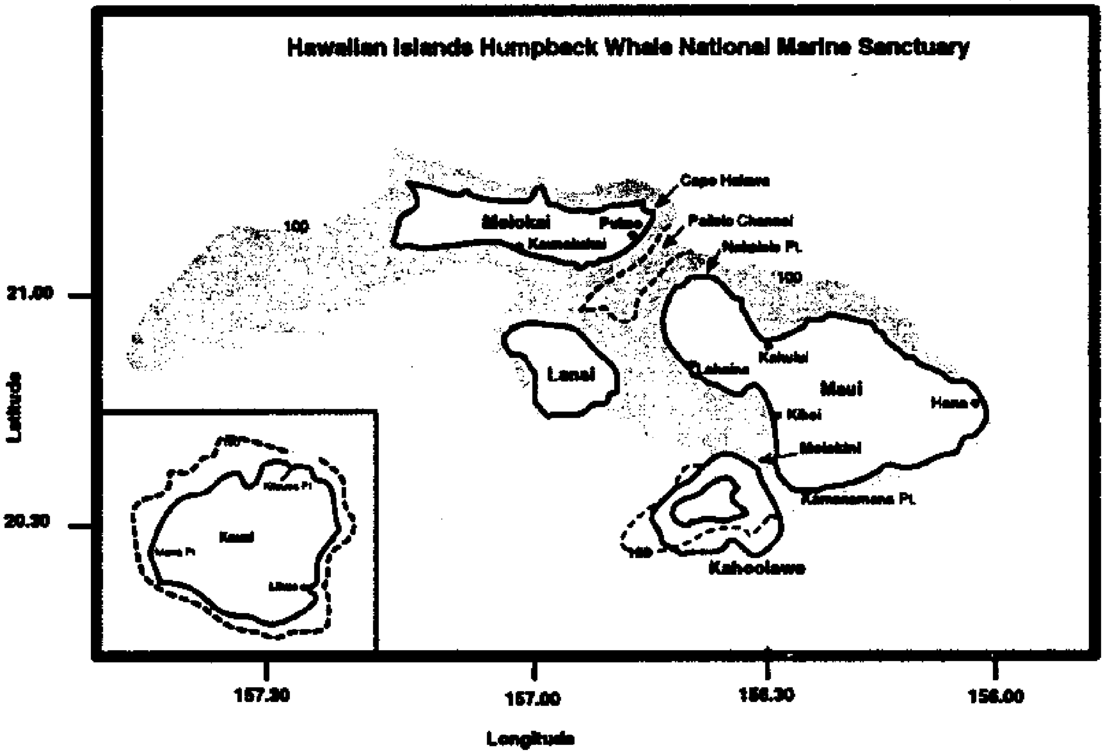
A SITE CHARACTERIZATION STUDY for the Hawaiian Islands Humpback Whale National Marine Sanctuary



Prepared for the

National Oceanic and Atmospheric Administration (NOAA)

by

University of Hawaii Sea Grant College Program

School of Ocean and Earth Science and Technology

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Table of Contents

Chapter 1

Introduction and Report Summary

Peter J. Rappa

Chapter 2

Review of the Physical Oceanographic Conditions Within the Designated Sanctuary

Jacquelin Miller

Chapter 3

Nearshore Marine Communities

Richard Brock

Chapter 4

Cetaceans in Hawaiian Waters

Joseph Mobley, Jr.

Chapter 5

Other Threatened and Endangered Species

Peter Rappa and Michelle Yuen

Chapter 6

Traditional Uses of the Marine Environment

Peter J. Rappa and Kathleen Aki

Chapter 7

Current and Potential Uses of the Designated Sanctuary Waters

David Tarnas

Chapter 8

Management Issues Related to Activities and Uses in Sanctuary Waters

David Tarnas

List of Figures and Tables

Figures

Tables

CHAPTER 1
INTRODUCTION AND REPORT SUMMARY

INTRODUCTION

In 1972, Congress passed the Marine Protection, Research, and Sanctuaries Act, as a response to a growing awareness of the environmental and cultural importance of our coastal waters. The Act authorizes the Secretary of Commerce to designate discrete areas as National Marine Sanctuaries to promote the comprehensive management of the ecological, historical, recreational, and aesthetic resources within them. National Marine Sanctuaries have been designated in coastal and ocean waters, in submerged lands, and in the Great Lakes and their connecting waters.

The establishment of a National Marine Sanctuary in Hawaii was first considered in December 1977, when the National Oceanic and Atmospheric Administration (NOAA) received the nomination for a proposed humpback whale national marine sanctuary in the waters between Maui, Molokai, Lanai, and Kahoolawe. This area has been identified as the principal breeding and calving area for the wintering population of endangered north Pacific humpback whales. In March 1982, NOAA declared the site an "Active Candidate" for designation as a marine sanctuary, however, based on comments received by NOAA from the public, local, and state agencies regarding the Draft Environmental Assessment/Management Plan, further consideration of the site was suspended. Interest was revived in October 1990 when Congress directed NOAA to determine the desirability and feasibility of establishing a sanctuary in the waters around Kahoolawe Island. The study indicated that more investigations needed to be completed before the Kahoolawe site could be considered. The study also recommended that additional areas within the Hawaiian Islands be considered as possible components of a proposed multiple-resource National Marine Sanctuary.

