine Recreational Fishery Survey. NMFS 1979-1980 OMNITRAK survey, USFWS 1998
Fishery impacts	Friedlander and Parrish (1997), Friedlander and DeMartini (2002), Hawaiʻi Fishing News, Division of Aquatic Resources fisheries database

Synopsis of biology of ulua (*Caranx ignobilis*) and omilu (*Caranx melampygus*)

A synopsis of the biology of ulua aukea, based primarily on the study by Sudekum *et al.* (1991) is given in Table 2. Ulua aukea is the largest of the carangids, with a maximum reported size of 170 cm and weight of about 87 kg or about 190 lb (Honebrink 2000). Ulua aukea is a moderately long-lived fish, with a maximum life span in the wild of about 20 years. However, large ulua aukea in captivity in the Pagoda Hotel water garden in Honolulu have lived for more than 30 years. Omilu life span is less than half that of ulua aukea, with few fish exceeding 8 years in age.

Both species spawn between May and August, with relatively early sexual maturation, 2 years for omilu and 3.5 years for ulua aukea. Jacks less than 10 cm FL (age 0+) recruit to sandy shorelines with peak period between August and December (Figure 1) with large inter-annual variance in recruitment observed (Figure 2).

Table 2. Summary of biology of ulua aukea (*Caranx ignobilis*) and omilu (*Caranx melampygus*) from Sudekum et al. (1991).

	Species	
	Ulua aukea *(C. ignobilis*)	Omilu (*C. melampgypus)*
Maximum size SL (mm)	1648	760
Maximum weight (kg)	86.7	10.0
Maximum age (yr)	20	8
von Bertalanffy growth	$Lt\ (mm) = 1838(1\text{-}e^{-0.111(t-0.097)})$	$Lt\ (mm) = 897(1\text{-}e^{-0.233(t+0.044)})$
Length weight equation: SL(mm),weight(g)	$Wt = 2.86 \times 10^{-5} L^{2.974}$	$Wt = 2.3 \times 10^{-5} L^{2.977}$
Average annual diet (kg/fish/yr)	150.69	47.82
Sex ratio (M:F)	1:1.48	1:1.39
Peak spawning season	May-August	May-August
Length at first maturity SL	600	350
Age at first maturity (yr)	3.5	2
Fecundity	NA	$F = 2.286 \times 10^{-9} L^{5.539}$

Sudekum et al. (1991) estimate that ulua aukea and omilu consume more than 30,000 metric tons of fish and invertebrates per year at French Frigate Shoals (ca. 500 km^2 of reef area to a depth of 20m) in the NWHI. These values exceed the estimated consumption by the three dominant shark species at this same location (DeCrosta et al. 1984) by a factor of 40 (Sudekum et al. 1991). The diet of ulua aukea consists primarily of parrotfishes (Scaridae), opelu (*Decapertus* spp.), aweoweo (Priacanthidae), eels (Muraenidae and Congridae), cephalopods (both squid and octopus), and a variety of crustaceans (lobsters, crabs and shrimp). The diet indicates that ulua aukea feeds nocturnally at least part of the time, and forages in both shallow water reef areas and open water habitats, feeding singly or in schools. Ulua aukea is one of the few species to eat large lobsters, and has been observed feeding on undersized and berried female discards from commercial fishing vessels operating in the Northwestern Hawaiian Islands.

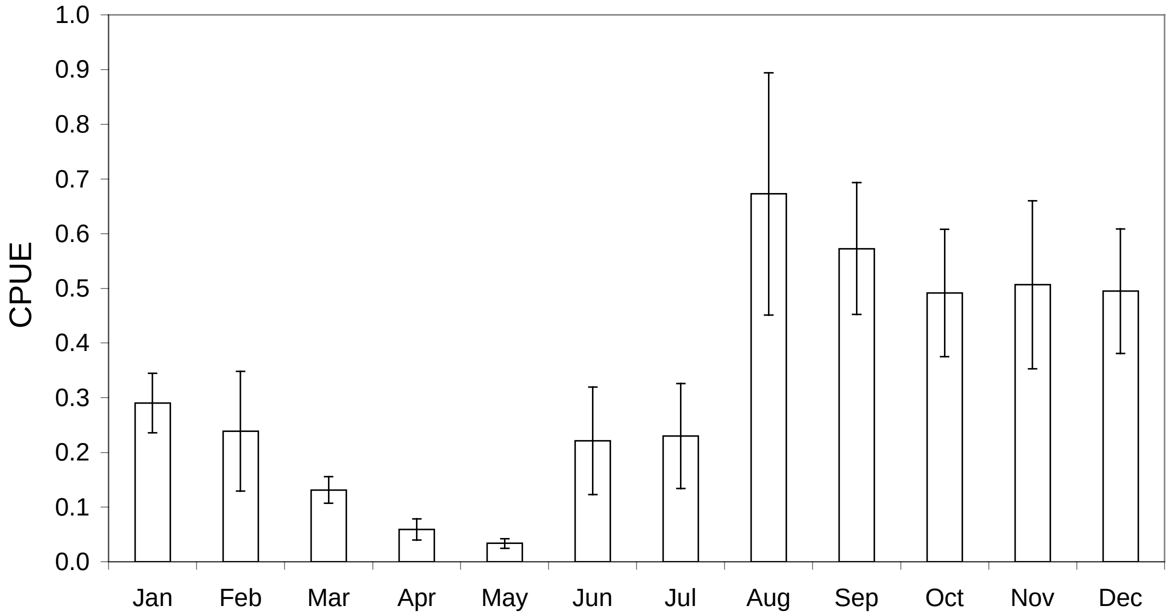

Figure 1. Mean monthly catch per unit effort (CPUE) for jacks (≤10 cm fork length, FL) captured in beach seines along the windward coast of Oahu from January 1994 to May 2003. Error bars are standard error of the mean. N = 2,573 (Oceanic Institute, unpub. Data).

Omilu have a similar broad diet of reef fishes, crustaceans and cephalopods, with wrasses (Labridae), parrotfishes, blennies (Blenniidae), goatfishes (Mullidae), lizardfishes (Synodontidae) and damselfishes (Pomacentridae) comprising the bulk of the diet. Omilu hunt singly, in pairs or small schools and appear to be more diurnal feeders than ulua aukea . Small schools of omilu have been observed in Papua New Guinea to drive schools of herring onto shallow beaches to trap them, where individual omilu will make runs into the densely packed mass of fish to feed (Dalzell, pers obs.).

Holland et al. (1996) tagged over 400 omilu around Moku o Loe (Coconut Island-Hawaiʻi Marine Laboratory Refuge). Only 5% moved greater than 3 km from the release site and more than 75% remained within 0.5 km of the release site. The limited range of dispersal of recaptured *omilu* and strong site fidelity observed from sonically tagged fish suggest that dispersal is much less than might be predicted for a highly mobile, piscivorous species (Holland et al. 1996).

Fisheries for jacks in Hawaiʻi

Hawaiʻi is probably one of the best locations globally for recreational fishermen to catch large 100+ lb ulua aukea and large 20+lb omilu with a rod and reel. The world angling record for ulua aukea is 66 kg (145 lbs.) from Maui (Randall 1996). Shore casting may take the form of "whipping" or casting repeatedly with a rod and an artificial plug or lure, or slide bait fishing, where the line is cast and set taught with a lead anchor. A baited hook attached to a branch line that is then slid down the main line and comes to rest near the lead anchor. This method of fishing is employed primarily to catch large ulua aukea. Spear fishermen can also catch ulua aukea and omilu; indeed, the record 191 lb ulua aukea for Hawaiʻi was caught by spear fishing.

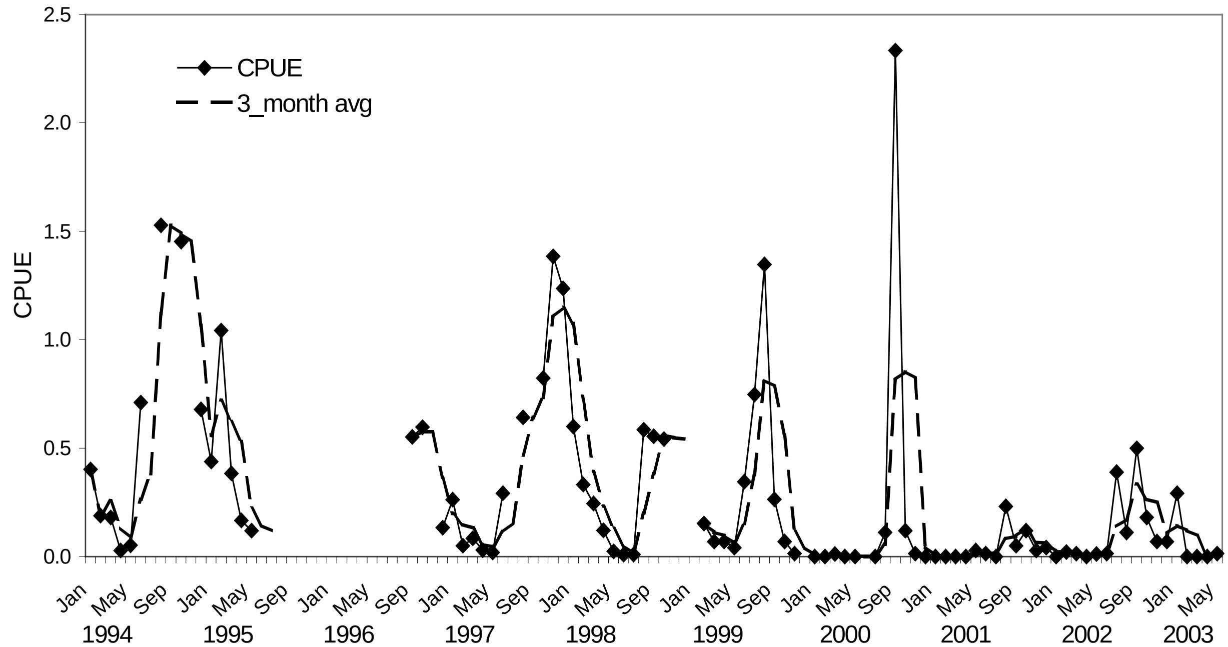

Figure 2. Mean monthly beach seine CPUE for jacks along windward Oahu from 1994 to 2003 (Oceanic Institute, unpub. Data).

On the island of Kahoʻolawe, two traditional Hawaiian methods of fishing are described for ulua. Kuikui fishing involved a stout wooden pole with thick; three ply olona cord, baited with moray eel (Reichel 1993). The pahoe method was conducted using a canoe and trailing bait with a bundle of mashed wood that made the ulua take the bait when they smelled it.

Gaffney (2000) has estimated that the value of recreational fishing for *ulua* to the State of Hawaiʻi amounts to about $31 million annually. A 1996 survey of recreational fishing in Hawaiʻi estimated three million recreational angler days per year (USFWS 1998). Of those anglers who identified a particular species, ulua was by far the most targeted species by recreational anglers (35%), followed by mahi mahi (18%), and tuna (17%).

Commercial fishing for jacks includes hook and line, netting and fish traps. Large schools of ulua aukea were often caught by surround seines, by fishing operations that also targeted other smaller carangids such as akule (*Selar crumenophthalmus*). The history of commercial landings of jacks as a group through the 20th century appears to be one of gradual decline. Cobb (1903) reports landing of ulua of 625,000 lbs. in 1900. This had declined to less than half this figure by the 1950s, dropping to just over 100,000 lb in the 1980s (Figure 3). Jacks as a group became associated with ciguatera due to a number of poisoning cases associated with kahala (*Seriola dumerili*), a favorite target of bottom fish fishermen until the concerns of ciguatera in the 1980s in Hawaiʻi. The dangers posed by ciguatera in jacks as a group and the potential legal liability posed by the sale of such fish caused the main fish markets in Hawaiʻi to refuse to handle such fish from 1990 onwards. Consequently targeting of jacks dropped considerably after this period (Figure 3).

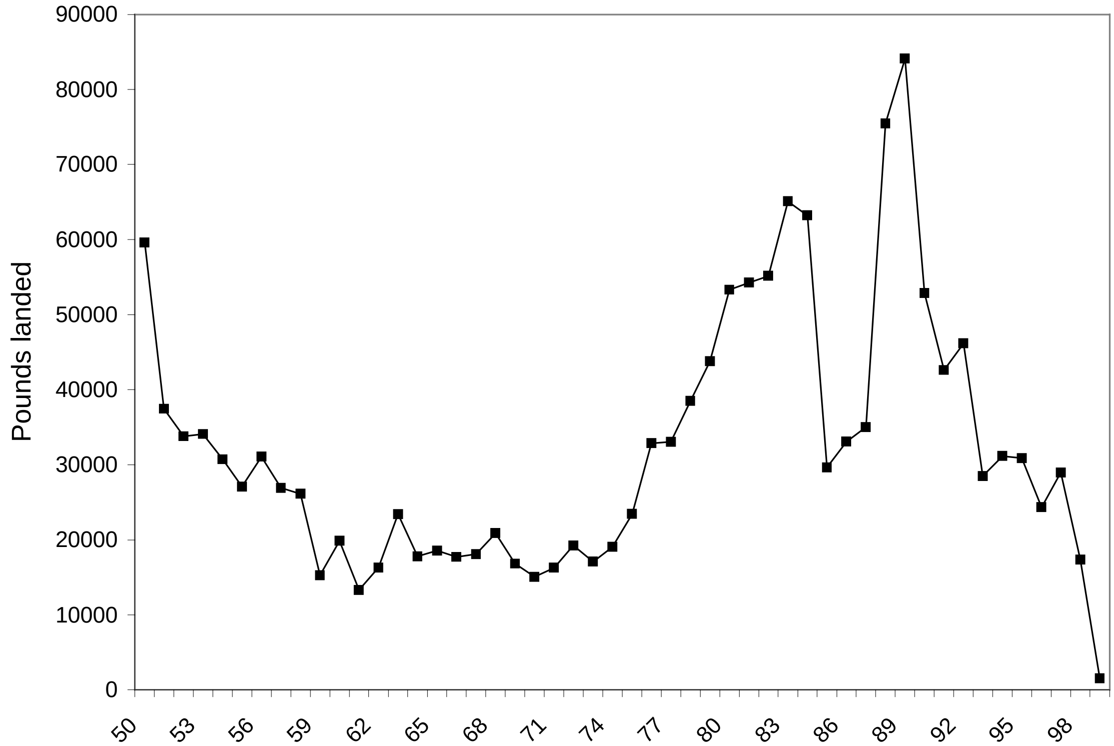

Figure 3. Hawai‘i state commercial landing data for all coastal jacks (excluding *akule* and *opelu*) from 1950 to 1999.

Impact of fishing on jacks in Hawai‘i.

Stocks respond to fishing mortality with declines in abundance, usually measured in fisheries by declines in catch per unit of effort (CPUE), and reduction in the average size of fish in the catch. Commercial catch data for all jacks in Hawai‘i is collected by the Hawai‘i Division of Aquatic Resources. Crude estimates of CPUE for a mix of fishing methods, although mainly hook and line fishing, for omilu and ulua aukea is shown as lbs caught per trip in Figure 4. Commercial catch rates for the common gears targeting ulua aukea are confounded by the aggregating of this species with other carangids up to 1980. Data for omilu, however, extends from the early 1950s to the present.

Omilu CPUE has remained relatively constant over time, but may suggest some long-term inter-decadal oscillations in CPUE. Catch rates declined during the 1950s to the late 1960s, and then over the next 20 years increased steadily until the early 1990s, declining thereafter. The shorter time series for ulua aukea shows increasing CPUEs in the 1980s and declines in the 1990s. The catch rates for an aggregate of other jack species showed an initial decline in CPUE in the 1950s followed by more or less steady flat CPUE trend from the 1960s to the present.

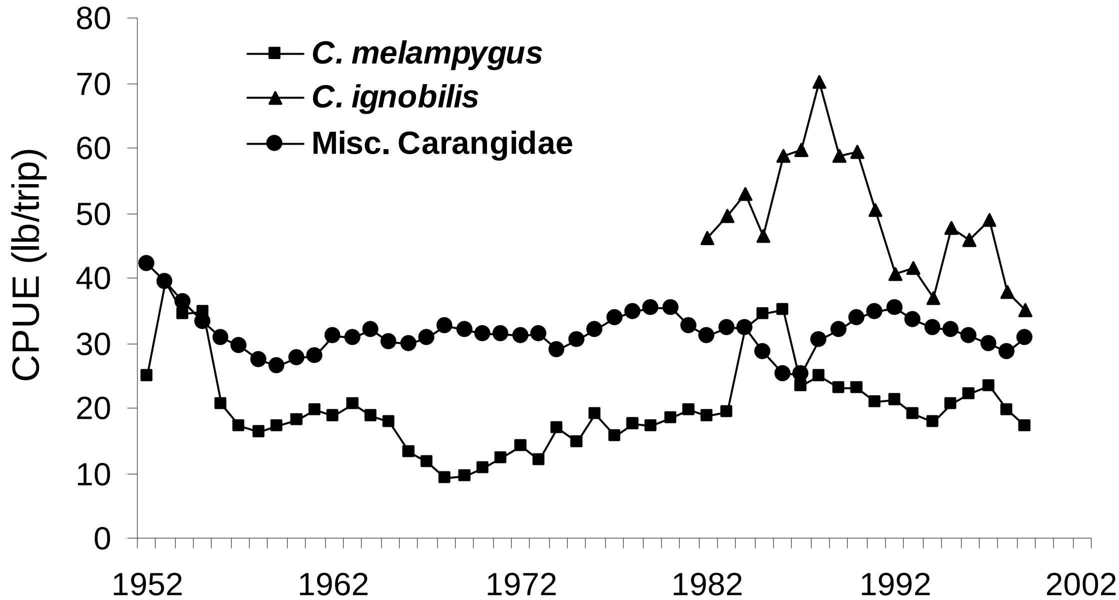

Figure 4. Catch rates (CPUE) for omilu (*C. melampygus*), ulua aukea (*C. ignobilis*), and miscellaneous jacks (Carangidae).

Information for average size of the catch of omilu in commercial extends from 1961 to the present (Figure 5). The data show a monotone increase in the mean size of omilu in the commercial catch. For ulua aukea, the data set is shorter, but indicates a declining trend in average size until the late 1980s, after which time the trend reverses with an increase in average size in the commercial catch. This decline then increase for ulua aukea may reflect the decline in fishing mortality following the ciguatera incidents of the 1980s, and decline in targeting this species. Ulua aukea was fished by surround seine fishing and may have been more "heavily fished" than omilu using this gear type.

The increase in omilu size is less easy to account for over the entire time series since it is not as heavily targeted by net fisheries, as it does not form large schools. Shown in Fig. 5 is also the time series for the total number of small vessels registered in Hawai'i by the Division of Boating and Ocean Recreation. This fleet includes not only the small boat commercial fleet, but also the much larger fleet of pleasure craft that may be used as fishing platforms by recreational fishermen. The increasing size trend for omilu broadly parallels the increase in small boat fleet, and may indicate that fishermen have been able to continue to find lightly fished populations of this species, through a combination of more and better fishing platforms allied to improvements in fishing gear and other technology such as global positioning devices, echo sounders and even mobile phones.

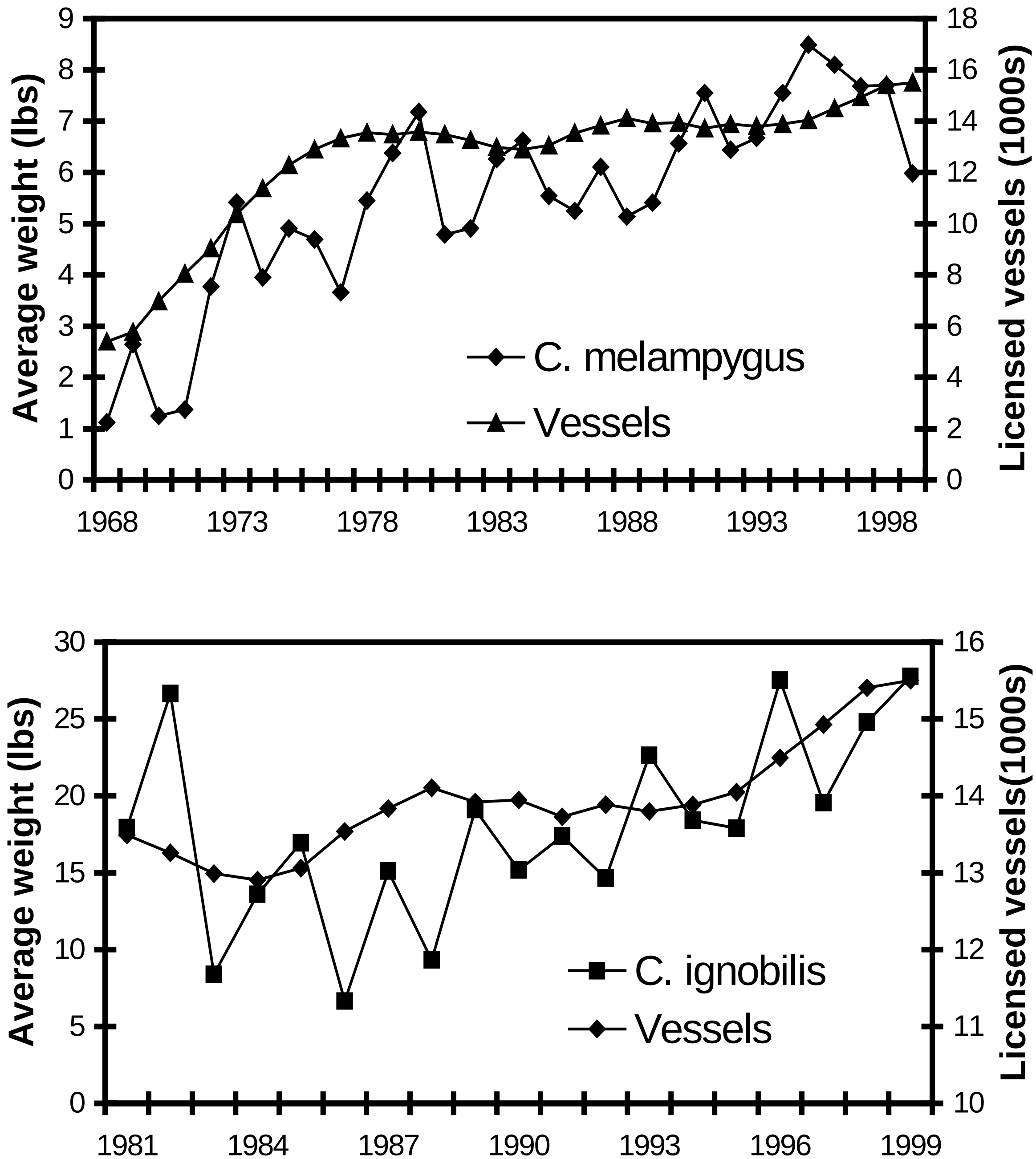

Figure 5. Average weight per year for omilu (*C. melampygus*) and ulua aukea (*C. ignobilis*) along with number of licensed vessels.

Recent recreational catches of large (>100+ lbs.) ulua aukea reported in the Hawai‘i Fishing News between 1990-2000 are shown by island in Fig 6, along with human population density as a proxy for recreational fishing effort. Perhaps not surprisingly, there is an inverse relationship between volume of large fish and population density, with most fish coming from the sparsely populated big island of Hawai‘i. Overall, there has been an increasing trend of large 100+ lb ulua aukea reported to Hawai‘i Fishing News over the past 50 years, particularly from the mid-1980s onwards (Fig 7). Whether or not this reflects abundance of large ulua aukea is confounded by factors such as human population growth in Hawai‘i (known) and the participation in recreational fishing, particularly slide bait angling for ulua (unknown). Nevertheless, this trend should be monitored, particularly the volume of females in the 100+lb class, which may represent a significant proportion of this species recreational potential in the Main Hawaiian Islands.

Of a sample of 1270 omilu/papio (*Caranx melampygus*/Carangidae) examined in a creel survey Hanalei Bay in the early 1990’s (Friedlander and Parrish 1997); less than 30% were of legal size (>7 in. TL = 139 mm SL, Fig 8) even for home consumption; and not more than about 30 individuals had reached the size (350 mm SL) for first reproduction (SFR). Less than 9% of all specimens measured would have been legal for catch by spear or for sale (1 lb. ≈ 263 mm SL). The small sizes at which some fishes are being caught and retained is a matter of concern for management of the stocks.

Jacks comprised more than 72% of apex predator biomass (equivalent to over 40% of total fish biomass) in the Northwestern Hawaiian Islands but less than one percent of the total fish biomass in the main Hawaiian Islands (Fig. 9) (Friedlander and DeMartini 2002). The limited fishing activities that have occurred in the NWHI has resulted in minimal anthropogenic impacts and a predator-dominated coral reef ecosystem that may well be the natural state, but these species are most susceptible to, and rapidly removed by human activities, thus making the natural state difficult to observe in most cases.

DeMartini et al. (2002). have shown that the limited amount of recreational fishing for *ulua* may have had an impact at Midway Island. Both ulua aukea and omilu were significantly less abundant at Midway Atoll, compared to French Frigate Shoals where no fishing takes place. Moreover, a comparison of the abundance of jacks as a group at French Frigate Shoals and Midway before and after the advent of the catch and release fishery at Midway suggests that carangids are less abundant there than prior to fishing (Figure 10).

Discussion

The data presented here suggest that fishing can and does impact populations of jacks in Hawai‘i. Five years of limited catch and release fishing at Midway appears to have affected population abundance of ulua aukea there, despite the non-retention policy. In he MHI, it is likely that the major source of fishing mortality for jacks is from recreational fishing, following the decline of commercial fishing. Indeed, it may be that fishing mortality and total mortality have actually declined as a result of the marginalization of commercial fishing. Moreover, recreational fishing may also be on the decline in Hawai‘i, as evinced by the lack of new members attracted to fishing clubs, which reflects a general trend throughout the United States.

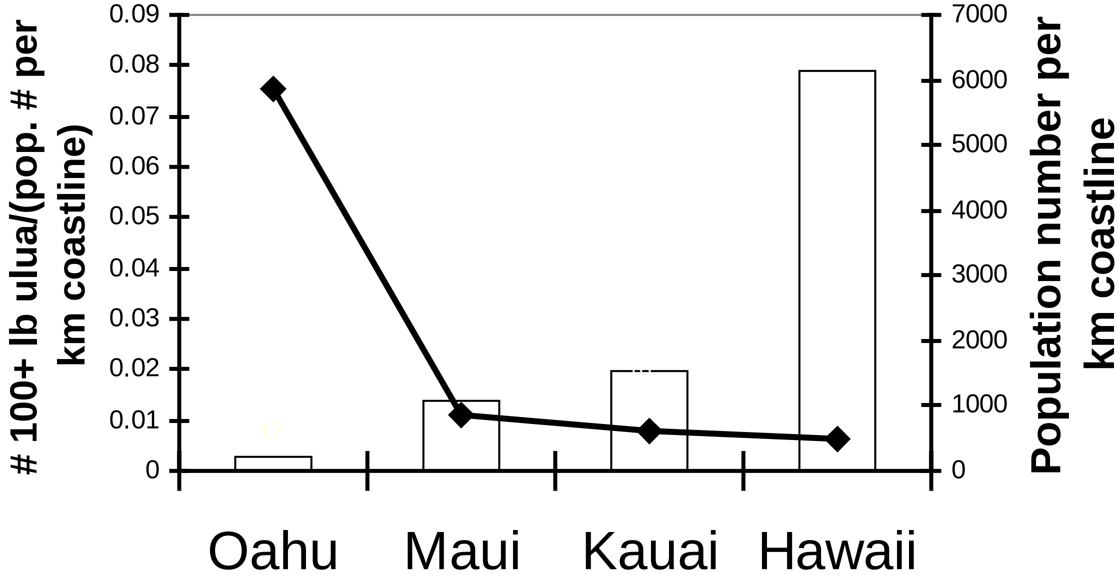

Figure 6. Catch rates for 100+ lb ulua aukea based on human population density per km of coastline. Bars represent catch rates per island while the line represents population number per km of coastline.

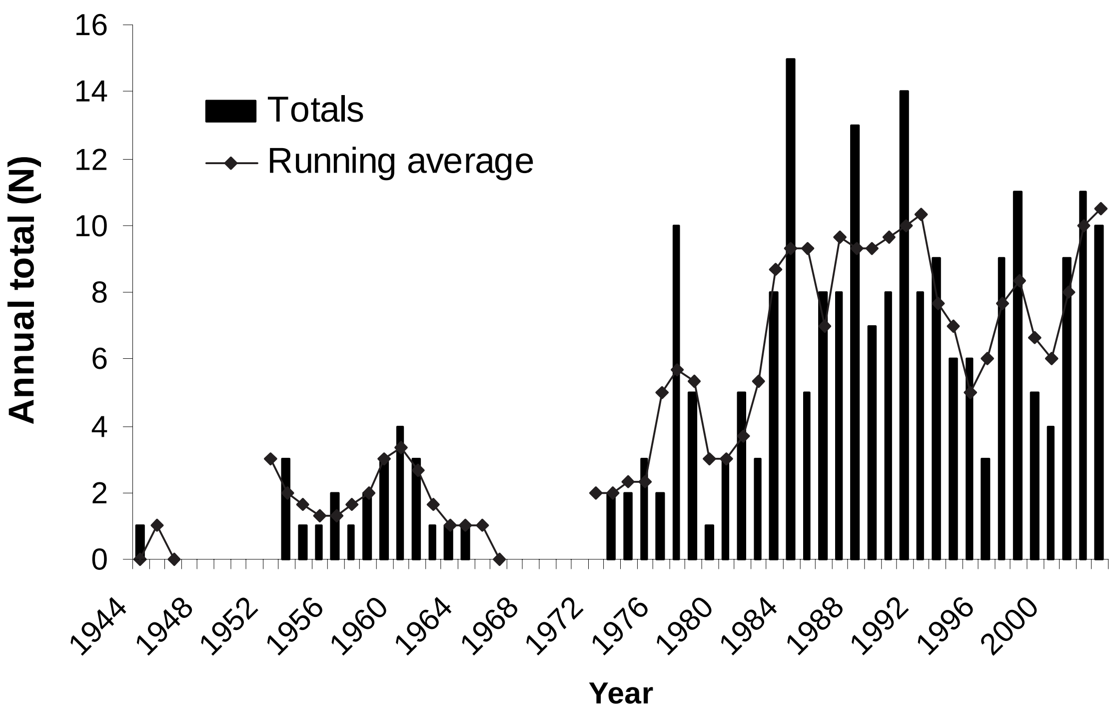

Figure 7. Number of 100+ lb. ulua aukea reported in Hawai'i Fishing News, 1944 to 2003.

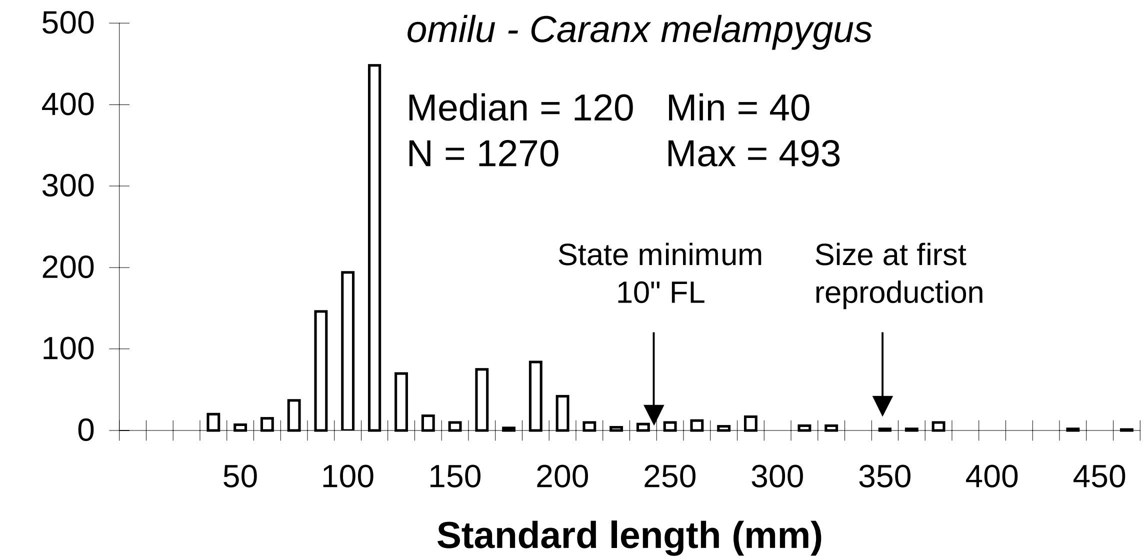

Figure 8. Size of omilu captured in Hanalei Bay during creel surveys conducted from 1992-94 (adapted from Friedlander and Parrish 1997). State minimum size limit is still 10 in. for home consumption.

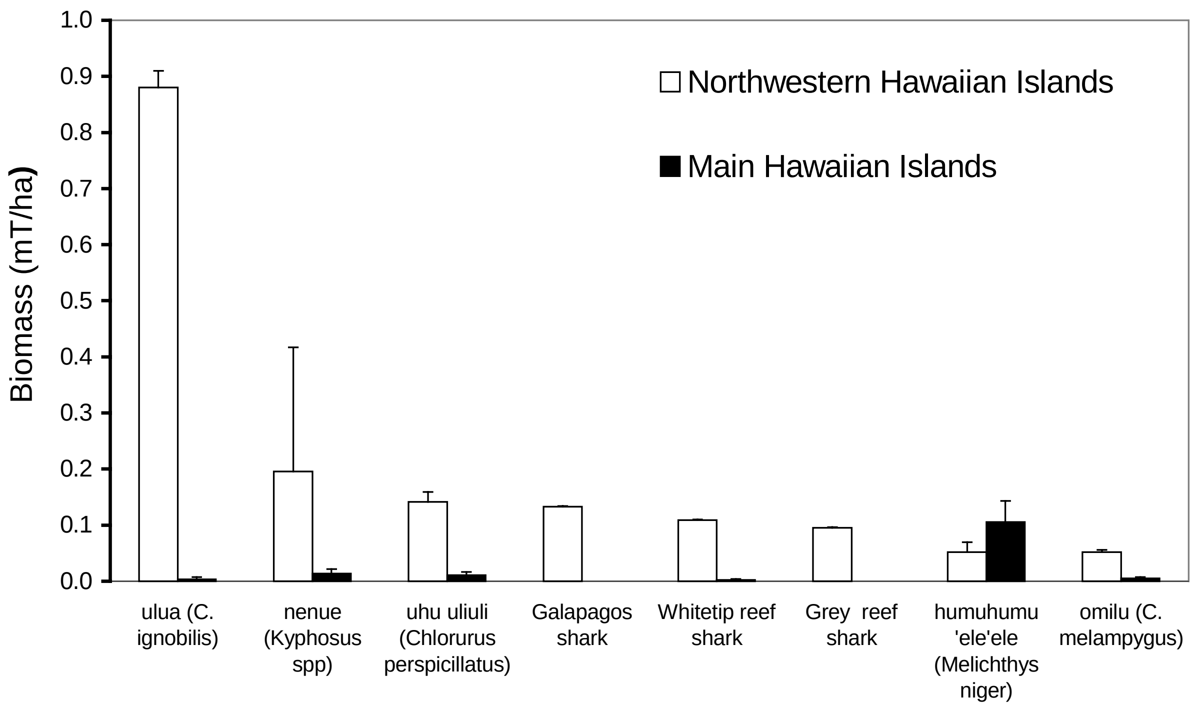

Figure 9. Grand mean biomass of the top eight taxa by weight in the Northwestern Hawaiian Islands (solid bars) and corresponding values for these taxa in the main Hawaiian Islands (open bars). Error bars are standard errors of the mean (from Friedlander and DeMartini 2002).

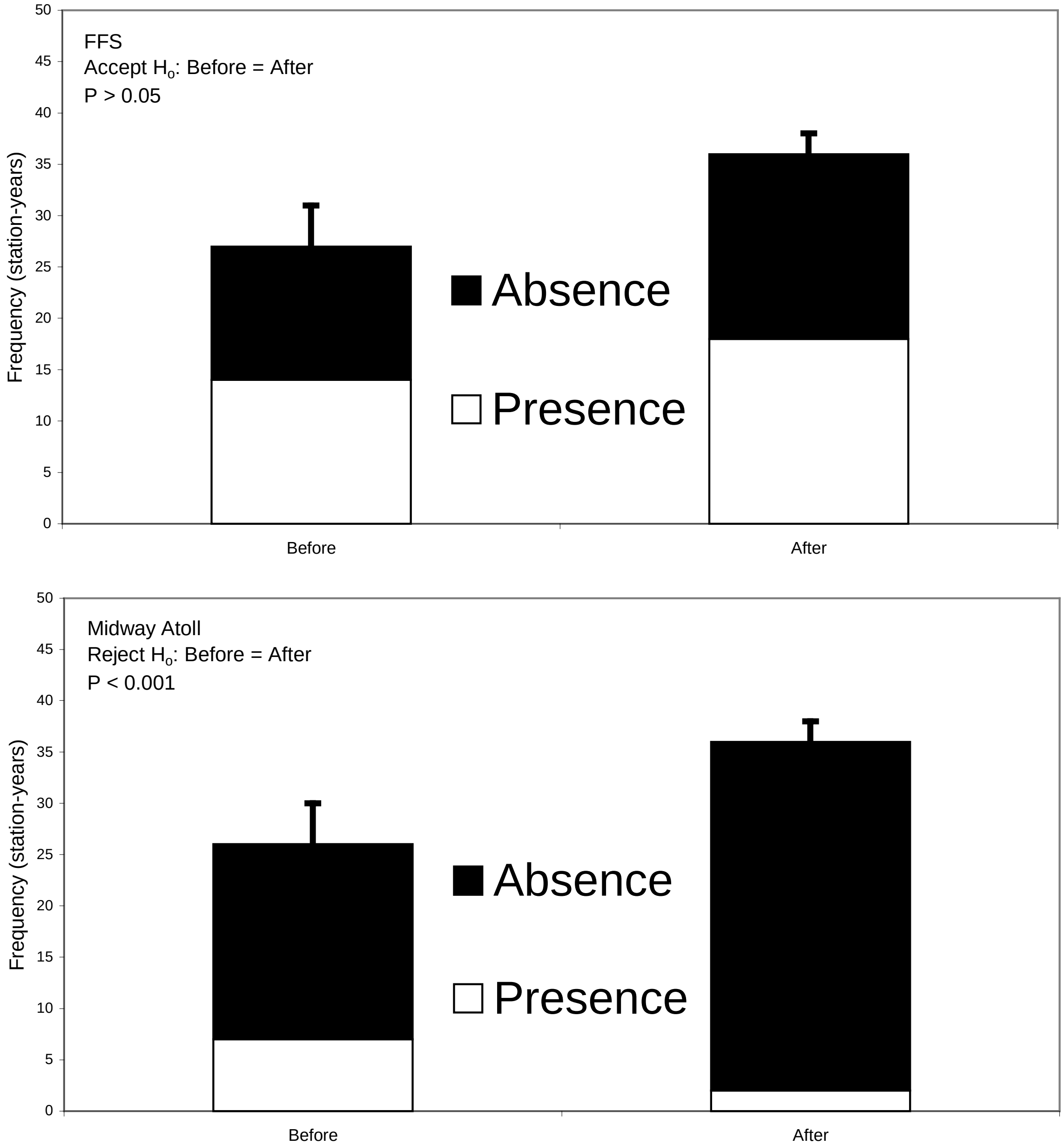

Figure 10. Relative presence-absence of ulua (*Caranx ignobilis*) at French Frigate Shoals (FFS) and Midway Atoll from 1992 (FFS) and 1993 (Midway) ("Before") and after 1996 ("After"). (Adapted from DeMartini et al. 2002).

However, without direct measures of mortality, the decline in mortality remains only a hypothesis. Recent tagging of jacks by DAR may provide information on mortality rates with which to make a better assessment of stock condition. Over 600 volunteer anglers have tagged and released over 6,200 jacks since 2000. These data are also providing information on the long distance and seasonal movements of ulua in the Hawaiian archipelago as well as helping to develop a catch and release ethic among recreational fishers. Such information will be essential inputs if there is additional development of Marine Protected Areas (MPAs) that are currently in vogue as a fishery management tool. Other management tools such as minimum sizes for coastal fish have recently been revised by DAR.

The Division of Aquatic Resources has recently set new larger minimum sizes for many reef species including ulua and papio in response to concerns about overfishing of inshore fishery resources in Hawai'i. For all larger jacks (excluding akule and opelu) the new minimum size is 10 in. FL for home consumption and 16 in. FL for sale. There is also a bag limit of 20 total ulua and papio per day. The trend towards greater catches of ulua aukea exceeding 100lb in the recreational fishery should continue to be monitored in case management action is needed to preserve large females. The DAR tagging program will be an invaluable source of information for the future management of these stocks. The development of larger, more effective marine reserves will create off-limits populations that can greatly reduce the high fishing mortality currently affecting jacks near many populated areas of the state. This control on fishing mortality should help to rebuild locally depressed stocks through the enhanced reproductive output of large females and through the spillover of adults into fished areas. A combination of management strategies will be required to rebuild stocks of ulua and other large coastal jacks to those levels experienced by previous generations.