On November 4, 1992, former President Bush signed Public Law 102-587, the Oceans Act of 1992, which created the Hawaiian Islands Humpback Whale National Marine Sanctuary. The proposed sanctuary lies between 20°30' and 22°20' north latitude and 156°00' and 159°30' west longitude. It occupies all contiguous coastal waters between the islands of Maui, Molokai, and Lanai and extends seaward of these islands to the 100 fathom isobath, a horizontal distance ranging from a few meters seaward of the shoreline on the eastern side of Maui to Penguin Bank (excluding the area within three nautical miles of Kahoolawe Island) some 24 nm southwest of Molokai. The sanctuary also includes a small triangular area in the northeastern tip of Kilauea Point on Kauai (Figure 1.1).

The primary purposes of the proposed sanctuary are to protect humpback whales and their habitat and to identify marine resources and ecosystems of national significance for possible inclusion in the proposed sanctuary. The Act also provides for the inclusion of Kahoolawe Island in the proposed sanctuary on January 1, 1996, unless, following an examination and assessment of the resources of the area, the Secretary of Commerce finds the area unsuitable.

In 1993, the Sanctuary and Reserves Division (SRD) of NOAA, requested the University of Hawaii Sea Grant Extension Service to conduct a Site Characterization Study of the congressionally designated Hawaiian Islands Humpback Whale National Marine Sanctuary. The purpose of the Site Characterization Study is to gather the most recent and substantive information available concerning existing resources in the designated area. The SRD will incorporate portions of the study into an environmental impact statement and management plan for the sanctuary and intends to modify portions of the Site Characterization Study for public distribution.

The objective of the Site Characterization Study is to identify existing physical and ecological resources within the congressionally designated sanctuary boundaries as well as historical and cultural resources associated with the use of the marine environment. Information on physical parameters such as the geology,

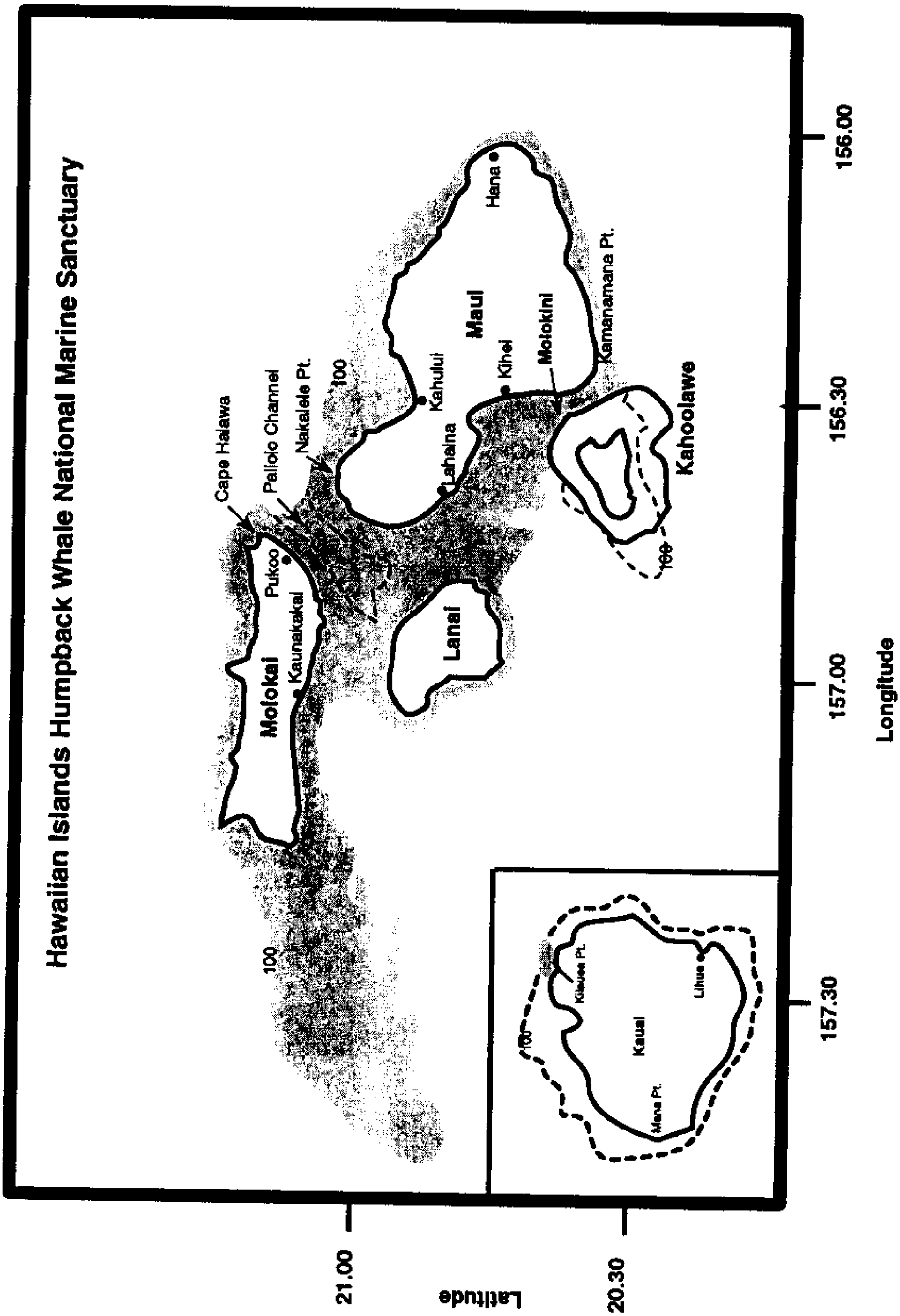
Hawaiian Islands Humpback Whale National Marine Sanctuary
Cape Halawa
Pailolo Channel
Nakalele Pt.
100
Pukoo
Kaunakakai
Molokai
Lanai
Lahaina
Kahului
Kihei
Maui
Molokini
Hana
Kamanamana Pt.
Kahoolawe
100
Kilauea Pt.
Kauai
Lihue
Mana Pt.
156.00
156.30
157.00
157.30
Longitude
21.00
20.30
Latitude