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Stock and Habitat Enhancement: Additional Tools for Managing Coastal Fish Stocks

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Abstract

Many coastal fisheries in the Hawaiian Islands show evidence of depletion through over- fishing or loss of critical habitat. While conventional stock management (imposition of harvest controls) may aid some over-fished stocks to recover, generally such recovery is slow and subject to variability of natural recruitment. Research into the feasibility of stock enhancement (release of hatchery-reared fish to supplement stocks and reproductive success) in Hawai‘i on striped mullet (‘ama‘ama, *Mugil cephalus)* and Pacific threadfin (moi, *Polydactylus sexfilis*) has demonstrated the potential contribution released fish can have on localized fisheries, and on-going research is examining the contribution of hatchery-reared fish to reproduction and stock recovery. For species for which critical habitat has been lost, additional or replacement habitat (artificial reefs) may mitigate some loss. To date, the Hawai‘i artificial reef program has focused on providing habitat to increase and enhance fishing opportunities by placing a variety of structures in coastal areas of sparse natural habitat (ships, barges, rubble, “Z” blocks) and in offshore waters (FADs). These reefs provide structure to support large fish of recreational or commercial importance.

Introduction

In Hawaii, as in other locations around the world, local fishery yields have leveled off or are decreasing (Shomura, 1987). Many stocks are over exploited, fully exploited, or of questionable status. While the State Division of Aquatic Resources, the responsible management agency, collects catch data for holders of commercial fishing licenses, most of these fishers target offshore pelagic or demersal fisheries. The state does not license recreational or subsistence fishers, nor does it systematically collect catch data from shoreline fishers who target coastal and inshore fisheries.

Resource managers have a range of options for managing depleted fisheries stocks. For growth-limited fisheries, where fishery yield is less than maximum sustainable yield due to over-fishing, managers typically enact regulations to restrict fishing effort, either through catch limits, size limits, gear restrictions, closed seasons, or some combination. Recently, managers are examining the effectiveness of establishing natural reserves or implementing community-based management for localized fisheries.

Recruitment-limited fisheries are those whose rate of natural reproduction and/or recruitment is less than that needed to maintain the population at optimal levels. The limit to reproduction is primarily due to severely depleted adult (reproductive) stocks, loss of spawning or nursery habitat, or both. In such cases, even complete bans on the taking of these stocks may not result in recovery, or recovery may be extremely slow because the net rate of increase of the population is low or inter-annual variations in recruitment result in only sporadic strong year classes. For recruitment-limited stocks, management options include increasing recruitment through propagation and release, most commonly of competent juveniles, but potentially of mature adults as well, or restoring degraded spawning and nursery habitat.

Coastal fisheries in Hawaiʻi are sensitive to natural variations in environmental conditions, particularly rainfall and runoff and high surf events, as well as man-made environmental perturbations such as coastal dredging and sedimentation from terrestrial sources. The impacts of these perturbations most strongly influence early survival and are one of the primary factors affecting internal variations in recruitment success.

Pacific threadfin, *Polydactylus sexfilis*, is an ideal candidate for a stock enhancement program. *P. sexfilis* is a member of family Polynomial, comprising 33 species with tropical and subtropical distributions. Pacific threadfin in Hawaiʻi is known as moi, the “fish of kings." It is one of the most culturally important, locally popular coastal fish species in Hawaiʻi. The Pacific threadfin fishery in Hawaiʻi is highly depleted, and in response, there are regulations setting limits on the daily catch, minimum size, and a closed season. All available evidence suggests that Pacific threadfin is recruitment limited, at least on the island of Oʻahu. Culture techniques for the species are well established. The fish spawn spontaneously in captivity, produce large numbers of healthy fry, and can be grown to a size appropriate for tagging within 60-90 days after hatch. The juveniles inhabit defined nursery habitats, high-wave-energy sandy beaches, while the adults move offshore to sand patches in hard bottom areas.

The Oceanic Institute has been conducting research into the enhancement of depleted fisheries for over a decade, currently focusing on Pacific threadfin, an important but depleted coastal fishery in Hawaiʻi. Our capability at the Institute to produce large numbers (100,000 per month) of healthy fry on a continuous basis, combined with Hawaiʻi's advantages of year-round warm temperatures, unpolluted coastal waters, and underrated habitats, form the foundation for innovative enhancement research.

Early research on Pacific threadfin focused on the determination of optimal release strategies (size, site, and season) (Leer et al. 1998). Having established a capability to produce, tag, and release large numbers of fry with reasonable return rates, the focus of our enhancement research has turned from "can we release and recapture fish" to "how do we conduct enhancement responsibly?”

Research Components

Four of the primary areas of research for Pacific threadfin stock enhancement development, identified for focus by the Hawai‘i Stock Management (HSM) Program at the Oceanic Institute, are release optimization; fisheries demographics, ecological interactions, and habitat utilization; genetic management; and the ecological basis of fishery production. All research has been conducted along the windward coast of the island of O‘ahu (Figure 1).

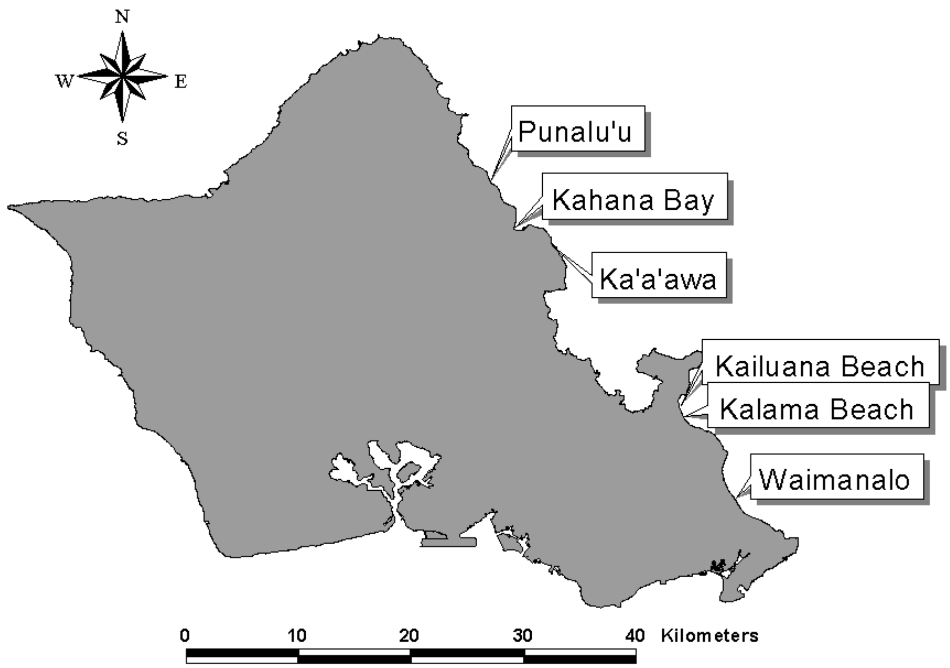


Figure 1. Map of O‘ahu, Hawai‘i, showing locations of primary sampling sites.

Tagging Technology

Before release, all fish receive coded wire tags (cwt, Northwest Marine Technologies) in the snout area to identify a release batch of the same size fish, date, and location. To determine tag retention rates, approximately 5% of each release lot are retained and examined monthly for one to six months, until the tag loss rate stabilizes (i.e., when the number lost had not increased since the previous month). Tag retention rates vary from 92.3% to 99.2%.

Release Optimization

The HSM Program conducted a multi-year study to examine the recapture rates of hatchery-reared moi released into Kahana Bay, Oʻahu from 1996-1999, focusing on the influence of size at release on recapture success (Ziemann et al, in prep). Release experimental design was based on patterns of natural recruitment. Releases were conducted primarily in fall and winter, the peak season for wild recruitment to the sandy beach nursery habitats. Releases and recapture sampling focused on the sandy beach habitat, which is known to be the preferred nursery habitat. Fish were sorted into four size classes and coded-wire tagged for size, location, season, and replicate batch. Release size classes ranged from 70 mm, the minimum size to safely handle and tag fingerlings, to 130 mm.

Two types of recapture methods were used: beach seining and recovery of fish from commercial and recreational fishermen through the use of a creel survey and reward program. Results varied from year to year, but some trends were evident. Because the release experiments patterned releases after known patterns of natural recruitment and thus eliminated extremes of size, out of season releases, or releases into unsuitable habitat, no major effects of size, site, or season were observed. One statistically significant difference was distinguished between beach seine recapture percentages for two size classes in the 1997 releases, in which 85-100mm FL moi were recaptured at about twice the rate of 100-115 mm FL moi. In 1997, the release period extended for two seasons of the year, allowing for a within-year comparison of summer and fall releases. For that year, smaller fish appeared to survive better than larger fish in both summer and fall, but recapture rates were slightly higher for summer releases than for fall releases. Based on these results and similar ones from a release in 1994, an optimal release strategy for Kahana Bay may be either to release small fish in the summer months or large fish in the winter.

Fisheries Demographics and Ecology

Contribution to the recreational fishery

The HSM Program conducted a multi-year study to examine the contribution of hatchery-reared fish to the recreational fishery along the windward coast of Oʻahu, Hawaiʻi (Friedlander and Ziemann, 2003). Over 340,000 fingerlings of various sizes were implanted with coded wire tags and released in nursery habitats along the windward coast of Oʻahu between 1993 and 1997. Because few Pacific threadfin were present in creel surveys conducted between 1994 and 1998, Oʻahu fishermen were offered a $10 reward for each threadfin (hatchery-reared and wild) caught. A total of 1,882 Pacific threadfin were recovered from the reward program between March 1998 and May 1999, including 163 hatchery-reared fish, an overall contribution of 8.7% to the fishery. Hatchery-reared fish were as high as 71% of returns in the release areas. Hatchery-reared fish were recovered on average 11.5 km (SD = 9.8 km) from the release site, though some had moved as far away as 42 km. Average age for recovered hatchery-reared fish was 495 days with the oldest being 1,021 days.

Cultured Pacific threadfin juveniles survived and recruited successfully to the recreational fishery, accounting for 10% of fishermen's catches on the windward side of O‘ahu. Recruitment to the fishery was highest for the 1997 release year; few juveniles from earlier releases were observed. Presence of a few large, fully-developed females in the recreational fishery suggests that hatchery-reared fish can survive, grow, and reproductively contribute to the population.

<u>Monitoring Natural Recruitment</u>

The HSM Program conducted monthly beach seine surveys continuously over a five-year period (1997-2001) at six nursery habitat beaches along the windward coast of the island of O‘ahu (Ziemann in prep). The beach seine measured 24 x 1.8 m with 1.3 cm mesh. During each sampling period, a consistent level of effort was followed. Sampling efforts consisted of a series of 6 to 12 seine hauls, depending on the length of sandy beach available; data were standardized to catch per unit effort (CPUE = number of fish caught per haul). Hauls were started at a distance of about 10 m offshore or in a water depth of about 1-1.5 m and pulled directly towards shore. Sampling generally occurred during mid-tidal heights in morning but without specific regard to tidal height, times of day, or weather condition. Sampling was only conducted when surf height along the shoreline was 0.6 m or less.

The CPUE for wild threadfin juveniles collected during the recruitment study is presented in Figure 2. Several patterns are evident. First, for all years, peak recruitment was observed during winter months (November – January), with low or no recruitment observed during summer months. Second, the inter-annual variability in overall recruitment was large, with highest monthly levels observed in 1997, and lowest levels observed in 2001. Finally, the extremely low levels observed in 2001 suggest that the particular combination of low adult population size and apparently poor larval survival resulted in almost total failure of the 2001 recruitment year class.

<u>Habitat Utilization</u>

Movement patterns and habitat utilization of moi (*Polydactylus sexfilis*) were assessed using data from tag-and-release studies and acoustic tracking (Friedlander and Ziemann in prep). The locations and dates of capture for each fish returned in the recreational fishery survey were analyzed to calculate net displacement (distance from release site). Long-term movement of over 60 km occurred along the windward coast of O‘ahu (Fig.3). **T**he sandy surf zone habitat at the Kahana Bay and Kailua Bay release sites provided good juvenile habitat while rocky high-wave-energy habitats such as Mokapu Peninsula and Kahuku provided better habitat for larger individuals. The smallest size class released (70-85 mm FL) had the greatest number of days at liberty and the longest range of movement. The smaller movement associated with larger size classes may be owing to their susceptibility to exploitation soon after release.

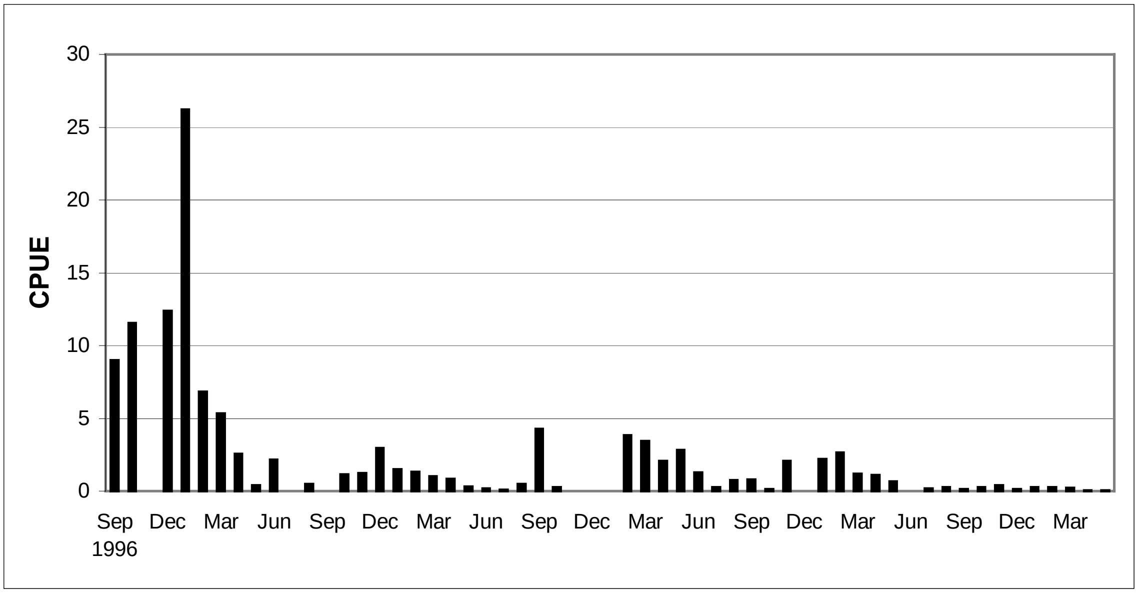


Figure 2. Mean monthly catch per unit effort (CPUE) for year 0 Pacific threadfin in nursery habitat on the windward coast of O'ahu.

Acoustic tracking of small (150-170 mm FL) hatchery-reared moi was conducted periodically over a two-year period (2000 - 2001). Hatchery fish were surgically implanted with a Vemco acoustic tag, stabilized for two days in a recovery tank, and released with 10-12 similar fish into nursery habitat in Kahana Bay or Kailua Bay. Fish were tracked continuously up to 48 hours after release with an acoustic receiver on a small boat. Position/bearing plots were recorded to estimate day and night habitat range and movement. Acoustic tracking showed limited movement along the sandy surf zone habitat during the day and increased activity at night with more movement offshore. Similar patterns were seen for most of the fish tracked.

Diet and Feeding

Because the diet of an organism has considerable influence upon survival and fitness, the acclimation of hatchery-reared fish to the natural diet is an important component to the success of a release program. Research examined the dietary composition of juvenile, subadult, and adult wild and cultured *P. sexfilis* from the coastal waters of east O'ahu, Hawai'i (Ogawa et al. in prep). The intention of this study was to establish the major dietary characteristics of wild *P. sexfilis* and to make general dietary comparisons between hatchery-reared and wild *P. sexfilis*. The dietary characteristics of wild and hatchery-reared *P. sexfilis* captured from the east coast of O'ahu, Hawai'i, were very similar. Small benthic crustaceans such as shrimps and amphipods dominated the diet of juvenile fish; whereas shrimps, crabs, and fish were the predominant prey items found in adult fish. These prey items are typical among polynemids. Differences in diet were found among size classes for both cultured and wild fish. Horn's overlap index was used to qualitatively compare diets and the Mann-Whitney rank sum test used to detect differences between relative prey weights. Cultured fish feeding habits immediately after release were dissimilar from wild fish, but cultured fish diets rapidly changed to approximate those of wild fish (Figure 4).

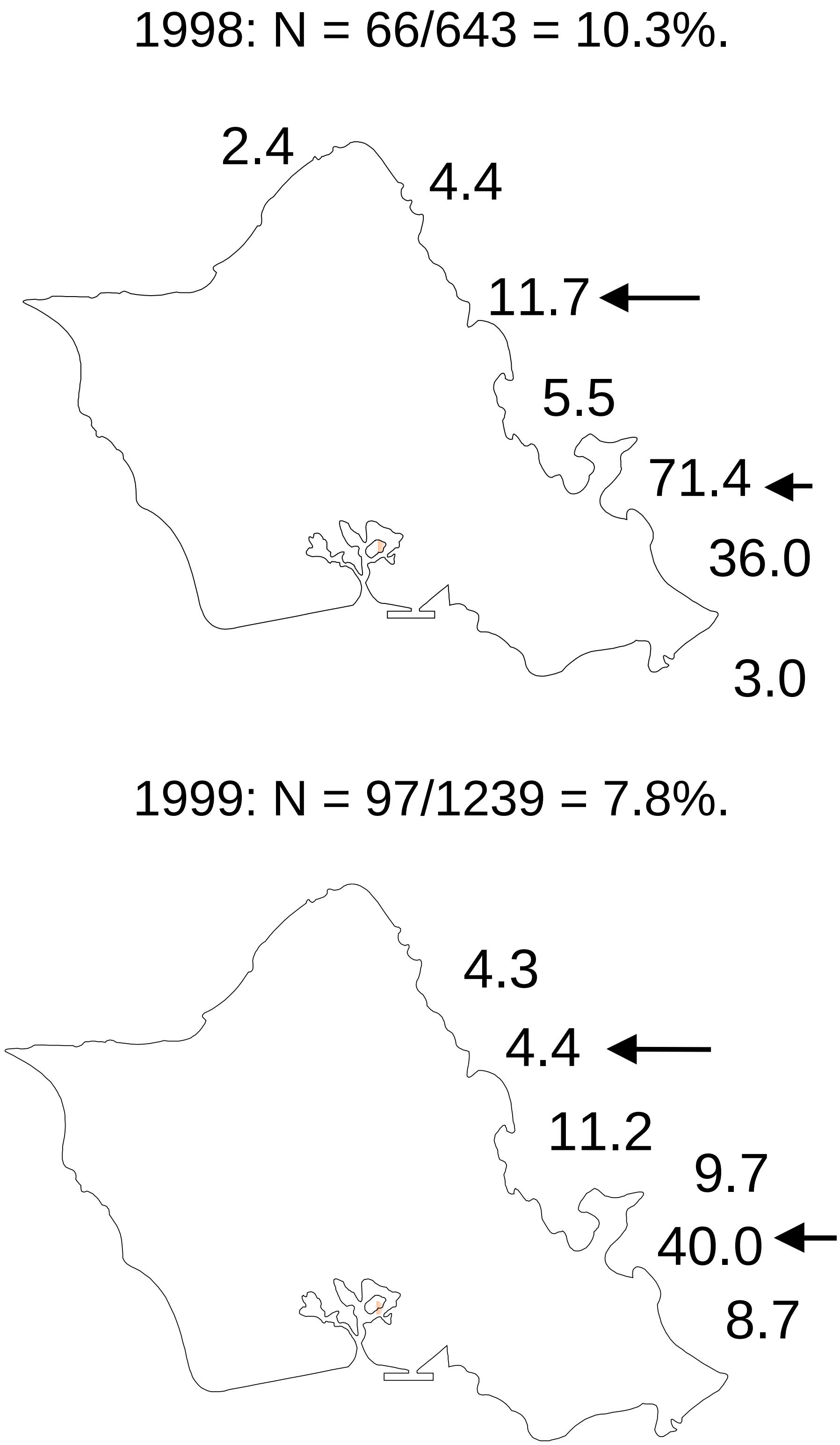


Figure 3: Location of collection and percent contribution of cultured fish released at Kahana Bay in 1997 to the recreational fishery. A: 1998, B: 1999 (adapted from Friedlander and Ziemann 2003).

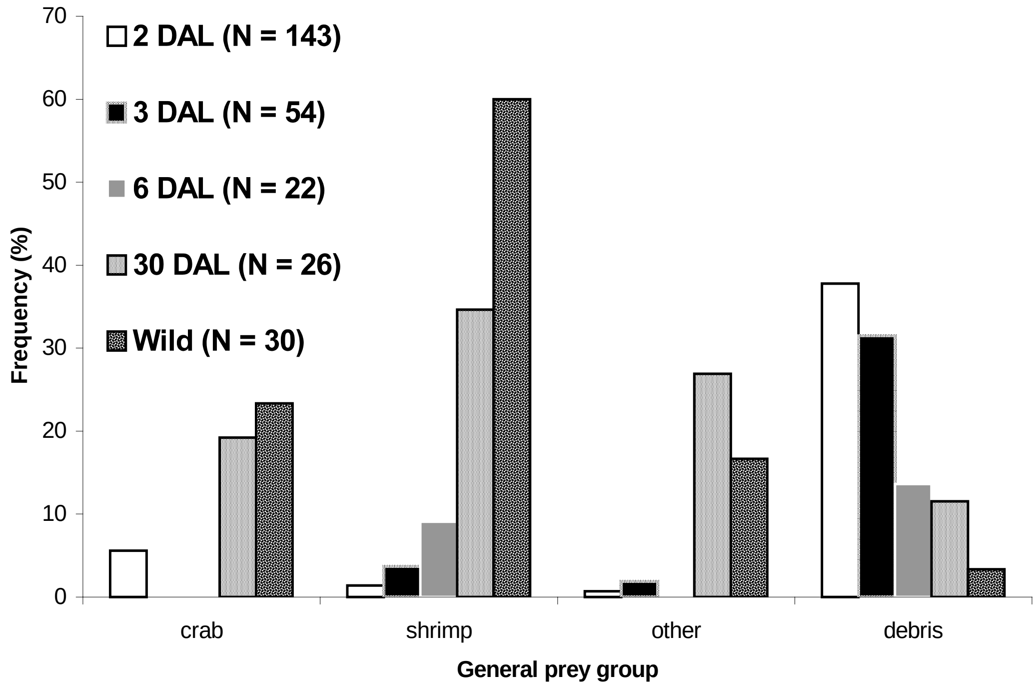


Figure 4. Primary food items found in stomachs of released Pacific threadfin at 2, 3, 6 and 30 days after release, and wild fish, collected in Kahana Bay.

Age and growth

Increased knowledge of early life history characteristics is needed to address fundamental questions of age and growth patterns of Pacific threadfin, which may be helpful in artificial propagation and larval rearing. The HSM Program conducted a study (Bloom et al., submitted) to validate daily increment formation in otoliths of Pacific threadfin, and to conduct preliminary age determinations on wild juveniles. Wild juvenile Pacific threadfin were collected in Kahana Bay, O'ahu, Hawai'i, from December 1998 to May 1999. Saggitae were removed, cleaned of endolymph tissue, and stored dry in cell culture trays. Otolith microstructure of wild juveniles was examined. Successful validation of "daily" growth rings was established from cultured juvenile fish of known age. Age estimations were made for wild juvenile Pacific threadfin (n=50). For wild juveniles collected in 1999, back-calculated hatch days indicated that the year class was the product of multiple spawnings over a four-month period in winter.

Genetic Management

Preliminary aspects of genetic management for Pacific threadfin stock enhancement research at the Oceanic Institute (OI) have been focused on genetic stock identification and broodstock management (Tringali et al., in press). To investigate genetic structure in threadfin populations potentially impacted by stock enhancement, wild specimens from four locations on Hawai'i (*n* = 41) and from three locations on O'ahu (*n* = 32) were assayed by sequencing 1045 base pairs of the mitochondrial DNA (mtDNA) control region. Overall, haplotype diversity was high (99.3%); a total of 61 unique haplotypes were observed from the 73 individuals assayed. However, nucleotide diversity was low (0.64%). No phylogeographic structure was evident in clustered haplotypes. Genetic variance was partitioned predominantly among individuals within populations (98%); approximately 1% of the genetic variance occurred between the threadfin from the islands of O‘ahu and Hawai‘i. Haplotype distributions did not differ significantly among these two locations. These data, which are preliminary, are suggestive of high gene flow on a regional basis. The female effective population size, estimated using a Maximum Likelihood Metropolis-Hastings sampling method, ranged approximately 200,000-400,000. The sampled population appears to have undergone a large, historical expansion. Taken together, data are consistent with an evolutionarily recent colonization of the species in the Hawaiian Islands.

Ecological Basis of Natural Recruitment

Rates of natural recruitment of Pacific threadfin to nursery habitats has been observed to be highly variable between years (Figure 2). Recruitment success is the result of the actions of a range of factors, both related to the number of larvae produced (size of the reproductive population, spawning frequency and success), and to environmental factors acting at the time of spawning and the early larval stage (low predator abundance, high food availability, favorable physical conditions). Preliminary data collected by the HSM Program suggests a relationship between natural recruitment and environmental factors (Figure 5; Ziemann and Friedlander, in press); in this case, mean annual temperature may be a proxy indicator of overall rainfall, which influences the input of dissolved nutrients into coastal waters.

The HSM Program has begun a research component to examine the ecological basis of natural recruitment in Pacific threadfin. The study entails monthly physical, chemical, and biological surveys focused on Kahana Bay, a primary site for early threadfin recruitment. Physical oceanographic studies include measurements of currents and determination of the impacts of tidal exchange on the distribution and concentrations of dissolved nutrients. Nutrient input studies are examining the sources and types of nutrients entering the bay and generating estimates of uptake and dispersal rates. Biological studies are focusing on the distribution, abundance, and major taxonomic components of the benthic and planktonic communities.

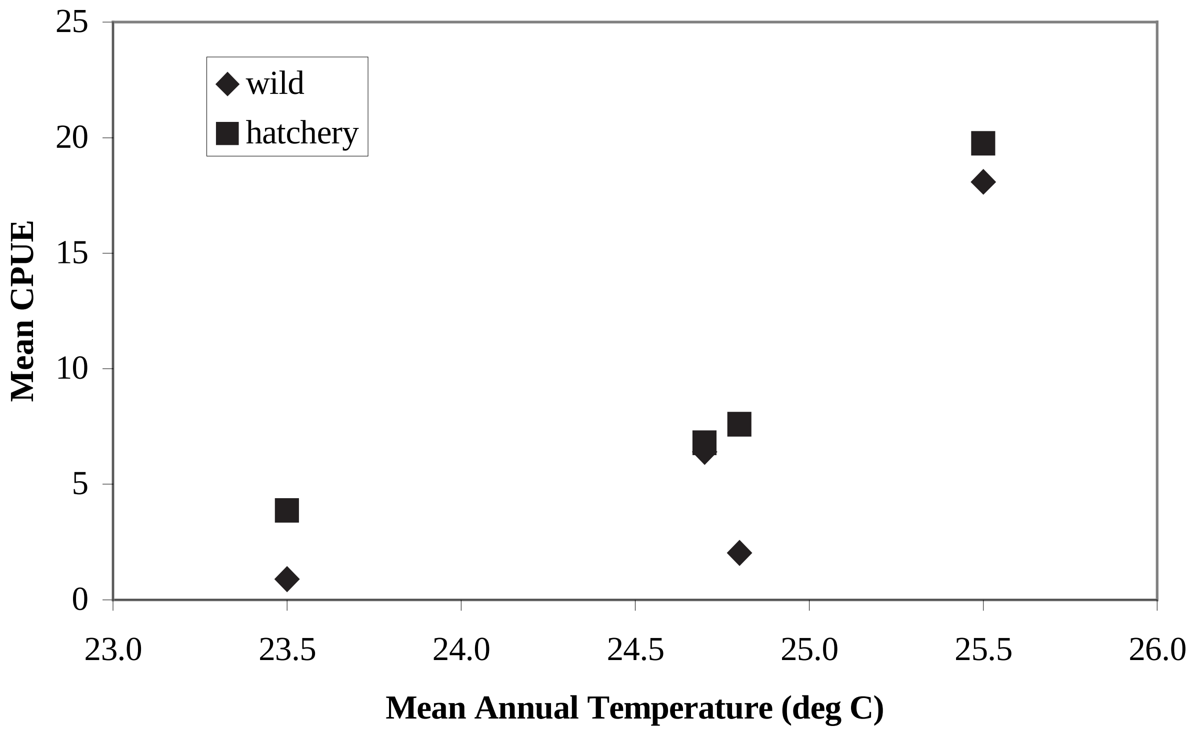


Figure 5. Plot of mean annual catch per unit effort for wild and released year 0 Pacific threadfin along the windward coast of Oahu, related to mean annual water temperature at Kahana Bay, Oahu.

Artificial Fish Shelter System Development and Operation

In Hawai‘i, much of our nearshore areas are habitat-poor with extensive barren ocean bottoms comprised of bands of flat limestone and large sand patches. During the mid-1950s, the Division of Aquatic Resources (formerly Fish and Game) placed a few experimental concrete structures at certain nearshore areas off the island of O‘ahu in an attempt to increase fish habitat. Substantial increases in reef fish populations around these structures were observed almost immediately. In 1961, the State implemented an artificial reef project under the Federal Aid in Sport Fish Restoration Program. The Maunalua Bay Artificial Reef on O‘ahu was the first artificial reef established (1961). This was followed by the establishment of the Keawakapu Artificial Reef off Maui (1962), and Wai‘anae (1963) and Kualoa (1972) Artificial Reefs off O‘ahu. Initially all of the Reefs were constructed with old automobile bodies. Except at the Kualoa Reef, other materials including concrete/conduit pipes, barges, and ships have been deployed. Totally, these reefs encompass an area of almost 2,000 acres. Over the years the car bodies gradually corroded away, and the loss of habitat caused a decline in the once-abundant fish populations. Artificial reef replacement began in the mid-1980s with the construction and deployment of simple, cost-effective fish habitat modules consisting of eight to ten used automobile tires embedded in concrete. Thousands of modules were added to the Maunalua Bay, Wai'anae, and Keawakapu Artificial Reefs, dramatically increasing the fish communities in these areas (Figures 6, 7 and 8).

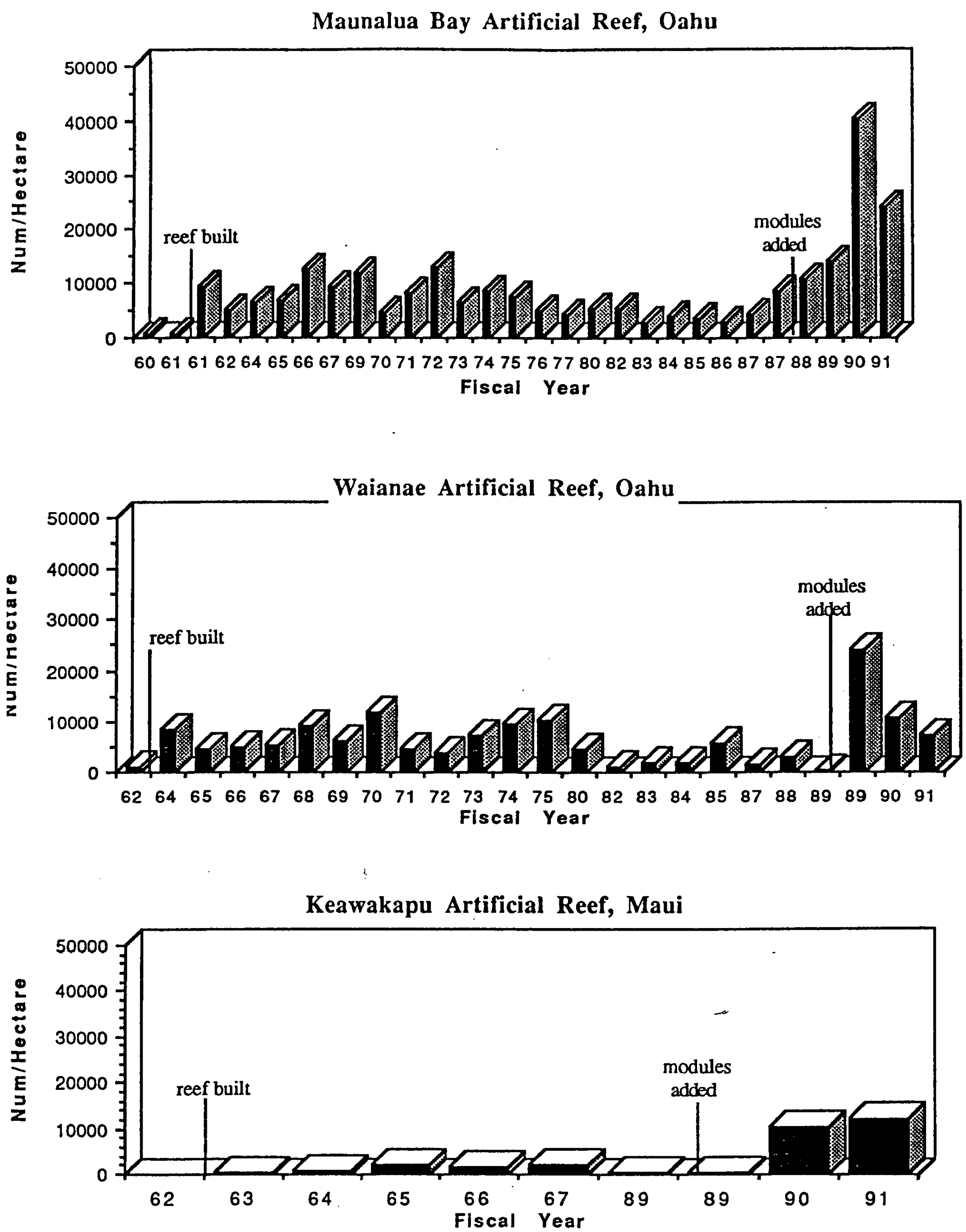


Figure 6. Fish abundance per hectare at Maunalua Bay, Waianae and Keawakapu Artificial Reefs.

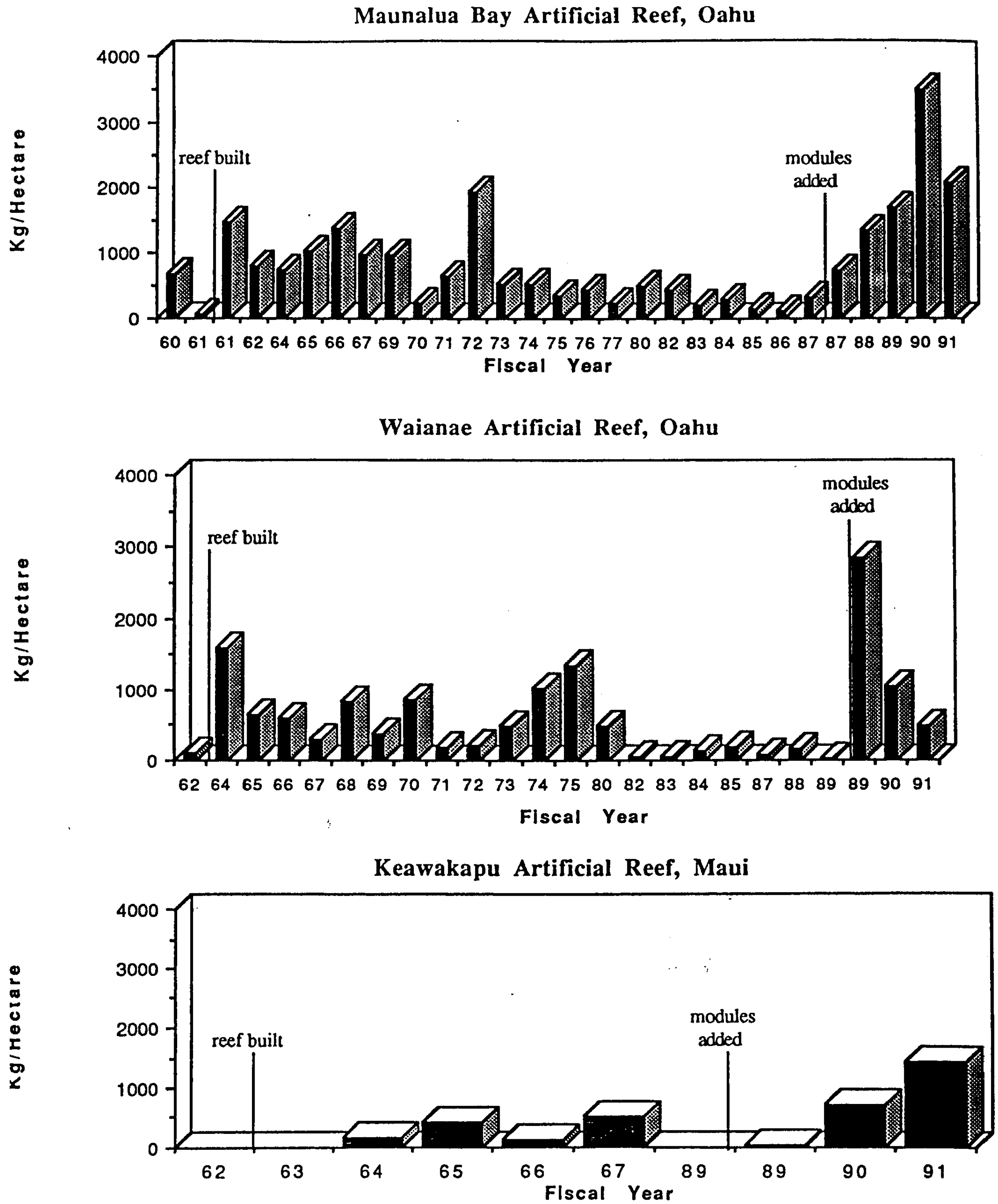
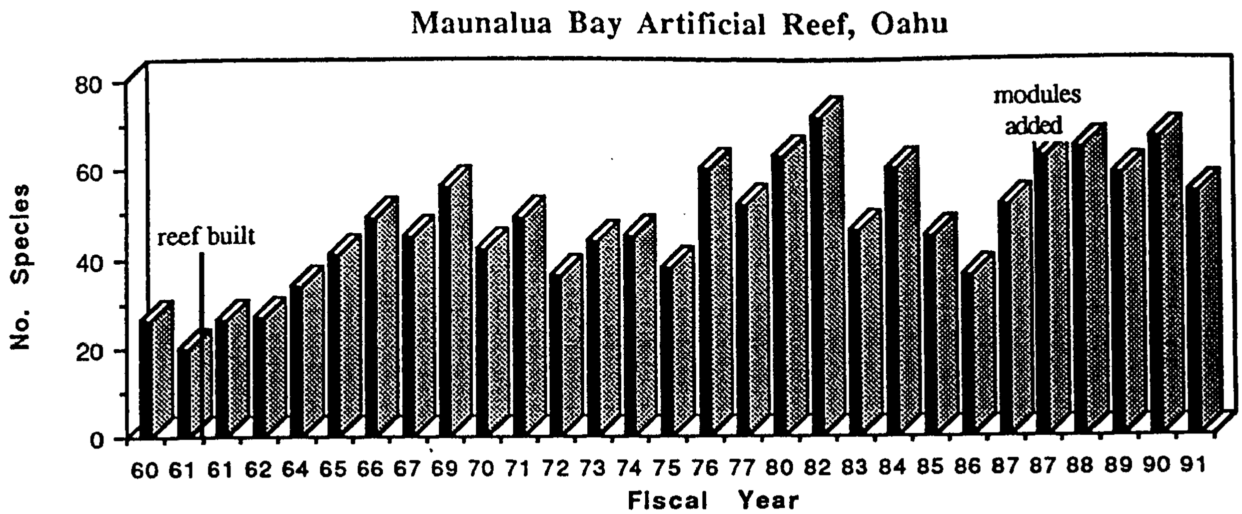
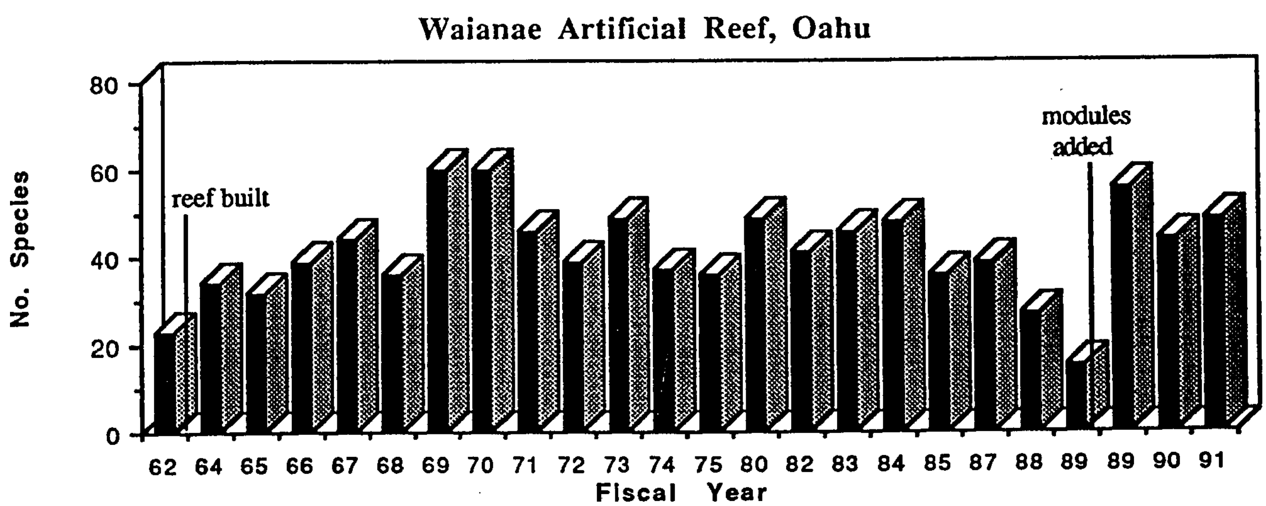


Figure 7. Fish biomass (kg/hectare) at Maunalua Bay, Waianae and Keawakapu Artificial Reefs.