Figure 1.1

oceanography, and water chemistry of the area, and current uses has been collected. Management issues dealing with the protection and utilization of existing resources were also examined. Special attention was given to humpback whales and their habitat although other marine resources were examined as well. This study will serve to identify gaps in existing knowledge concerning physical conditions and biological and cultural resources and will aid in the determination of future research and monitoring efforts.

The Site Characterization Study was prepared by a multi-disciplinary team from the University of Hawaii and assembled by the University of Hawaii Sea Grant Extension Service. Team members include: Dr. Richard Brock, Associate Researcher and Fisheries Specialist, University of Hawaii Sea Grant Extension Service; Mr. David Tarnas, West Hawaii Extension Agent, University of Hawaii Sea Grant Extension Service; Dr. Joseph Mobley, Associate Professor, Department of Psychology, University of Hawaii, West Oahu; Ms. Jacquelin N. Miller, Associate Coordinator, University of Hawaii Environmental Center; Mr. Peter J. Rappa, Coastal Resource Extension Agent, University of Hawaii Sea Grant Extension Service; Ms. Kathleen F. Aki, Graduate Assistant, University of Hawaii Sea Grant Extension Service; Ms. Michelle Yuen, Student Assistant, Sea Grant Extension Service.

A preliminary version of this document was reviewed by the following individuals:

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The views expressed in this report are solely those of the authors and do not reflect an institutional position of the University of Hawaii Sea Grant College Program, or NOAA's Sanctuaries and Reserves Program.

GENERAL SUMMARY

Chapters 2 through 8 provide detailed information on specific topic areas including physical oceanography, nearshore marine communities, cetaceans, threatened marine species, traditional and current uses of the marine environment, and management issues related to activities within the designated sanctuary. Each chapter also includes a list of recommendations for futures studies and proposed management guidelines.

Physical Oceanographic Conditions

The Hawaiian Islands were formed during the last few million years by the gradual accretion of basaltic lava flows and ejecta. Their geologic features have been formed by successive periods of volcanic activity interspersed with submergence, weathering, and eustatic changes in sea level. Abundant rainfall and persistent northeasterly trade winds contribute to the steady weathering of the islands. Sandy beaches are found along the shorelines of all the islands but are best developed on Kauai, the oldest of the main islands, and least developed on Hawaii, where mountain building is still occurring.

Although the Hawaiian Islands are at the northern edge of the tropics, they have a subtropical climate due to the cool ocean currents and persistent northeasterly trade winds that occur about 80% of the time. The average wind velocity is between 10 and 20 kt, but velocities over 20 kt for over a week are not uncommon. Ocean temperatures are less than that of other areas at the same latitude and range from 21° C to 29° C (70° F to 85° F).

Coastal current measurements off the Hawaiian Islands suggest a mean velocity at less than 20 cm/sec in most cases, although, extreme variability is the rule, not the exception. Water circulation around the islands is driven by a combination of forces including tides, the West Wind Drift, circulation of the Eastern Pacific Gyre, and local wind and eddy systems.

There may be many unique or unusual features found within the proposed sanctuary boundaries, however, those pertinent to the physical oceanography seem to focus on two very distinctive characteristics: bathymetry and eddy circulation. The bathymetry of the area, bound by Maui, Molokai, Lanai, and Kahoolawe, along with the extension of the shallow Penguin Bank southwest of Molokai, represents a unique, semi-enclosed, shallow protected sea in the midst of an expansive ocean. There is almost no information in the published literature as to the specific characteristics of this interisland area.

Nearshore Marine Communities

The Hawaiian Islands are among the most isolated in the world. This isolation has played a major role in the development of the archipelago's shallow marine communities. The origin of most Hawaiian inshore marine species is from the Indo-West Pacific Faunal Region, the center of which is in the region of the Malaysian Peninsula and the Philippine Islands. Because of the isolation and northerly geographic setting (resulting in relatively low water temperatures), the shallow Hawaiian marine fauna is considered to be depauperate. There are about 450 species of inshore fishes and 40 species of corals in Hawaiian waters. Many of the shallow water invertebrates have a greater diversity of species; the Mollusca are represented by about 1,000 species, the Polychaeta by about 243 species and the Bryozoa by about 200 species.

More than half of the shoreline of the older islands of the chain (i.e., Kauai, Oahu, Molokai, Lanai, and Maui) is fringed by coral reef. In general, Hawaiian reefs are not as well developed or diverse as reefs of other Pacific islands, again due to the relative isolation of the archipelago and its geographic position at the northern extreme of coral reef development. The reefs are wide, shallow platforms extending as much as 300 m seaward from the shore. The reef flats are predominately sand, coral rubble, and coralline algae. Crustose coralline algae are the dominant reef builders on Hawaiian reefs with coelenterate corals being relatively unimportant in the overall fringing reef habitat.

In addition to coral communities associated with fringing reefs, corals extend subtidally to depths of at least 50 m in Hawaiian waters, although the greatest development of these reefs is at depths from a few meters down to about 30 m. Prime examples of coral community development may be seen on submarine surfaces of recent lava flows off the coast of Maui and in the waters between Maui and Molokai. Coral communities are well developed around the islet of Molokini where commercial dive tours have capitalized on this. Coral communities are better developed where they are protected from high wave activity; thus, the leeward (western) coasts often have well-developed examples. Hawaiian coral communities show a zonation that is related primarily to wave exposure and indirectly to depth.

Disturbance on coral reefs comes from many sources including those that are natural (such as storm waves or storm water runoff) to those caused by human activities. Impacts from natural sources may include intense storm events, volcanic eruptions, large-scale El-Nino events, episodes of massive sedimentation, and population explosions of the coral-feeding crown-of-thorns starfish, all of which may cause large-scale mortality in coral communities.

There are numerous human-induced disturbances that occur on coral reefs. Some of these anthropogenic stresses are more wide-spread than are others. Important forms of human disturbance include (1) sedimentation, (2) pollution, (3) the discharge of heated effluents, (4) over-fishing, and (5) the introduction of exotic fishes.

Cetaceans in Hawaiian Waters

A total of 24 cetacean species (five Mysticetes; 19 Odontocetes) have been observed in Hawaiian waters, though only 15 with any regularity. Of the Mysticetes, humpback whales are the only species with more than incidental occurrence. Since humpback whales presumably do not feed while in Hawaii, the primary forces affecting their behavior and distribution while wintering in Hawaiian waters are those associated with reproductive success.

Based on the 1993 aerial survey results, four Odontocete species were identified as occurring in shallow coastal waters along the major Hawaiian Islands, thus potentially falling under the jurisdiction of the sanctuary. These species include bottlenosed dolphins (*Tursiops gilli*), false killer whales (*Pseudorca crassidens*), spinner dolphins (*Stenella longirostris*), and spotted dolphins (*Stenella attenuata*). The 1993 survey results indicated Odontocete species to be particularly abundant in the waters surrounding Kauai and Niihau. They were less abundant in the four-island region (Maui, Kahoolawe, Lanai, Molokai) and Penguin Bank regions where humpback whale densities are greatest.

Comparison of results from earlier aerial surveys (1977–80) with recent surveys using identical methods (1990) suggest that the number of humpback whales wintering in Hawaiian waters may be increasing. Additionally, abundance estimates from surveys performed between 1977–93 have shown a consistent pattern of increase.

Humpback whales generally prefer shallow waters. Of the 403 groups of humpback whales sighted in 1993, 73% were in waters less than 100 fathoms.

The combined aerial survey results show clear preferences of humpback whales for different island regions. Ranked in decreasing order of sighting rate (pods/hr of survey), the regions are as follows: Penguin Bank, four-islands regions (Maui, Lanai, Molokai, and Kahoolawe), Kauai and Niihau, Hawaii, and Oahu. This preference has been stable for 15 years of surveys.

Other Threatened and Endangered Species

Five species of marine turtles are known to inhabit Hawaiian waters: green sea turtle (*Chelonia mydas*), hawksbill sea turtle (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), and the olive ridley (*Lepidochelys olivacea*). Only the endangered hawksbill turtle and the threatened green sea turtle are commonly found in Hawaiian waters. Hawksbills nest on the main Hawaiian islands primarily on several sand beaches on the island of Hawaii and on the east end of Molokai. More than 90% of the breeding and nesting of green turtles occurs at French Frigate Shoals in the Northwestern Hawaiian Islands (NWHI), although a substantial population resides and returns to the waters within Maui and Kauai Counties.

Of the 30 species of native Hawaiian birds listed as endangered or threatened by the U.S. Fish and Wildlife Service, only one is commonly found in the vicinity of the designated sanctuary, the Hawaiian dark-rumped petrel (*Pterodroma phaeopygia sandwichensis*).

Breeding populations of the endangered Hawaiian monk seal, (*Monachus schauinslandi*) occur almost exclusively in the NWHI. The population is estimated to be approximately 1,200 individuals. Monk seals are rarely seen in the main Hawaiian Islands although, seal births were observed on Kauai in 1988 and on Oahu in 1991.

Traditional Uses of the Marine Environment

The Hawaiian Islands were most probably settled by Polynesian voyagers sailing from the Marquesas Islands. A second group of Polynesian settlers arrived later from Tahiti. Hawaiians used the ocean for fishing, aquaculture, trade, transportation, and communication. In addition, the marine waters figured predominantly in religious practices including the worship of personal deities.

Hawaiians evolved a different set of "use rights" than the Western practices of open access to marine resources. The vestiges of these use rights carry over today and may have a bearing on the management of the proposed sanctuary. Based on customary land and nearshore reef tenure there exist "konohiki fisheries" in which access to fish is controlled by the adjacent land owner. About 41 konohiki fisheries are in existence today. Additional rights in deeper water fisheries known as "koa huna" fisheries may also exist.