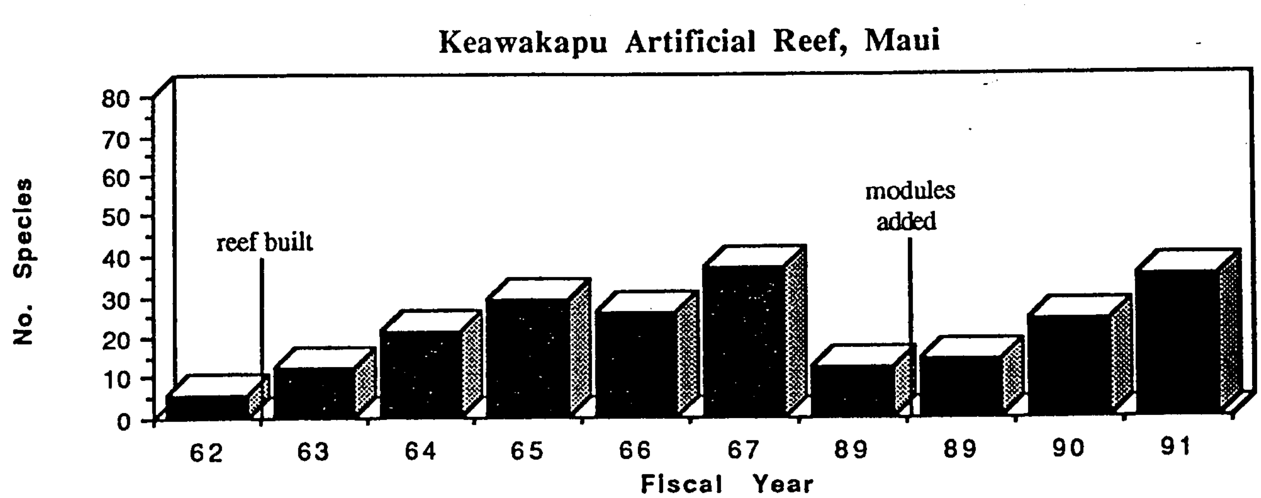


Figure 8. Number of fish species observed at Maunalua Bay, Waianae and Keawakapu Artificial

In 1987, a project was initiated to provide habitat for deepwater bottom fish by establishing an artificial reef site in waters 300-400 feet deep. Four barges donated by the U.S. Navy and more than 8,000 tons of material (i.e., damaged conduit pipes, concrete slabs, and boulders) have been deployed at a site 1.5 miles off ‘Ewa Beach, O‘ahu. Hand line sampling and submersible observations document a developing bottom fish community at the ‘Ewa Deepwater Artificial Reef. During an eight-year period between 1987 and 1994, a total of 3,630 fish was caught in 232 hours of hand line fishing for a catch-per-unit effort of 15.5 fish-per-line-hour. Forty-three fish species were captured and identified (39 from hand line fishing and 4 from trapping) from the Reef. The majority of the bottom fish caught at the Reef were opakapaka (*Pristipomoides filamentosus*) comprising 43.7 percent (1,585 specimens) closely followed by taape (*Lutjanus kasmira*) comprising 42.8 percent (1,555 specimens) of the catch.

In recent years, thousands of specially designed “Z” or “N” shaped modules cast from surplus concrete donated by a local concrete company were constructed and deployed at shallow water artificial reef sites.

Summary

Research into the feasibility of stock enhancement in Hawai‘i on Pacific threadfin has established the information necessary to design and implement a responsible enhancement program, and has demonstrated the potential contribution that released fish can have on localized fisheries. Our research has shown: the optimal release strategy matches natural recruitment patterns; cultured fish adapt quickly to natural conditions; and experimental releases have made significant contributions to O‘ahu recreational moi fishery. The threadfin population, on the island of O‘ahu at least, is severely depleted, suffering from both low adult population size and low and variable recruitment. Research has shown significant interactions between adult population size, natural recruitment, and the impacts of releases. Current research is examining fisheries demographics and ecology, genetics, the ecological basis of recruitment success, and means to determine the contribution of hatchery-reared fish to reproduction and stock recovery. Major questions on factors affecting population size, nursery-carrying capacity, and recruitment success, wild vs. hatchery fish interactions, and the long-term (multi-generational) effects of releases remain.

In 1961, the State of Hawai‘i implemented an artificial reef project under the Federal Aid in Sport Restoration Program. Initially all of the reefs were constructed with old automobile bodies, concrete conduit pipes, barges, and ships. Over the years the car bodies gradually corroded away and the loss of habitat caused a decline in the once- abundant fish populations. Reef replacement began in the mid-1980s with the construction and deployment of simple, cost-effective fish habitat modules consisting of eight to ten used automobile tires embedded in concrete. Thousands of modules were added to existing artificial reef sites, resulting in a dramatic increase in fish communities in these areas. In 1987, a project was initiated to provide habitat for deepwater bottom fish by establishing an artificial reef site in waters 300-400 feet deep. Hand line sampling and submersible observations document a developing bottom fish community at the site. In recent years, thousands of specially designed “Z” or “N” shaped modules were deployed at shallow water artificial reef sites.

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Status and Management of Hawai‘i's Akule Fishery

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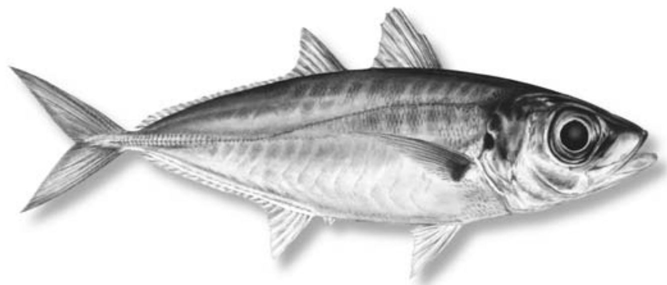

Introduction

The akule, or bigeye scad (*Selar crumenopthalmus*), a member of the family Carangidae (Jacks), is a popular and important commercial and recreational fishery species in Hawai‘i. In 2000, a reported 1,096,726 pounds (498,512 kg) were landed commercially, for a reported ex-vessel value of $1,568,422 (Division of Aquatic Resources commercial catch reports). Most (85%) of the commercial harvest of akule is made by fishermen using seine or gill nets to enclose schools of akule that gather close to shore in relatively shallow water. Spotter planes are sometimes used to find the akule schools. A much smaller proportion (about 15%) of the commercial harvest is taken by hook-and-line (primarily hand line) gear.

As well as being a valuable commercial species, the akule is also a sought-after recreational and subsistence catch. The juvenile akule (called hahalalu or halalu) are a popular quarry of recreational shoreline fishermen. While commercial catch data exist, little data on recreational landings are available for akule.

In recent years, hook-and-line fishermen have complained that the harvest of akule by net fishermen has harmed the resource and competition for fishing areas has increased. Similarly, conflicts have arisen between recreational/subsistence fishermen and commercial fishermen.

Status of the Akule Resource

The public perceptions of a diminishing abundance of akule and gear competition in the fishery are nothing new. Kawamoto (1973) noted a concern by both commercial and recreational fishermen about declining akule resources and competition between net and hand line fishermen for the akule. Kawamoto concluded that the resource appeared to be sound and the regulatory measures then in effect were adequate for management of the fishery. Almost 30 years later, an extensive analysis of the akule fishery (Weng and Sibert 2000) using commercial fishing data concluded that the akule resource in the Main Hawai‘ian Islands is basically healthy and is lightly to moderately exploited.

Weng and Sibert examined historical landings data reported on catch reports by commercial fishermen. The following figures are from their 2000 report, used with permission.

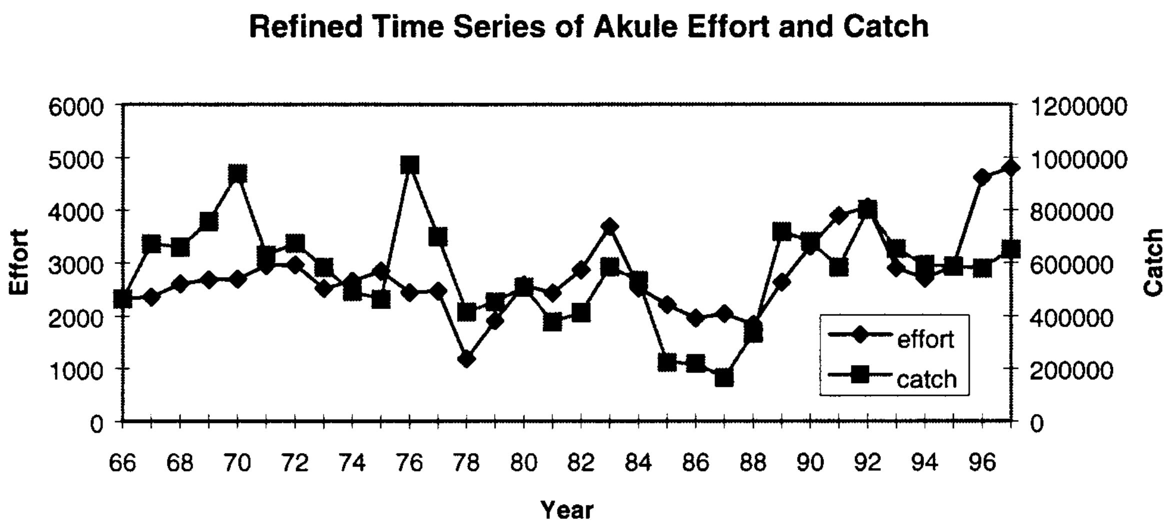

Figure 1. Historical effort (trips) and catch (pounds) of the akule fisheries (Weng and Sibert 2000).

While landings have varied widely over the 31 year period shown here, recent landings have reached as high a level as were previously attained in 1970 and 1976. Effort has remained high in recent years as well. However, there is no obvious trend in total landings or effort over the period.

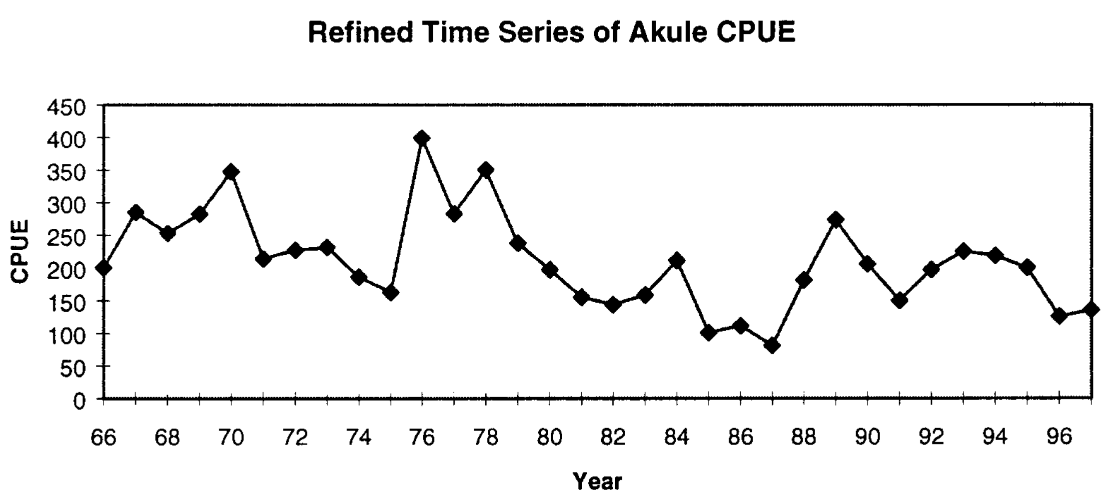

Figure 2. Historical CPUE (pounds/trip) of the commercial akule fisheries (Weng and Sibert 2000).

The CPUE has also fluctuated widely over the same period and in 1997 was fairly low. However, a clearly declining trend is not evident.

Weng used a modified Schaefer surplus production model to study the akule biomass and stock condition. The hypothetical relationship plotted in Figure 3 indicates that for an over-exploited stock, the data points would fall along the left descending curve of the plot, while a lightly-exploited stock would fall along the right descending curve. A stock at MSY would be at the peak.

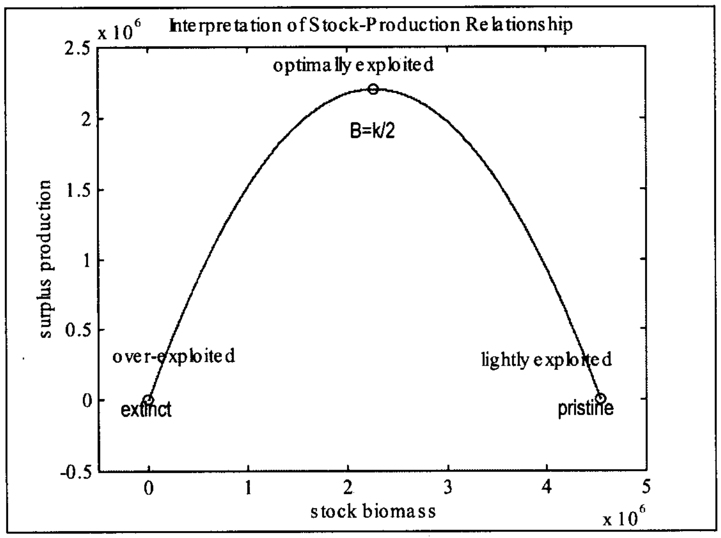

Figure 3. Hypothetical Stock-Production Relationship (Weng and Sibert 2000).

When the historical data were plotted, the points fell along the right side of the plot, indicating that the akule in the Main Hawaiian Islands are lightly exploited and the fishery is sustainable. The biomass is well above the level at MSY.

Management Issues

Despite the apparent abundance of akule, the fishery remains the concern of fishermen and resource managers. The primary issue appears to be competition among fishermen using various fishing methods and representing various sectors. Most of the akule are landed commercially using purse seine or surround net (55%), followed by gillnet (18%), inshore hand line (15%), unclassified net (8.3%), and akule net (3.5%). In other words, net gear takes 85% of the commercial akule landings. The conflict seems to occur primarily between the large operations using nets and the individual fishermen using hook-and-line gear. The net operators are primarily commercial and most of the hook-and-line fishermen are recreational or part-time commercial fishermen. Net operators sometimes set their nets in areas that overlap with hook-and-line fishing grounds, hence the ensuing gear conflict. The conflicts were documented in a DAR report (Kushima and Miyasaka 2001).

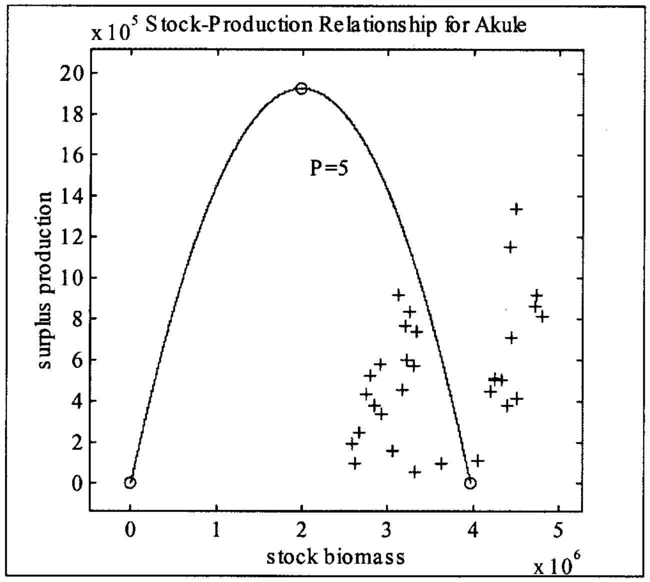

Figure 4. Surplus production for Akule vector-*k* model (Weng and Sibert 2000).

The commercial net operators often use spotter aircraft to locate large schools of akule and lay a purse seine net around the school. They may hold the school in the net for up to several days to enable spacing of deliveries to the market. The hook and line fishermen far outnumber the net fishermen but their landings fall far below the net fishermen.

State of Hawai'i Management Responses

The Department of Land and Natural Resources' Division of Aquatic Resources (DAR) is responsible for managing the fishery resources of the State of Hawai'i. DLNR implements part of that management responsibility through fishing regulations. DLNR regulates fishing through two processes 1) the Hawai'I Revised Statutes (HRS), and 2) the Hawai'i Administrative Rules (HAR). During the Legislative Session, the State Legislature enacts HRS that either directly regulate fishing or authorize DLNR to adopt HAR. DLNR adopts HAR all year around through the administrative rules procedures. The Division of Conservation and Resources Enforcement is authorized to enforce both HRS and HAR.

Under certain circumstances, DLNR uses this authority to address user conflicts among different fishing groups. The user conflicts between net fishers and pole-and-line fishers are not new issues. Such conflicts occur wherever the two groups fish in the same area at the same time. There are unconfirmed reports of such conflicts from over thirty years ago. The akule issue was brought to the forefront during the 1998 Legislative Session, when several bills were introduced to resolve the issue. DLNR asked the Legislature to allow the department time to identify and discuss the issues with the community before any Legislative action was to be taken. The Legislature agreed and DAR began its investigation.

Between March 1998 and January 2001, DAR held twenty-eight public meetings on O'ahu, Kaua'i, Maui, and the island of Hawai'i to discuss user conflicts and related issues in the akule fishery. The conflicts occurred where hook and line fishermen and net fishermen tried to fish in the same areas, especially at specific locations around Kaua‘i. Three major user groups were identified: 1) the recreational pole and line fishermen, 2) the commercial hook and line fishermen, and 3) the commercial net fishermen. A collaborative process was initiated to attempt to find agreement among the user groups on a management solution (Kushima and Miyasaka 2001). The role of DAR at that time was to assist the three groups to come to mutual agreement to address their differences. Unfortunately, the groups were not able to reach an agreement. It became DAR’s task to decide how this conflict would be managed.

The DAR proceeded to establish two new HAR and amended three existing HAR to reduce the user conflicts and enhance resource conservation in January 2002. These HAR had three main provisions 1) establish no-netting zones and a daily bag limit at three specific areas on Kaua‘i, 2) establish new regulations for the use of nets to take akule Statewide, and 3) establish a new Statewide commercial bag limit for hahalalu.

The most prominent issue was the conflict between shoreline pole and line fishers and the commercial net fishers at three specific sites on Kauai. Both groups agreed that the best way to address this issue was to establish fishery management areas (FMAs) where “buffer zones” could allow the groups to co-exist without interfering in each other’s fishing. The main dispute was where the line would be drawn. DAR saw the establishment of no-netting zones and a daily bag limit of 75 akule within the Hanamaulu Bay, Kauai (HAR Chapter 49), Port Allen (HAR Chapter 13-49.5) and Nawiliwili Harbor (HAR Chapter 13-49.6), Kauai, as the fairest way to divide the access to these resources so that both groups could continue to operate.

DAR established new regulations for the use of nets to take akule Statewide to reduce the potential for conflicts in areas outside of the three FMAs. In theory, if the nets used to take akule had to be a larger mesh size, then more hahalalu would be available for the shoreline fishers. A larger minimum net mesh size of 2.75” stretched mesh for non-commercial harvest was established statewide (HAR Chapter 13-75). Commercial netters may use a net with a minimum stretch mesh size of 2.5” for surround net and 2.75” for gill net. A minimum size of 8.5” for net caught akule from July through October was already in effect.

A commercial bag limit of 200 pounds was placed on halalu (juvenile akule <8.5” long) from July through October (HAR Chapter 13-95). The purpose of this provision was to aid enforcement of the existing restriction on netting of hahalalu during July through October. Enforcement of this provision was difficult due to the need to prove that the hahalalu were netted unlawfully during the net closed season. While the commercial bag limit would not eliminate the problem of unlawful netting of hahalalu, it would make the sale of netted hahalalu much more difficult since the fisher would have to now sell his fish to several dealers instead of just one dealer since his catch would normally be over the 200-pound limit.