Aquaculture was another important historical use of the marine environment. Fishponds were introduced on Oahu prior to the thirteenth century by settlers from the Society Islands. Estimates vary from 360 to 488 on the number of fishponds that were built in the Hawaiian Islands. Only the remains of 157 fishponds can be found today. Of the 157, fewer that 57 could be considered in restorable condition.

Control of Hawaii's channel waterways was an important part of Hawaiian society. This importance is reflected today in modern Hawaii's claim to state ownership of interisland waters.

Current and Potential Uses

Current and potential uses of the waters of the designated Hawaiian Islands Humpback Whale National Marine Sanctuary include commercial fishing, beach-going, boating, boardsailing, yachting, kayaking, tour boating, snorkeling, whale watching, jet skiing, parasailing, canoeing, charter boat fishing, shipping, research, waste disposal, ocean thermal energy conversion activities, high voltage seabed mining, and the installation of an underwater cable.

The commercial fishing catch from Maui represents nearly 3% of the state total. Molokai and Lanai each contribute 0.25% and 0.11%, respectively. Penguin Bank, located west of Molokai and within the sanctuary's boundary is noted for its productivity.

The shoreline of Maui is heavily used for recreation while Molokai and Lanai are less intensely used because of a smaller population and fewer visitors to those islands. Recreational boating is an important activity in Maui and Kauai Counties.

The tour boat business includes activities such as snorkel cruises, scuba diving, raft rides, day trips to Lanai, whale-watching, and excursions on submarines and semi-submersibles. Of the 30 companies active in the Maui County tour boat industry in 1990, snorkeling cruises on sail and motor boats provided about 79% of the revenue. Whale watching provided the next highest amount of income of 8% and the remaining revenue was produced by activities such as ferry transportation to Molokai and Lanai, sail charters, glass bottom boat trips, sunset and dinner cruises, inflatable raft riding, and submarine tours.

The charter boat fishing industry in Maui has been active and thriving for many years. The Maui-based charter boat fishing fleet is divided between Lahaina, Maalaea Harbor and Mala Wharf, with the majority of vessels based at Lahaina.

Recreational fishing is a significant, yet unquantified fishery in sanctuary waters. Recreational fishers outnumber commercial fishers 50 to 1, and nearly 75% of small boat owners engage in fishing as their primary activity.

The two major harbors in the designated sanctuary are Kahului on Maui and Nawiliwili on Kauai. The shipping routes for the harbors on Maui and Molokai transit the sanctuary waters through the interisland channels of the Maui County islands.

There is one National Pollution Discharge Elimination System (NPDES) permit for direct point-source discharge of wastes into the waters of the sanctuary and this is for the Lahaina Sewage Treatment Plant. Of greater concern than direct discharges of waste into the sanctuary waters, is nonpoint source pollution. Hawaii State Department of Health reports that the most critical marine water quality problem facing the state is sedimentation, a type of nonpoint source pollution.

Management Issues Related to Activities and Uses in Sanctuary Waters

The primary management issues facing the national marine sanctuary are (1) reducing the density of ocean activities in the humpback whale habitat to prevent detrimental interference with the whales, (2) working with the existing program to control nonpoint source pollution affecting the quality of the coastal waters of the sanctuary in which the humpback whales live, and (3) addressing the concern of the effectiveness and fairness of the distance regulations in dealing with intentional interference of vessels with humpback whales. If the scope of the sanctuary expands to include other marine resources, then management issues related to coral reef conservation will need to be addressed.

RECOMMENDATIONS

- Conduct detailed bathymetric surveys of the four-islands region and include physical parameters such as water chemistry, currents, temperature, and bathymetry.
- Identify and track terrigenous-based water pollutants.
- Conduct quantitative research on the nearshore marine resources of the designated sanctuary.
- Identify other marine resources that would benefit from protection and management through a national marine sanctuary.
- Conduct additional research and monitoring on whale distribution and whale habitat.
- Conduct additional research on the impacts of human activities on whale behavior.
- Conduct additional research and management efforts on reducing the impacts of nonpoint source pollution on whale habitat.
- Incorporate the management strategies recommended in the recovery plans for sea turtles and monk seals as part of the management regime of the designated sanctuary.
- Examine native Hawaiian fishery rights and their implications for the designated sanctuary.
- Examine the implications of Hawaiian religious practices on the designated sanctuary.
- Encourage fishpond restoration efforts for educational purposes.
- Evaluate the effectiveness and fairness of the distance regulations in managing interactions between vessels and humpback whales.
- Establish a state-wide system of day-use mooring buoys.
- Update and revise the ocean recreation management plan.
- Establish a comprehensive environmental monitoring program.
- Develop additional education programs.

CHAPTER 2

REVIEW OF THE PHYSICAL OCEANOGRAPHIC CONDITIONS WITHIN THE DESIGNATED SANCTUARY

DATA SOURCES

Information for the physical oceanographic conditions of the designated sanctuary was based primarily on published and peer-reviewed papers and scientific reports. In addition, efforts were made to gather pertinent information from environmental impact statements, theses prepared for University of Hawaii advanced degrees, and personal interviews with researchers. Information from non-technical sources was not included.

GEOLOGY

The Hawaiian Islands were formed during the last few million years by the gradual accretion of basaltic lava flows and ejecta. Their geologic features have been formed by successive periods of volcanic activity interspersed with submergence, weathering, and eustatic changes in sea level (Wyrtki 1990). The islands rise 9,100 m above the sea floor, and the island of Hawaii has a maximum elevation of 4,500 m above sea level (U.S. Environmental Protection Agency 1980; Menard 1964).

The volcanic activity that created the Hawaiian Islands formed comparatively gradual mountain masses that rise abruptly from the relatively smooth archipelagic apron of the adjacent sea floor. This apron extends some few tens of kilometers outward from the islands and is peculiar because it slopes slightly upward from the base of the islands. This is in contrast to aprons bordering the Marquesas, Samoan, Society, Marshall, and Line Islands where the slope is a smooth curve grading downward from the island base to the apron. The Hawaiian apron appears to have been deformed. The sea floor at the base of the islands is slightly depressed and forms a moat-type structure around the islands. Beyond the moat is a bulge or arch, apparently formed by the weight of the island pushing the displaced material outward. The crest of this bulge around the Hawaiian Islands is 150 km to 180 km from the base of the islands and the outer limit of the bulge ranges from 330 km to 370 km from the islands. The moats are of modest relief, ranging from 0.5 km to 1.5 km, and are approximately the same depth as the adjacent sea floor (Menard 1964).

The islands generally are surrounded by coral reefs. Abundant rainfall and persistent northeasterly trade winds contribute to the steady weathering of the islands. Sandy beaches are found along the shorelines of all the islands but are best developed on Kauai, the oldest of the main islands, and least developed on Hawaii, where mountain building is still occurring. Beach materials other than black sand, which results from the disintegration of lava as it contacts cold sea water, are formed from the weathered carbonate coral reefs, shell fragments, and calcium carbonate tests of benthic foraminifera (Muller 1974). In addition, some beach sand is derived from the partial weathering of lava, particularly near the mouths of some rivers, notably the Waimea River on Kauai.

GEOMORPHOLOGY/BATHYMETRY

The islands of Maui, Lanai, Molokai, and Kahoolawe are the remnants of a single massive volcanic conglomerate formed by at least six major and one minor volcano. During a period of low sea level (in the recent geologic past), these four islands were connected to form a single island called "Maui Nui" (Macdonald et al. 1983; U.S. Department of Commerce 1983). This island had an area of about 5,200 km^2 (about one-half the size of the present island of Hawaii). Extensive periods of erosion, emergence, and subsidence in combination with changes in sea level shaped Maui Nui to its present configuration, drowning the base of the island and creating not one, but four separate islands. The adjoining submerged base of Maui, Lanai, and Molokai ranges in depth from about 30 m to 80 m. Hence, about half of the designated sanctuary is less than 80 m in depth (Figure 1.1).

Penguin Bank is noted for major concentrations of humpback whales during their winter stay in Hawaiian waters. The average depth of water over Penguin Bank is about 60 m but ranges from 50 m to 200 m. There is a lack of information regarding the specific geology of the very near coastal waters (i.e., 100 m to 200 m depths). Observations made from research submersibles at Penguin Bank and in the general vicinity of the designated sanctuary, indicate that at depths of 60 m to 120 m the bottom is composed primarily of sand with occasional outcrops of coarse sediment, limestone talus, limestone holes, and platforms (Barbara Muffler, Hawaii Undersea Research Laboratory pers. comm. 1993). In addition, carbonate organisms including red and green calcareous algae, bryozoans, corals, and pen shells have been observed at depths of 40 m to 90 m on Penguin Bank (Agegian and Mackenzie 1989).

Bottom photography off of other coastal sites throughout the state, (e.g., Kahului Harbor, Maui; Nawiliwili, Kauai; Pearl Harbor, Oahu; Port Allen, Kauai; and Hilo, Hawaii) showed remarkable similarity at depths of 300 m to 1,600 m. At each site, the bottom was characterized by silty sand and clay with only occasional cobbles, boulders, and rocky outcrops. Whereas these data reflect conditions slightly beyond the 100-fathom isobath, observations from submersible dives suggest that these characteristics are consistent with the shallow near coastal regions with an increase in the presence of rocky outcrops and coral rubble at the shallow depths.

The nearshore topography of Oahu is characterized by a series of marine terraces. The terraces, which are separated by escarpments, reflect periods of emergence, submergence, and changes in sea level. Specific bathymetric data have not been located for the nearshore areas of the islands of Maui, Molokai, and Lanai. On Oahu, however, the upper level terrace extends seaward to about 60 m followed by a steep escarpment and then a second or intermediate terrace from about 70 m to 120 m. Another steep escarpment is found at this depth and then a gently sloping terrace extends from about 130 m to the 600 m contour (Brock and Chamberlain 1968). Sonic depth recorders indicated a relatively flat or gently sloping bottom at depths near 200 m (100-fathom isobath) (U.S. Environmental Protection Agency 1980). With few exceptions, the bottom topography from 400 m seaward is very steep and drops almost immediately to the abyssal plains at 4,800 m (2,400 fathoms). Because the submerged coasts of Maui, Molokai, and Lanai probably experienced similar periods of erosion, subsidence, emergence, and changes in sea level, it is proposed that the terraces on Oahu reflect similar types of geomorphic conditions as those in the sanctuary area.