In spite of these measures, the user groups were not completely satisfied with the results. The shoreline pole-and-line fishers, in particular, felt that the “solution” did not provide them enough protection from nets within their favorite fishing areas. While the net fishers were not happy that they had to “give up” parts of their fishing grounds, they were able to support the solution.

Because of the events of September 11, 2002, the piers at Nawiliwili Harbor, where the pole-and-line fishers fished from, were closed for security reasons. The no-netting zone in this harbor became an area where no one can exploit the fish. DAR would like to postpone any further amendments to allow things to settle as a result of the current rules before re-visiting them to see if a better solution can be achieved.

Unofficial copies of the rules may be obtained from the DAR web site at http://www.state.hi.us/dlnr/dar/har_toc.htm.

Acknowledgements

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Marine Protected Areas and Community-based Fisheries Management in Hawai‘i

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Abstract

The poor performance of conventional fisheries management has led to increased interest among resource managers in marine protected areas (MPAs), including no-take marine reserves — areas of the sea permanently closed to fishing and protected from other major human impacts. There are a variety of marine areas in Hawai‘i that have some type of protected status. The size and quality of habitats within these protected areas vary greatly and management regimes range from areas where all fishing is prohibited to areas where virtually all forms of fishing are allowed. Areas completely protected from fishing have distinct fish assemblages with higher standing stock and species diversity than areas where fishing is permitted or areas that are partially protected from fishing. Locations under community-based management with customary stewardship harbor fish biomass that is equal to or greater than that of no-take marine protected areas, although light fishing pressure and the remoteness of these locations may also contribute to the high biomass observed. In addition to levels of protection, good habitat diversity, complexity, and reserve size have been shown to have a positive effect on fish standing stock, whereas, areas with partial protection from fishing and/or poor habitat quality have limited value in protecting local marine resources. The recently created Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve represents a vast (1.4 million hectares) coral reef ecosystem with limited human impacts. The remoteness and limited fishing activities in this area allow it to function as a large no-take reserve that is dominated by large apex predators such as sharks and jacks. These predators have a profound impact on the structure of the entire coral reef ecosystem and their dominance may represent a more intact trophic structure compared with most coral reef ecosystems today, where abundance levels of these top-level carnivores have been greatly reduced due to fishing. Subsistence fishing is culturally and economically important to many rural communities throughout the main Hawaiian Islands. The Hawaiians of old depended on fishing for survival and developed an approach to harvest management based on identifying the specific times and places that fishing could occur so as to not disrupt basic processes and habitats of important food resources. A number of communities throughout Hawaii are currently strengthening local influence and accountability for the health and long-term sustainability of their marine resources through revitalization of local traditions and resource knowledge. There has been a renaissance of traditional community-based management throughout the Pacific; and rediscovery of these traditional techniques, coupled with MPAs including no-take reserves,

offers great promise for improving the health of our coastal marine environment and the management of marine fisheries in Hawai‘i.

Decline in nearshore resources

Coastal fisheries in Hawai‘i are facing unprecedented overexploitation and severe depletion (Gulko 2000). This decline in abundance, particularly around the more populated areas of the state, is likely the cumulative result of years of chronic over fishing (Shomura 1987, Harman and Kitakaru 1988, Gulko et al. 2000). Fishing pressure on nearshore resources in heavily populated areas of the Main Hawaiian Islands (MHI) appears to exceed the capacity of these resources to renew themselves (Smith 1993). This is most evident on the island of O‘ahu where over 72% of the state’s population resides (Figure 1). Throughout Hawai‘i, the abundance of reef fishes in areas not protected from fishing is substantially lower than in areas where fishing is prohibited (Grigg 1994, Friedlander 2001, Friedlander et al. 2003).

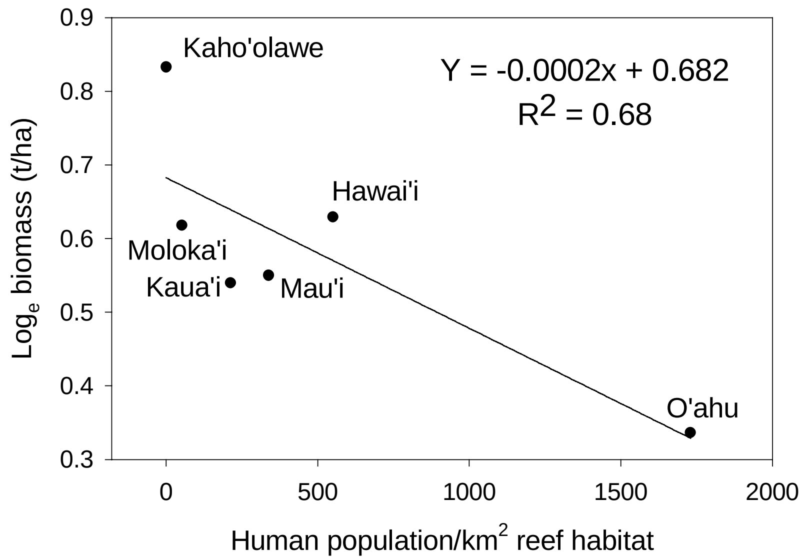


Figure 1. Mean fish biomass ($\log_e$ (x) metric tons per hectare) and human population density (people/ km^2 of reef habitat) by island. Adapted from Birkeland and Friedlander 2001.

Factors contributing to the decline of inshore fisheries in the MHI include a growing human population, destruction or disturbance to habitat, introduction of new fishing techniques (inexpensive monofilament gill nets, SCUBA, spear guns, power boats, sonar fish finders), and loss of traditional conservation practices (Brock et al. 1985, Lowe 1996, Birkeland and Friedlander 2002, Friedlander et al. 2003). The proliferation of long and inexpensive gill nets has allowed new fishers to enter the fishery and set nets deeper and in locations not previously harvested (Clark and Gulko 1999). Intensive fishing pressure on highly prized and vulnerable species has led to substantial declines in catch as well as size and has raised concerns about the long-term sustainability of these stocks (Friedlander and Parrish 1997, Friedlander and DeMartini 2002, Friedlander and Ziemann 2003). Despite the opinion of many fishermen that over harvesting is one of the major reasons for the long-term decline in inshore marine resources, there is poor compliance with state fishing laws and regulations (Harman and Katekaru 1988). The lack of marine-focused enforcement and minimal fines for those few cases that have been prosecuted contribute to a lack of incentive by the population to abide by fisheries management regulations.

Except for the commercial surround-net fishery for akule and ‘ōpelu, the coastal fisheries in Hawai‘i can be characterized as small, multigear, multispecies recreational/subsistence fisheries with fairly low yield (see Everson and Friedlander, this volume). Under-reporting by commercial fishers and the existence of a large number of recreational and subsistence fishers without licensing or reporting requirements have resulted in uncertainty in actual fisheries catch statistics for the state (Lowe 1996). In an island state such as Hawai‘i, where as much as 35% of the resident population fishes (Hoffman and Yamauchi 1972, USFWS 1988), the nearshore recreational and subsistence catch is likely equal to or greater than the nearshore commercial fisheries catch, with more species taken using a wider range of fishing gear (Friedlander and Parrish 1997, Gulko et al. 2000, Everson and Friedlander this volume).

Marine protected areas

In recent years, primarily due to the failure of conventional management practices to promote sustainable fisheries, marine protected areas (MPAs) have become an increasingly important tool for managing marine fisheries in both temperate and tropical seas. Marine protected areas can protect habitats and biological communities from fishing and other extractive uses that can lead to loss of biodiversity and changes in species interaction (Dayton et al. 1995, Boehlert 1996, Hixon and Carr, 1997). Marine fisheries reserves are thought to enhance fisheries by protecting spawning stocks, providing refugia for prerecruits and by exporting biomass to adjacent fishing grounds (Roberts and Polunin 1991 and 1993, Roberts 1995, Bohnsack 1996). MPAs create an off-limits population, which in theory can provide greater stability in the dynamics of the exploited population and can be incorporated into a management system as a buffer against uncertainty (SladekNowlis, and Friedlander in press)

This review of MPAs in Hawai‘i examines the management schemes of various reserve types, the effectiveness of these reserves in protecting fish standing stocks, comparison of the Northwestern Hawaiian Islands (NWHI) to the Main Hawaiian Islands (MHI), and cultural and subsistence practices within selected areas around the state.

MPAs in Hawai‘i

There are a variety of marine areas in Hawai‘i that have some type of protected status. These include Marine Life Conservation Districts (MLCDs), Fisheries Management Areas (FMAs), Fisheries Replenishment Areas (FRAs), a Marine Laboratory Refuge, Natural Area Reserve (NARs), Kahoolawe Island Reserve (KIR), National Wildlife Refuges, the Hawaiian Islands Humpback Whale Sanctuary (Clark and Gulko, 1999) and the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve. However, many of these reserves are either too small, lack suitable habitats, or are not fully protected from fishing and therefore do not function effectively as refuges (Friedlander 2001, Friedlander et al. 2003, Meyer 2003).

In response to the impacts of aquarium fish collecting and strong community opposition, Fish Replenishment Areas (FRAs) were established on the island of Hawai‘i to conserve the fish stocks. Descriptions of these areas and the activities of the West Hawai‘i Fishery Council are given in the chapter by Walsh et al. (this volume).

Grigg (1994) found that MLCDs support reef fish standing stock ca. 60% greater than areas open to fishing. The author also noted that fisheries target species that normally flee in heavily-fished areas were more abundant and much tamer in MLCDs. He also found that areas of high spatial complexity that harbored high fish biomass had a much greater economic value from non-consumptive uses such as snorkeling and SCUBA diving compared with the value derived from the one-time extraction of the resources.

DAR MLCD program

The state of Hawai‘i, Department of Land and Natural Resources, Division of Aquatic Resources (DAR) administers the state’s Marine Life Conservation District (MLCD) program, which is designed to conserve and replenish marine resources statewide (DLNR/DAR 1992, Table 1). Hanauma Bay on O‘ahu was the state’s first MLCD, created in 1967 and followed by Kealakekua Bay on the Big Island in 1969. Analyses were conducted on the DAR long-term monitoring data at each MLCD. The long-term data consisted of visual surveys of fishes along one or two belt transects (229 m by 12 m; 750 ft by 40 ft) inside each reserve that have been periodically surveyed since their inception. Fish biomass was recorded as lbs/acre. Time-series analysis was only conducted on the Hanauma Bay data owing to the lack of temporal autocorrelation and small sample sizes for the remaining data sets. For all MLCDs, $\log_e (x)$ data were smoothed using a negative exponential smoothing function (polynomial regression and weights computed from the Gaussian density function) for presentation purposes. The high variability and low power associated with these estimates precluded most forms of statistical analyses, but the smoothed data gives some insight into trends observed at each MLCD.

The Hanauma Bay, Honolua Bay, Molokini Crater, and Manele Bay MLCDs all showed some increase in fish biomass since their inceptions (Figure 2A). These MLCDs are all complete no-take for reef fishes except for Manele Bay, but this site has moderate protection from fishing, good enforcement, and limited access. Although the fish biomass in Hanauma Bay has increased since its creation, the best fit for the time-series analysis was a quadratic model with higher standing stock in the 1980s and a slight downward trend in the 1990s (autoregressive Lag 1 = 0.45, $P = 0.037$; linear trend = -783.3, $P = 0.007$; quadratic trend = -11.34, $P = 0.005$). Fish feeding restrictions and limits on the number of visitors and commercial operators occurred at Hanauma Bay in 1990, and the decline in feeding may partially explain the decline in fish biomass observed during surveys. However, Honolua Bay and Molokini follows a similar trend to Hanauma Bay, with higher standing stock in the 1980s. An overall decline in densities of fishes in the northwestern Hawaiian Islands was observed between the early 1980s and the early 1990s (DeMartini et al. 1996). This decline appears to be associated with a change in oceanic productivity in the central North Pacific over this time period (Polovina et al. 1994, DeMartini et al. 1996) and this inter-decadal oscillation may partially explain the observed declines in fish biomass in MLCDs in the main Hawaiian Islands.

Table 1. Summary of Hawai‘i MLCD characteristics. Use – level of use as classified by DAR (DAR 1992). Protection from fishing based on regulations, not on enforcement of these regulations.

MLCD	Acres	Year estab.	Use	Protection from fishing	Permitted activities
O‘ahu					
Hanauma Bay	101	1967	High	High	Complete no-take
Pupukea[1]	25	1983	Mod	Low	Pole and line from shore Harvest of limu (seaweed) Spear fishing – snorkel only Net fishing – northern portion
Pupukea[2]	175	2000	High	Mod	Pole and line from shore (2 lines only) Harvest of limu (seaweed) up to 2 lbs. Surround net for opelu (Aug/Sep) Surround net for akule (Nov/Dec)
Waikiki	76	1988	High	High	Complete no-take
Hawai‘i					
Kealakekua Bay	315	1969	High	Mod	Pole and line – 60% of MLCD Throw net – 60% of MLCD Akule and opelu – 60% of MLCD Crustaceans – 60% MLCD
Lapakahi	146	1979	Low	Low	Pole and line – 90% of MLCD Throw net – 90% of MLCD Lift net for opelu – 90% of MLCD
Waialea Bay	35	1985	Low	Low	Pole and line Netting
Old Kona Airport	217	1992	Mod	Mod	Throw net from shore Pole & line from shore
Lana‘i					
Manele-Hulopo‘e	309	1976	Mod	Mod	Hook & line (shore) – 100% of MLCD All fishing except spear, trap, and net (other than thrownet) – 50% of MLCD
Mau‘i					
Molokini Shoal	77	1977	High	High	Trolling in 60% of MLCD
Honolua-Mokule‘ia Bays	45	1978	Mod	High	Complete no-take

Pupukea[1] – 1983 to 2002
Pupukea[2] – 2002, amended 2003

The remaining six MLCDs either showed no change over time or have actually declined in fish standing stock since they were established as MLCDs (Figure 2B). Kealakekua showed an increase in the 1980s but biomass estimates in the late 1990s are near those observed in the early years of the MLCD. Standing stock in the Pupukea MLCD dipped sharply throughout the 1990s but has rebounded somewhat in recent years. The remaining MLCDs showed either a decline or no apparent change in biomass over time. The Waikiki MLCD is a no-take area but is small and has limited habitat necessary to support high fish standing stock (see following sections). The other three MLCDs either have moderate or low protection from fishing and/or the current management strategies do not appear to be having a positive effect on fish standing stock.

MPAs on O'ahu

On the island of O'ahu, there are three MLCDs and one FMA. These four areas represent a wide variety of habitat types and management strategies. Despite the differences in location, size, and habitat type there is a dramatic difference in the standing stock of fish biomass between the Hanauma Bay MLCD and the other protected areas (Friedlander 2001, Figure 3). Hanauma Bay has been a fully protected no-take area since 1967.

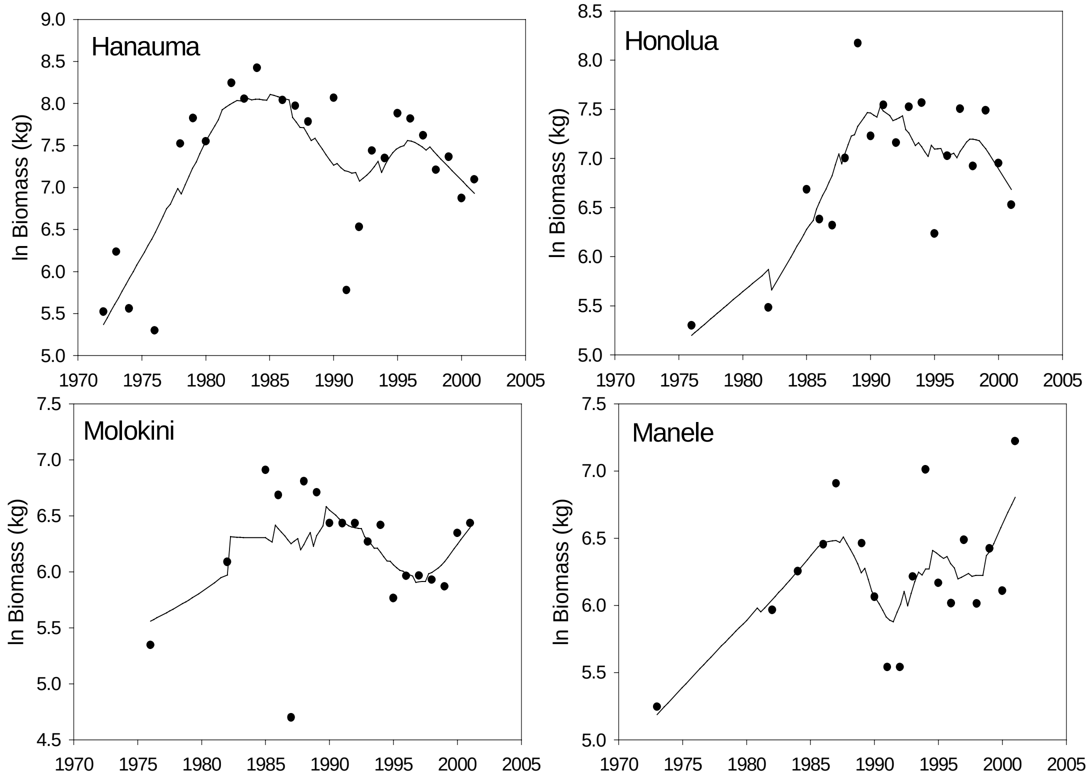
Although the Waikiki MLCD has been a no-take area since 1988, low habitat heterogeneity, degraded reef environment, and small size have resulted in this area having a very low standing stock of fish. However, the size and number of fishes is greater within the MLCD compared to adjacent habitats (Friedlander and Brown 2003, Meyer 2003). Meyer (2003) noted that abundance and size of both target and non-target species was greater in the Waikiki MLCD compared to adjacent fished areas, suggesting that fishing is not the only factor determining patterns in abundance and size. The author noted that despite having generally poor habitat quality, the habitat within the MLCD had greater complexity compared to the adjacent areas. Based on tracking data and the distribution of critical habitat, Meyer (2003) also determined that the area of the Waikiki MLCD (0.32 km^2) would need to be at least tripled in size (1 km^2) to begin to effectively protect more mobile species such as jacks and goatfishes.

The Pupukea MLCD was very small (10 hectares) and allowed a wide range of fishing activities to occur within its boundaries. Not surprisingly, this area possesses the lowest standing stock of fish compared to the other protected areas on O'ahu. Modifications to the Pupukea MLCD regulations have recently increased the size of the MLCD and limited most fishing activities. The results from these protected areas around O'ahu point to the fact that a no-take marine protected area with good habitat diversity and complexity can have a positive effect on fish standing stock.

Rotational closures

The Waikiki-Diamond Head Shoreline Fisheries Management Area (FMA) was established in 1978 as a rotating closed area. From 1978 to 1988, management was on a four year cycle with the entire area closed to fishing for two years, then open to hook and line fishing only for one year, followed by one year open to all fishing methods (Brock and Kamm 1993). From July 1998 onward, the management regime was changed to one year closure and one year open to all fishing except gillnets and night spear fishing.

A.



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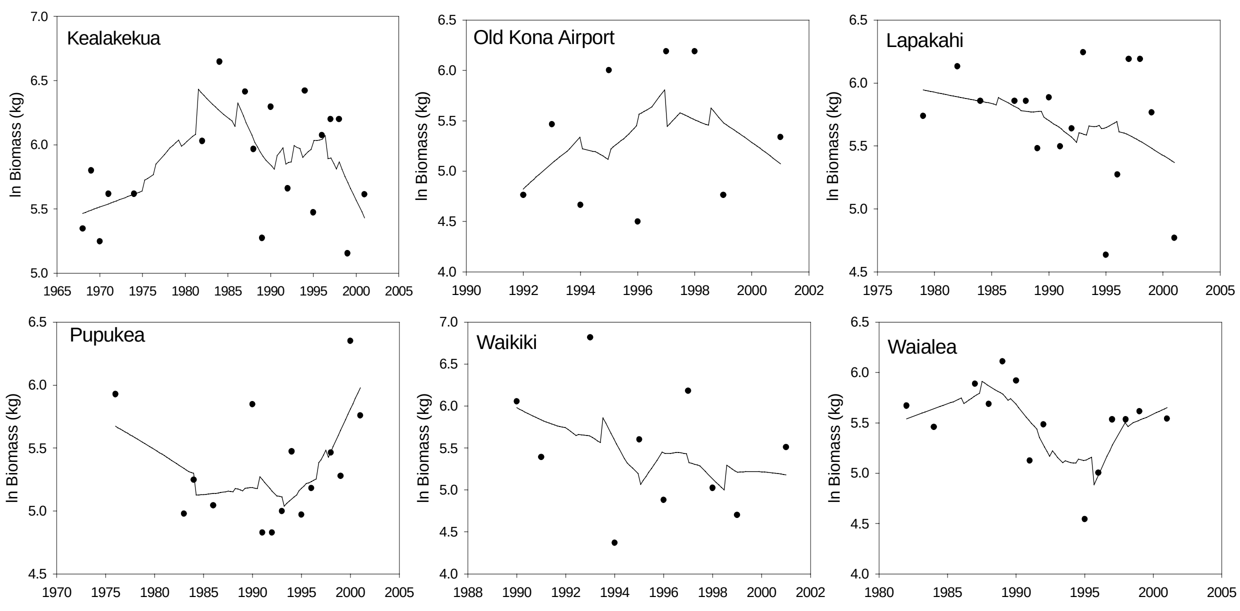

Figure 2. trends in estimates of fish biomass ($\log_e$(x) pounds/acre) in MLCDs around Hawaii. Log_e (x) data were smoothed using a negative exponential smoothing function Data from Hawaii DLNR, Division of Aquatic Resources.