METEOROLOGY AND CLIMATOLOGY

Although the Hawaiian Islands are at the northern edge of the tropics, they have a subtropical climate due to the cool ocean currents and persistent northeasterly trade winds that occur about 80% of the time (U.S. Department of Commerce 1983). The average wind velocity is between 10 and 20 kt, but velocities over 20 kt for over a week are not uncommon (Figure 2.1) (Patzert 1970). Ocean temperatures are less than that of other areas at the same latitude and range from 21° C to 29° C (70° F to 85° F). Occasional periods of southerly, or kona winds may bring storm events.

Winds blow many miles across the ocean before reaching the Hawaiian Islands. Rainfall occurs when warm, moisture-laden trade wind air is forced up and over mountain peaks causing condensation of atmospheric moisture. The northeastern sides of the islands (the direction of the prevailing winds) are usually the wettest. As the winds descend the leeward slopes, they become warm and dry, thus making the leeward coasts some of the driest areas in the state. Southerly winds can also bring rains and, in fact, the more serious storms frequently come from the south. Rainfall exceeding 24 inches in four hours has been recorded (Stearns 1967). Rainfall over the state varies from 25 cm (10 in) near leeward shores to almost 1,270 cm (500 in) at Mount Waialeale on Kauai. Maximum precipitation usually occurs between altitudes 600 m and 1,830 m (2,000 ft and 6,000 ft). Precipitation is highly variable, however, and is heavily influenced by local topography and the sheltering effects of adjacent islands. This is particularly noticeable on the islands of Kahoolawe and Lanai, which are relatively low and shielded from the trade winds by other islands. Consequently, these islands are very dry and suffer severe wind erosion problems (Blumenstock and Price 1967; Stearns 1967; Blumenstock and Price 1967; U.S. Department of Commerce 1991; Hawaii DBEDT 1990).

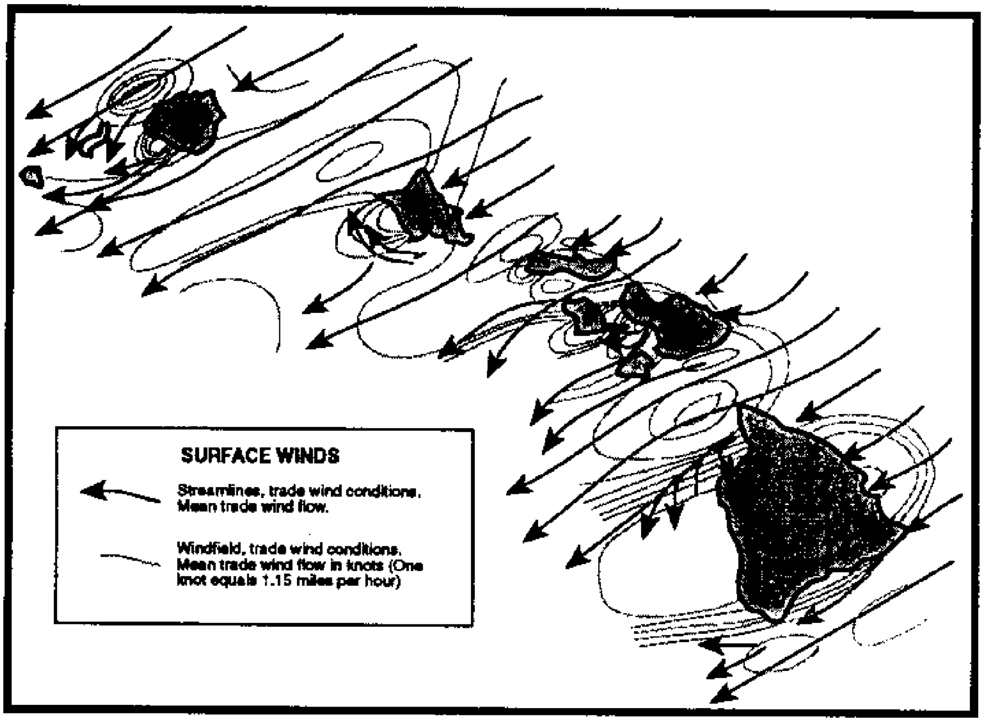

Figure 2.1 Hawaiian Surface Winds

The importance of the air-sea interaction is evident in an analysis of the meteorological and oceanographic conditions of the Hawaiian Islands. The islands present a formidable barrier to the northeast trade winds. This is particularly true for the island of Hawaii, which presents a solid barrier of approximately 120 km to the winds (Figure 2.2) (Patzert 1970). Alenuihaha Channel, between Maui and Hawaii, is bound by mountains higher than those bounding both sides of the Kauai Channel. The "thickness" of the atmospheric layer in which the trade winds are dominant extends to a height of approximately 1,800 m (Patzert 1970). The relationship between the height of the islands and the elevation of the trade wind flow is clearly demonstrated in Figure 2.2 (Patzert 1970). The islands are over 1,000 m above the trade wind layer. The other major islands may also serve as a barrier to the wind, but are below the maximum height of the trade winds.