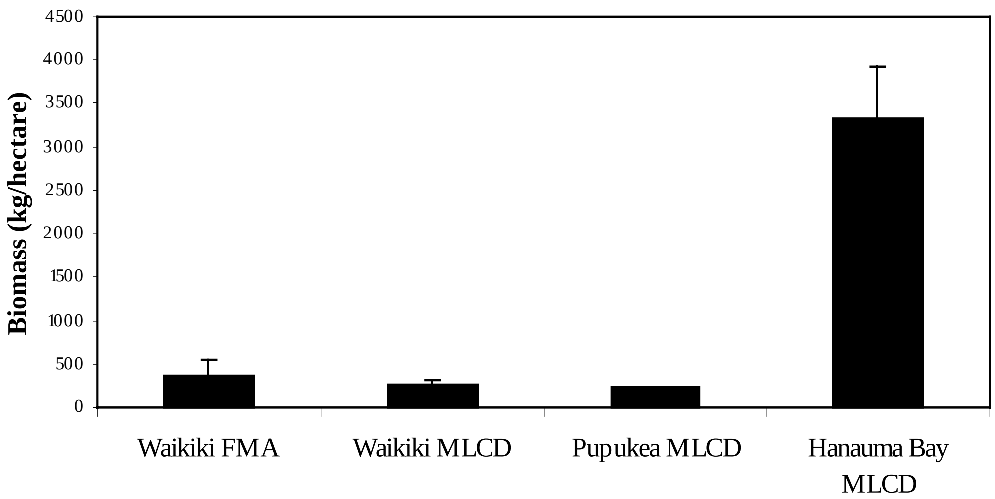

Figure 3. Fish biomass at three Marine Life Conservation Districts (MLCDs) and one Fisheries Management Area (FMA) around the island of O'ahu from 1994 to 1998. Mean values with standard error of the mean. Data from Hawaii Department of Land and Natural Resources, Division of Aquatic Resources (Friedlander 2001).

Visual census data of fishes conducted by DAR since 1978 has shown that fish biomass was higher when the area was closed to fishing or open to hook and line only (Figure 4; Brock and Kamm 1993). Despite these closures, standing crop of fishes never exceeded 50 g/m2 and Brock and Kam (1993) attributed this to the lack of adequate shelter habitat. The benefits derived from the closure were quickly lost when the area was open to all types of fishing, but hook-and-line fishing appeared to have little impact on fish standing stock. (Brock and Kamm 1993). Current regulations prohibit fishing on odd-numbered years and prohibit trap and net fishing, except throw nets, and nighttime spear fishing during even-numbered open years. Holland and Meyer (2003) found that alternating closures is less important than the fact that no nighttime spear fishing or gillnetting was allowed in the FMA during open years. Recent analysis of DAR survey data (1985-2000) from the Waikiki-Diamond Head FMA revealed a recovery for most trophic and taxonomic groupings in closed years with declines occurring in open years (DAR unpub. data).

Comparison of management regimes

The Hawaii Coral Reef Assessment and Monitoring Program (CRAMP) sampled the fish and benthic communities at 60 locations around the main Hawaiian Islands in 2000 (Friedlander et al. 2003). Of these 60 locations surveyed, 18 had some level of protection from fishing associated with them. No-take areas (Hanauma Bay MLCD, Honolua Bay MLCD, Molokini Crater MLCD, and Moku o Lo'e (Coconut Island-Hawaii Marine Laboratory Refuge) had the highest values for most fish assemblage characteristics followed by areas under customary stewardship (Kaho'olawe Island Reserve and Ahihi-Kinau Natural Area Reserve). Locations under community-based management with customary stewardship harbored fish biomass that was equal to or greater than that of no-take marine-protected areas although light fishing pressure and the remoteness of these locations may also contribute to the high biomass observed (Fig. 5).

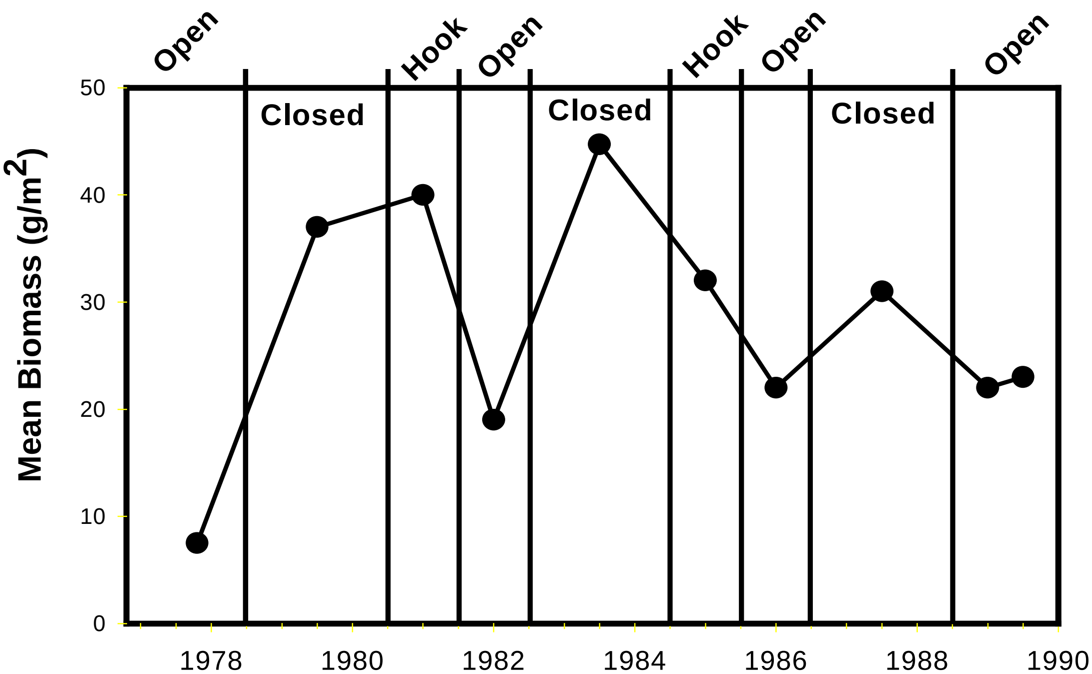

Figure 4. Fish biomass (g/m^2) observed during visual censuses at the Waikiki-Diamond Head FMA from 1978 to 1989. Open – open to all fishing activities, closed – closed to all fishing, (Modified from Brock and Kamm 1993).

Areas with limited protection from fishing had values for fish assemblage characteristics that were lower than areas where fishing was restricted and similar to areas completely open to fishing. The Pupukea MLCD is a partially protected area that has recently received additional protection through the expansion of existing boundaries and the restriction of most fishing activities within the reserve. The existing data will help to serve as a baseline to determine if these new regulations will enhance the fish assemblage within the reserve over time.

Movement of fish relative to MPAs

The open nature of marine systems via adult movement and reproductive dispersal is a major consideration in marine reserve design . Reserves will be more effective if they serve as sources by retaining adults and allowing some degree of export of reproduction (PDT 1990; Sladek Nowlis 1997; Sladek Nowlis and Roberts 1999). In addition, knowledge of the fish assemblage structure is critical in establishing reserve size because despite the ability to migrate large distances, most coral reef fishes possess a relatively small home range. Holland et al. (1993) found that the population of weke (white goatfish, *Mulloidichthys flavolineatus*) showed high site fidelity with 93% of recaptures occurring at the release site around Moku o Lo‘ e (Coconut Island) patch reef, a no-fishing conservation zone established over 30 years ago. The high site fidelity and limited range of diel movement of these fish suggest that small reserves can effectively protect populations of mature adults because emigration of adults into adjacent areas is minimal (Holland et al. 1993).

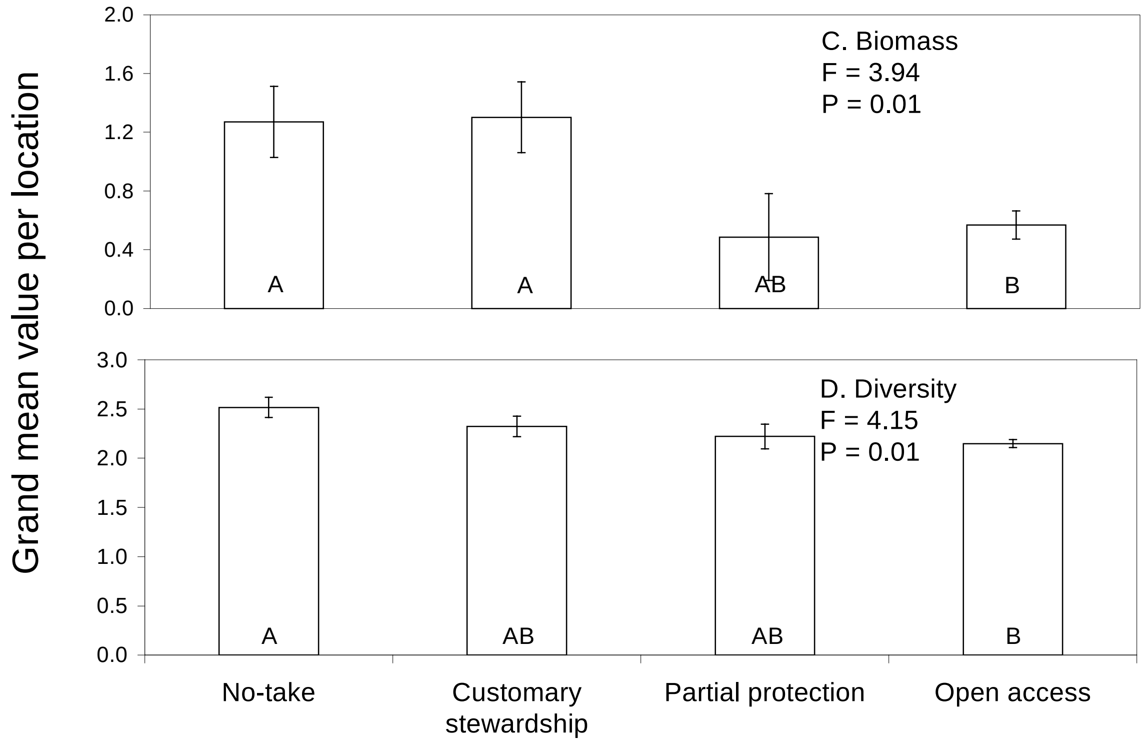

Fig. 5. Comparisons of fish assemblage characteristics among various levels of protection from fishing. Grand mean values per location. Biomass = t/ha. Error bars are one standard error of the mean. Levels of fishing protection with the same letter designation are not significantly different (Bonferroni adjusted multiple comparisons test, $\alpha = 0.05$, adapted from Friedlander et al. 2003).

Short-and long-term movement patterns of moil (blue trevally, *Caranx melampygus*) were monitored around Coconut Island (Moku o Lo‘e) (Holland et al. 1996). The limited range of dispersal of recaptured (75.5% within 0.5 km of the release site) and strong site fidelity observed from sonically tagged fish suggest that dispersal is much less than might be predicted for a highly mobile, piscivorous species. The authors suggest that small refugia (e.g. 5 km of reef face) could provide significant protection for this species despite its potential for long-range movements.

Kumu (whitesaddle goatfish, *Parupeneus porphyreus*), an endemic goatfish and important fisheries species, were acoustically tracked around the Coconut Island refuge for periods up to 93 h (Meyer et al. 2000). The home ranges of all fish were within the boundaries of the Coconut Island reserve. This small reserve (< 1 km^2) was capable of protecting both large juveniles and some spawning size individuals (Meyer et al. 2000). Kala (blue spined unicornfish, *Naso unicornis*) were acoustically tracked for periods of up to 22 days in the shallow, high-energy fringing reef habitat in the Waikiki Marine Life Conservation District (Meyer and Holland 2001). The home ranges of all of the *kala* tracked were completely encompassed by the boundaries of the 0.32 km^2 Waikiki MLCD, but Meyer (2003) noted that the Waikiki MLCD would have to be 3 to 4 times larger to include the home ranges for jacks and goatfishes

Northwestern Hawaiian Islands (NWHI)

Remote locations with limited fishing pressure are some of the few remaining examples of coral reefs without major anthropogenic influence. The Northwestern Hawaiian Islands (NWHI) provides a unique opportunity to assess how a natural coral reef ecosystem functions in the absence of ongoing major human intervention. This chain of small islands, atolls, submerged banks, and reefs stretch for more than 2,000 km northwest of the high windward main Hawaiian Islands. The majority of the islets and shoals remain uninhabited, although Midway, Kure, Laysan, and French Frigate Shoals have all been occupied for extended periods by various government agencies over portions of the last century.

The NWHI contain a number of examples of species-specific, limited-take MPAs. Recreational and commercial fishing activities are restricted within the 10-fathom isobath of most of these islands (20 fathoms around Moku Manamana or Necker Island) owing to their status as a National Wildlife Refuge managed by the U.S. Fish and Wildlife Service (USFWS). The National Marine Fisheries Service (NMFS) has also designated 10 areas out from shore to 20 fathoms in the NWHI as critical habitat for the federally endangered Hawaiian monk seal. Commercial fishing in the NWHI within 100 m depth targets mostly bottom fish and lobster, each of which is managed separately by the NMFS through the actions of the Western Pacific Regional Fisheries Management Council. Both of these fisheries are limited entry with fewer than 20 vessels allowed to operate in either fishery. Typically, only a small proportion of these vessels actively fish in any given year. A 50-mile protected species zone exists around the NWHI that restricts longline fishing, and seasonal area closure zones were in effect for the take of NWHI lobster until the entire fishery was recently closed.

The federal waters of the NWHI received significant new levels of protection in December 2000, when President Clinton established the NWHI Coral Reef Ecosystem Reserve by Executive Order 13178 and amended with Executive Order 13196 in January 2001. This large reserve area, extending 1,200 nautical miles (2,200 km) in length and 3-50 nautical miles (6-93 km) from shorelines, is to be managed by the Secretary of Commerce and is in designation process for a National Marine Sanctuary. The Executive Order also established fifteen Reserve Preservation Areas within the reserve in which extractive use is prohibited with limited exceptions.

A comparison between the Northwestern Hawaiian Islands (NWHI), a large, remote, and lightly fished area, and the main Hawaiian Islands (MHI), an urbanized, heavily-fished area, revealed dramatic differences in the numerical density, size, and biomass of the shallow reef fish assemblages (Friedlander and DeMartini, 2002). Grand mean fish standing stock in the NWHI was more than 260% greater than in the MHI. The most striking difference was the abundance and size of large apex predators (primarily sharks and jacks) in the NWHI compared to the MHI. More than 54% of the total fish biomass in the NWHI consisted of apex predators, whereas this trophic level accounted for less than 3% of the fish biomass in the MHI (Figure 6). In contrast, fish biomass in the MHI was dominated by herbivores (55%) and small-bodied lower-level carnivores (42%). Most of the dominant species by weight in the NWHI were either rare or absent in the MHI and the target species that were present, regardless of trophic level, were nearly always larger in the NWHI.

One of the few large benthic predators found on Hawaiian coral reefs is the Hawaiian Grouper or hapu'u (*Epinephelus quernus*). This species is rare at SCUBA depths in the MHI but is frequently observed on the fore reef at Kure and Midway Atolls. Owing to its restricted shallow-water range, curious nature, and status as an endemic species, hapu'u should be given high priority for protection. A number of species such as the endemic uhu uliuli or spectacled parrotfish (*Chlorurus perspicillatus*), the endemic 'a'awa or Hawaiian Hogfish (*Bodianus bilunulatus*), and mu or bigeye emperor (*Monotaxis grandoculis*) are quite abundant and obtain large size in the NWHI. These species are heavily exploited for commercial, subsistence, and recreational use in the main Hawaiian Islands, and their reduced number and size in the MHI is likely the result of over fishing (Friedlander and DeMartini 2002).

These differences represent both near-extirpation of apex predators and heavy exploitation of lower trophic levels in the MHI compared to the largely unfished NWHI. Although some MPAS in the MHI sustain more fishes than adjacent open areas, these areas cannot adequately represent unfished ecosystems within their borders because they are too small and the fishing impacts surrounding them are too large. As a result they have some limits on their value as reference areas. These findings strongly support the need for better management of reef fishes in the MHI.

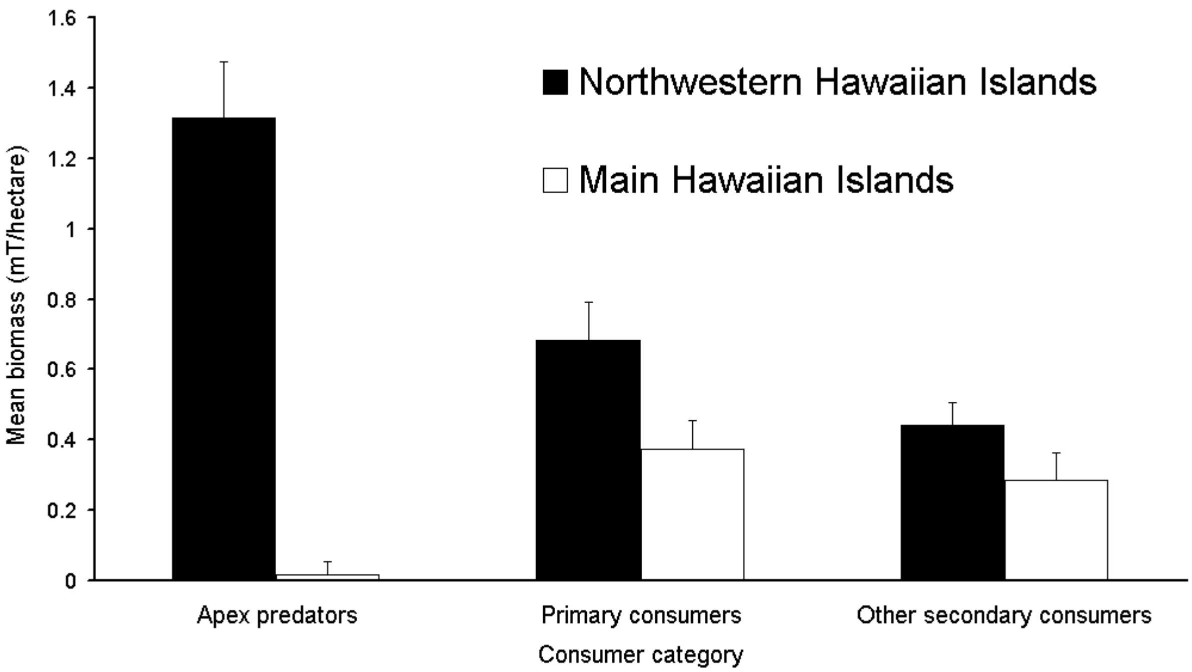

Figure 6. Trophic comparisons of fish assemblages in the NWHI and MHI. (From Friedlander and DeMartini 2002).

Community-based management

The Hawaiians of old (pre 1800) depended on fishing for survival, which motivated them to acquire a sophisticated understanding of the factors that caused limitations and fluctuations in their marine resources. Based on their familiarity with specific places and through much trial and error, Hawaiian communities were able to develop ingenious social and cultural controls on fishing that fostered, in modern terminology, “sustainable use” of marine resources. Harvest management was not based on a specific amount of fish but on identifying the specific times and places that fishing could occur so as to not disrupt basic processes and habitats of important food resources (Friedlander et al. 2002, Poepoe et al. 2003). By allowing fish populations to replenish themselves, and by not interfering with important activities such as spawning, Hawaiian communities in the past were able to maintain the productivity and fisheries yield of the coral reefs near their villages.

Fishing activities and catch distribution were strictly disciplined by rules (kapu). Overseers (konohiki) enforced the kapu or fishery closures on behalf of ali‘i (chiefs). Fishery closures were employed in locations throughout the islands of Oceania for various purposes (Johannes 1978). These closures were often imposed to ensure large catches for special events or as a cache for when resources on the regular fishing grounds ran low. On the island of Satawal in Micronesia, the chief closed a portion of the reef to fishing in order to preserve the area as a breeding ground for fish and to supply the surrounding reef (McCoy 1974). Traditional practices are still in use today. Recently a number of villages in Samoa have established community-owned marine protected areas as a means of replenishing adjacent fishing areas (King and Faasili 1998).
There has been a renaissance of traditional community-based management throughout the Pacific and rediscovery of these traditional techniques offers great promise for improving the management of marine fisheries. In coastal communities, fishermen and -women combine empirical information on fish behavior, the physical environment, and fish habitats to determine when, where, and how to fish (Ruddle 1994). This information in some communities has been passed down over many generations, and traditional knowledge can play an important role in designing effective fishery management systems (Johannes 1997). Many of the management tools we use today such as closed areas, closed seasons, size limits, and restricted access were used by Pacific Islanders centuries ago to manage their fisheries resources (Johannes 1978)

A number of communities throughout Hawaii are currently strengthening local influence and accountability for the health and long-term sustainability of their marine resources through revitalization of local traditions and resource knowledge. Some examples are provided below.

Mo‘omomi Bay, Molokai

The community in the Ho‘olehu Hawaiian Homesteads on the island of Moloka‘i is actively engaged in managing their resource as well as educating users about traditional methods. Subsistence activities, including farming and fishing, supply about one-third of the food needed by the approximately 1,000 Hawaiian residents of this community (Hui Malama o Mo‘omomi 1995). In 1993, the Governor’s Moloka‘i Subsistence Task Force suggested that the Ho‘olehua Hawaiian Homestead be allowed to manage shoreline marine resources in nearby areas for subsistence fishing. The 1994 Hawai‘i State Legislature created a process for designating community based subsistence fishing areas. In response to this legislation the Hui Malama o Mo‘omomi prepared a fisheries management plan for the northwest coast of Moloka‘i (Hui Malama o Mo‘omomi 1995).

Community resource monitors emphasized high resolution monitoring of the area using traditional observation methods and adapted science-based methods to fit specific information and educational needs within the community. Interpretation of the detailed resource information recorded in the monitors' daily journals provides the basis for understanding local fisheries' dynamics and adjusting fishing effort so that resources are not harvested at the wrong times and places (Friedlander et al. 2002, Poepoe et al. 2003). By identifying peak spawning periods for important resource species, traditional closures or kapus can be applied so as not to disturb the natural rhythms of these species. By observing spawning behavior and gonad development, community monitors were able to develop a calendar identifying the spawning periods for the major resource species in Moʻomomi Bay during the 2000 calendar year that can be used to validate the establishment of seasonal kapus to protect spawners (Figure 7).

Community-sanctioned norms for fishing conduct are reinforced through continual feedback based on site resource monitoring, education, and peer pressure. The most effective means of eliciting proper conduct of fishing is through education of young people in the community to understand that they have responsibilities, as well as rights, for marine resource use. The continuation of traditional Hawaiian practices in and around Moʻomomi Bay helps to maintain social and cultural identity and provides reinforcement of values shared by the Hoʻolehua community. The repetition of subsistence fishing activities is one of the ways that knowledge, values, and identity are transferred to succeeding generations Cultural survival is thus entwined with resource conservation.

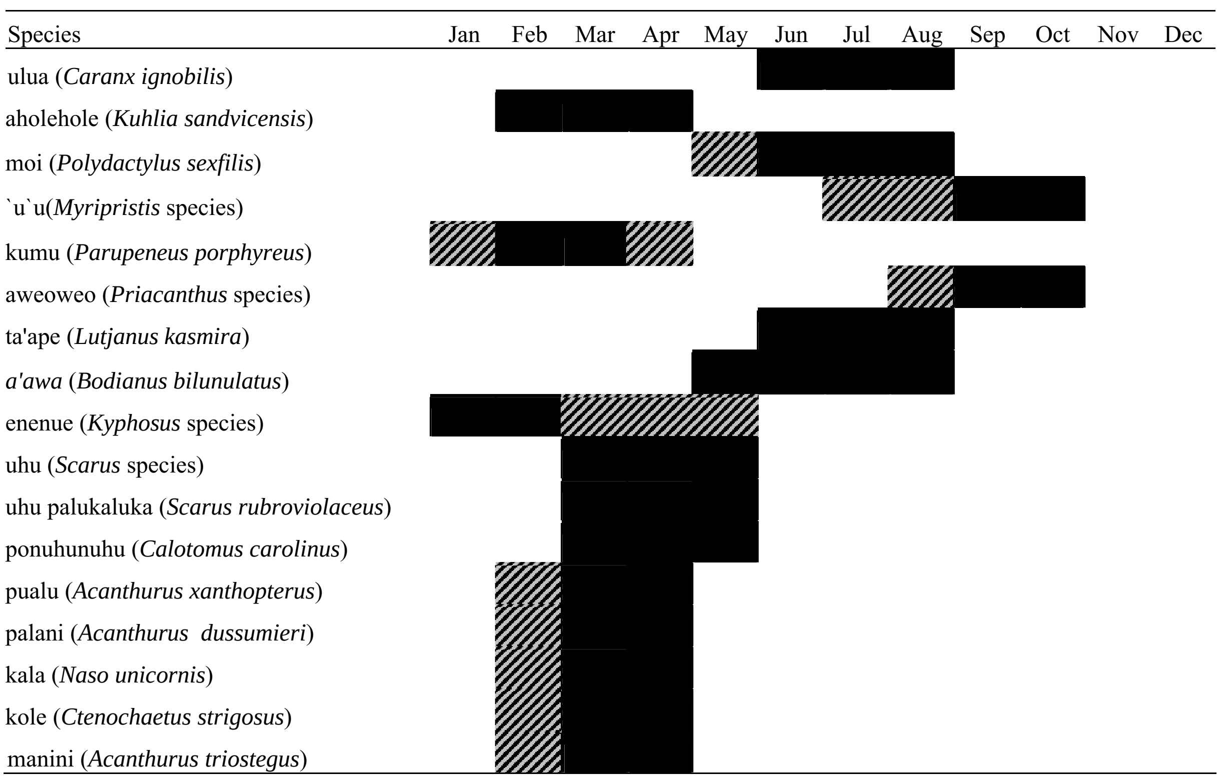

Fig. 7. Moʻomomi Bay fish spawning calendar for the year 2000 for key resource species. Black boxes indicate months of peak spawning. Grey boxes indicate other months when spawning was observed (Friedlander et al. 2002, Poepoe et al. 2003)

Hawaiian moon calendar

The moon calendar is a tool that Hawaiians of old developed for holistic understanding of marine and terrestrial environments and is based on lifetimes of observations and experiences (Edith Kanakaʻole Foundation 1995). The moon calendar emphasizes certain repetitive biological and ecological processes (e.g., fish spawning, aggregation, feeding habits) that function at different time scales (e.g., seasonal, monthly, and daily) that can then be validated by fishermen's own observations for specific locations (Poepoe et al. 2003).

The moon calendar emphasizes natural processes that repeat at different time scales: seasonal, monthly, and daily (Poepoe et al. 2003). Distinctions are made between two general seasons (kaʻu or dry; hoʻoilo or wet) and three general phases of the moon after the new moon (Figure 8): hoʻonui (nights of enlarging moon); poepoe (nights of full moon); and emi (nights of diminishing moon). A deeper understanding of the moon calendar provides the biological and ecological context for proper harvesting.

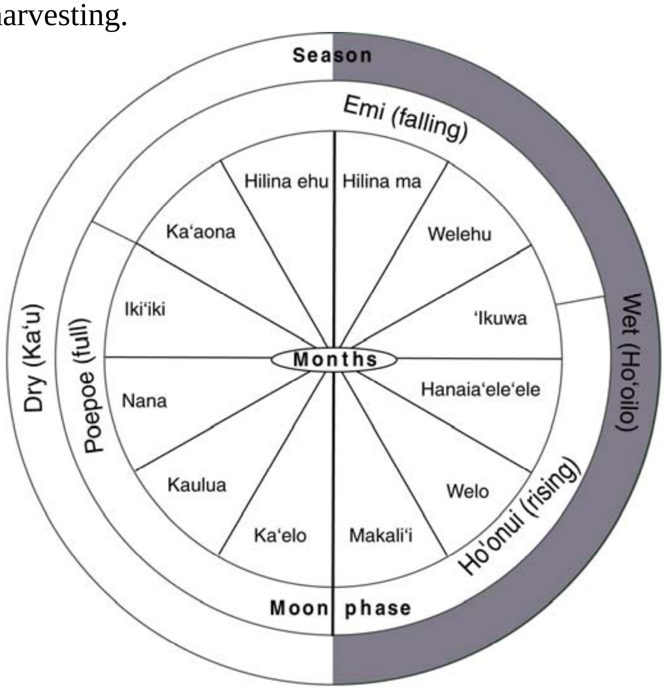

Figure 8. Hawaiian moon calendar showing months, seasons, and moon phases that are used to guide fishing activities. Names used for months in this calendar are specific to Molokaʻi (from Friedlander et al. 2002, Poepoe et al. 2003)

Hawaiian model for conservation of moi

The Pacific threadfin (*Polydactylus sexfilis*) or moi is a very popular and much sought-after sport and food fish in Hawaii that also supports a small subsistence fishery (Friedlander and Ziemann, 2003). In ancient Hawaiian culture, moi were reserved for the ruling chiefs and prohibited for consumption by commoners (Titcomb 1972). Hawaiians developed a number of traditional strategies to manage moi for sustainable use. Kapus or closures were placed on moi during the spawning season (typically from June through August) so as not to disrupt spawning behavior

(Poepoe et al. 2003). Moi are protandric hermaphrodites, initially maturing as males after a year at about 20-25 cm and then undergoing a sex reversal, passing through a hermaphroditic stage, and becoming functional females between 30 and 40 cm fork length at about three years of age (Santerre et al., 1979). Traditional Hawaiian conservation principles for moi included restrictions on harvest of pala moi (hermaphrodites) or moi (females), depending on population structure, and restrictions on harvest during the spawning season. Minimizing the disturbance to spawning and nursery habitats was another important conservation practice. Awareness of the need to protect both immature moi and the female breeding stock from over harvest is an example of how Hawaiian resource knowledge can validate Western science, which has "discovered" and named this method of conservation "slot limits," which are employed in a number of fisheries around the world to conserve reproductive populations.

Table 2. Seasonal movement and aggregation of moi (from Poepoe et al. 2003)

Fish size	Dispersed	Aggregated	Aggregated and spawning
Adults (mana moi, pala moi, moi)	Fall through winter	Spring: in reef holes prior to spawning	June, July, and August: one spawning per month cued by moon phase
Juveniles (moi liʻi)	Leave for adult habitat after grown	In fall, as new recruits feeding in sand bottom areas with nearby rocky shelter	N/A

ʻĀhihi-Kinaʻu, Maui

ʻĀhihi-Kinaʻu is the only marine Natural Area Reserve (NAR) within the State. Established in 1973 this reserve was the first no-take area in Maui County and also restricted motorized vessels within the boundary waters. Fishing within the ʻĀhihi-Kinaʻu Natural Area Reserve has only been conducted since 2000 and the take of fish has been insignificant (13 kg). The catch consisted primarily of nearshore species such as uouoa (sharpnose Mullet, *Neomyxus leuciscus*), manini (convict Surgeonfish, *Acanthurus triostegus*), and aholehole (Hawaiian Flagtail, *Kuhlia sandvicensis*).

Additionally, approximately two kg of ʻopihi (limpets, *Cellana* spp.) was harvested from the reserve since 2000. These organisms have been severely depleted in most populated areas of Hawaii, and their number and size in the reserve is an encouraging sign. Average size of ʻopihi alinalina (the Yellow Foot limpet, *Cellana sandwicensis*) exceeded minimum size by 1.6 times while the opihi makaiauli (Black Foot limpet, *Cellana exarata*) exceeded minimum size by 1.4 times. Enforcement of this region is difficult, but so is shoreline accessibility that ultimately promotes the high standing stock of both marine fish and invertebrates.

Kaho‘olawe

From 1941 to 1994 this island functioned as a natural reserve due to the fact that it was under control of the U.S. Navy and served as a military bombing range until 1990. No fishing was permitted from 1955 to 1968, but then restrictions were eased to allow for fishing on one or two weekends per month (Dames and Moore 1997). In 1994, Kaho‘olawe was conveyed back to the State of Hawaii with the provision that the Navy supervised the ordnance cleanup. Full control by the state of Hawaii is slated for 2003 or until all ordnance is removed from critical areas. The Kaho‘olawe Island Reserve Commission was established to manage the island and the surrounding waters in trust for the general public and the future Native Hawaiian sovereign entity (Dames and Moore, 1997). This commission fosters access for native Hawaiians to practice cultural, spiritual, and subsistence activities on the island and in the adjacent marine waters. The ocean management plan prepared for the commission outlines fishing areas, cultural and subsistence activities, and enforcement policies that aim to integrate traditional practices with contemporary management.

Since 1996, catch reports have been filed for various areas around Kaho‘olawe including the CRAMP site at Hakioawa. To date only 182 kg of catch have been reported from this site, with ‘ama‘ama (striped mullet, *Mugil cephalus*) accounting for the largest percentage of the take (25%). In spite of this cultural take, the site at Hakioawa still ranked fourth in the state in terms of fish standing stock at long-term CRAMP monitoring sites (Friedlander et al. 2003).

Enforcement for the reserve is conducted by state (Division of Conservation and Resource Enforcement) and federal agencies (Coast Guard) that patrol the waters around the island reserve. Additional surveillance is provided by cultural practitioners using the resources and commercial helicopter operators that ferry people and supplies to the island on a daily basis.

Although the catch from these locations is undoubtedly higher owing to underreporting and poaching, the remoteness of these locations combined with the light fishing pressure, enforcement, and community oversight has resulted in high standing stock of reef fishes compared to other locations in Hawaii. Social enforcement of a code of conduct is more effective than government control and regulations, but local community commitment is imperative.

Miloli‘i, Hawai‘i

Often referred to as one of Hawai‘i’s last fishing villages, community members at Miloli‘i in South Kona on the island of Hawai‘i have recently initiated a traditional fishing project to revive some of the stewardship values associated with traditional fishing and fisheries management techniques. The Miloli‘i community was once famous for the fishing of ‘ōpelu (*Decapterus* spp.). ‘Ōpelu that was caught by community members was not only distributed as an important subsistence resource but was also dried and sold to generate cash income. While opelu is still fished by a few community members, traditional technology and practices have not been in regular use for over fifty years. As was common throughout Hawai‘i, numerous traditional practices associated with ‘ōpelu fishing helped to maintain healthy stocks of these fish. These included using only vegetable matter as chum, because fish-matter chum would cause more rapid decomposition of dried fish and would attract predators to spawning aggregations, thus disrupting aggregation areas. Additional practices were returning a minimum of two reproductive fish to the water with each net that was hauled in, using nets that were not capable of removing entire aggregations, restricting fishing during spawning periods, and strictly enforcing seasonal closures. Other aspects of traditional fishing of ‘ōpelu including a very intimate knowledge of the aggregation sites (koas) of the fish and regular tending or feeding of these koas prior to commencing fishing. Koas would be tended a minimum of three days per week by feeding vegetable matter to the aggregating fish. Typically certain koas were tended and subsequently fished by certain families. Tending would continue for approximately two months prior to opening of fishing season.

Today, some members of the Miloli‘i community have started to fish ‘ōpelu again in the traditional way as part of an effort to teach youth about resource stewardship. The point of the effort is not so much to enforce or recreate the traditional system but to instill in youth a sense of responsibility for marine management that was a central value associated with traditional fishing. The goal is to establish a foundation of stewardship values that can then be translated to other near-shore fisheries. One immediate manifestation of this effort is that for the first time in over 60 years, a traditional ‘ōpelu canoe is now being used in these waters to fish in ways that once worked to sustain both people and the stocks of fish upon which they depended. Additional activities that are accompanying this attempt to revive stewardship values associated with traditional fishing include teaching youth and other community members how to scientifically monitor biological resources in their areas, collecting historical knowledge from Kupuna (wise elders) about changes in the area’s marine resources, and teaching youth how to collect, document, and present marine resource knowledge through film. Key community members believe that the sharing of traditional knowledge and values with youth will help build a solid foundation for future wise choices in resource management.

Conclusions

Declining fisheries resources and loss of coral reef ecosystem biodiversity has led to the need for a more holistic approach to marine resource management. Marine reserves can, in addition to their potential to enhance fish catches, protect stock characteristics, reduce the impact of bycatch on vulnerable species, rebuild over fished stocks, maintain habitat characteristics and ecosystem processes, provide biological reference points, and provide insurance against management mistakes. Marine reserves serve both as a precautionary and an ecosystem management tool.

Fully-protected no-take reserves in the MHI have been shown to have higher standing stocks of reef fishes compared to areas where fishing is permitted or areas with partial protection from fishing (Grigg 1994, Friedlander 2001, Friedlander et al. 2003, Holland and Meyer 2003, Meyer 2003), yet these reserves account for less than 1% of the area surrounding the MHI (Gulko et al. 2000). There are a number of “protected areas” in Hawai‘i with limited protection from fishing or poor habitat quality and these locations do not function effectively in conserving fish populations from over-exploitation. Meyer (2003) stated that small reserves might be locally effective in increasing target species abundance and size if they are large enough to contain the home ranges of the key target species. However, he noted that the total amount of no-take area in the MHI (<1%) is substantially less than the theoretical optimal size necessary for regional fisheries replenishment (>40%) and he suggests that the current regional effect of Hawai‘i’s marine reserves is negligible on fisheries enhancement.

The largest well-protected area in the MHI, Kaho‘olawe, had the highest biomass observed of any of the main Hawaiian Islands and had similar biomass to Kure and Midway Atolls, the location with the lowest biomass in the NWHI. Kure and Midway Atolls receive some fishing pressure from the recreational sport fishery (catch and release) based at Midway (R. Shallenberger, US Fish and Wildlife Service, pers. comm.). DeMartini et al. (2002). have shown that the limited amount of recreational fishing for ulua aukea (*Caranx ignobilis*)may have had an impact at Midway Island. Both ulua aukea and moil were significantly less abundant at Midway Atoll, compared to French Frigate Shoals where no fishing takes place. Moreover, a comparison of the abundance of jacks as a group at French Frigate Shoals and Midway before and after the advent of the catch and release fishery at Midway suggests that carangids are less abundant there than prior to fishing.

The NWHI represents a large no-take area now protected from fishing and previously a de facto reserve due to its isolation (Friedlander and DeMartini 2002). The limited fishing activities that have occurred in the NWHI have resulted in minimal anthropogenic impacts. These reefs are among the few remaining large-scale, intact, predator-dominated reef ecosystems left in the world and offer a chance to examine what could occur if larger, more effective, no-take marine protected areas were implemented in the MHI. These areas should not only be set aside for their intrinsic value, but also for their value to enhance fishing and hedge against fisheries collapses by potentially providing sources of recruits and propagules. The NWHI is one of the few places left in the world that is sufficiently pristine to study how unaltered ecosystems are structured, how such ecosystems function, and how they can be most effectively preserved. The differences in fish assemblage structure in this study are evidence of the high level of exploitation in the MHI and the pressing need for ecosystem-level management of reef systems in the MHI as well as NWHI.

There has been a renaissance of traditional community-based management throughout the Pacific and rediscovery of these traditional techniques offers great promise for improving the management of marine fisheries. Each community will have to develop management strategies that are compatible with their own unique situation. Environment, history, and resources will all dictate what type of management regime is most suited for each individual community. In areas of the State where community ties are weak and multiple conflicting uses occur, more contemporary forms of management must be implemented.

An integrated approach for contemporary management should include licensing of fishermen, improved data collection, enforcement of existing regulations and/or changes to these regulations, and the establishment of functioning marine protected areas. The input of people from coastal communities will be vital to good design of marine reserves and to maintaining public support for them. Without this support, enforcement may be greatly compromised, and future political changes can lead to the opening of marine reserve (Alcala and Russ 1990).

Reserves represent precautionary management by creating a safety net against management mistakes (SladekNowlis and Friedlander in press). They also represent ecosystem management by allowing ecosystems to function naturally within their borders. They may also actually provide fishery enhancements, particularly if local fisheries are over fished. Even if the fisheries are generally not over fished, marine reserves can create a buffer that protects vulnerable species with relatively little opportunity cost to the fishing industry. Marine reserves are not a panacea for fisheries management. But, given their many benefits and relatively few costs, marine reserves should be a well-used tool in the toolbox of the modern fishery manager.

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