Long-term measurements of winds taken by Honolulu Weather Bureau ship observations clearly show the marked effect on atmospheric circulation imposed by the islands (Figure 2.1). Wind speeds decrease in the lee of each island whereas winds in the channels increase in strength. This effect is stronger in the Alenuihaha

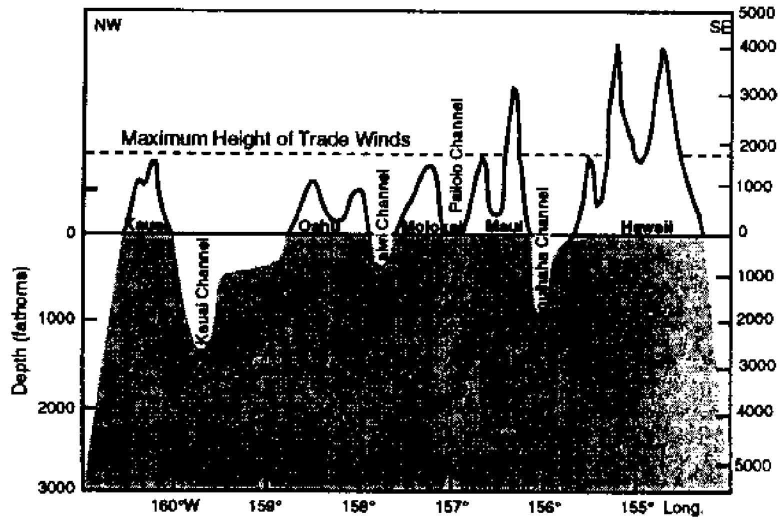

Figure 2.2 Maximum Height of Trade Winds

Channel than in the other channels where velocities of 20 kt to 25 kt are not uncommon. It has been postulated (Patzert 1970) that the increase in wind velocity is due to the constriction of trade wind flow in the channel by the high mountains on either side, much like the "Venturi effect" of flows through a narrowed opening. Shear effects upon the incident trade winds are also seen in the lee of Hawaii. Cyclonic eddies develop to the north and anticyclonic eddies develop to the south. Atmospheric eddies have been shown to be a permanent feature during trade wind conditions in the lee of Hawaii and may occur in the lee of the other main islands as well, but are likely to be far less intense because the other islands are much lower and smaller than Hawaii.

The presence of atmospheric eddies is also illustrated by the rainfall regime of the west (Kona) coast of Hawaii. As previously mentioned, rainfall throughout most of the islands is considerably greater on exposed windward coasts than on the more protected leeward coasts; however, this is not the case along the leeward coast of Hawaii. Kona receives up to 150 cm/yr (60 in/yr) of precipitation in contrast to other leeward areas that receive less than 50 cm/yr (20 in/yr) (Patzert 1970) because of the blocking effect of the mountains (Mauna Loa in particular) on the trade wind showers. Although Kona receives more rainfall in the summer months, when trade winds are strongest, the rainfall cannot be attributed completely to the trade winds. One explanation for the observed high rainfall belt in Kona is the land-sea breeze circulation in the lee of the high mountains. Another is that the period of maximum rainfall along the Kona coast coincides with the convergence zone between the cyclonic and anticyclonic eddies to the west of the island. The minimum monthly rainfall along the Kona coast occurs during the winter when trade winds are their weakest. It is believed that the Kona coast rainfall regime is a consequence of these quasi-permanent, offshore, atmospheric eddies (Patzert 1970). The importance of these wind conditions to the designated sanctuary will be apparent when their role in ocean circulation is discussed in a forthcoming section.

Hours of daylight have been postulated to influence the migration of the humpback whales from polar feeding grounds to tropical calving areas (Dawbin 1977). In Hawaii, there is little variation between the length of the days and nights from one part of the state to another because all the islands lie within a narrow latitudinal band (Blumenstock and Price 1967). Variation in length of day in Honolulu for example, ranges from 13 hr 20 min (without twilight) to 14 hr 10 min (including twilight) at the longest day and 10 hr 50 min to 11 hr 40 min (with and without twilight) for the shortest day (Blumenstock and Price 1967). This small variation in solar energy from one time of the year to another partially explains the slight changes in seasonal temperatures throughout much of the state. Persistent trade winds are a major factor in moderating the overall climate of the islands.

CHEMISTRY/WATER QUALITY

There are three major water masses around the Hawaiian Islands: the North Pacific Central (NPC), the North Pacific Intermediate (NPI), and the Pacific Deep Water (PDW) (Table 2.1) (Sverdrup et al. 1942). Of these, the NPC, which forms the shallow water masses and ranges in depth from 100 m to 300 m, is found within the sanctuary. This water mass is characterized by temperatures ranging between 10° C and 18°C and salinities of 34.2% to 35.2% (U.S. Environmental Protection Agency 1980). The NPC water has the highest salinity of the three, but this is countered by higher temperatures so its relative density is lowest.

TABLE 2.1. MAJOR WATER MASSES OF THE NORTH PACIFIC

Water mass	*Depth (m)*	*Temperature(° C)*	*Salinity(g/kg)*
North Pacific Central	100–300	10–18	34.2–35.2
North Pacific Intermediate	300–1,500	5–10	34.2–34.5
Pacific Deep Water	1,500–bottom	1.1–2.2	34.6–34.7

Source: U.S. Environmental Protection Agency 1980.

According to Patzert (1970), the vertical distribution of salinity between the ocean's surface and 150 m depth, increases slightly to 35.1%. The depth of this maximum can vary depending on the presence of a cyclonic eddy when the salinity maximum has been recorded at the surface. This indicates an upwelling of 150 m, completely removing the water of lower salinity at the sea surface.

Variations in Hawaiian surface water temperatures range from a mean minimum of about 21° C (70° F) from January to February to a mean maximum of about 27° C to 28° C (81° F to 82° F) from June to October. Mean monthly maximum and minimum temperatures recorded at Kaneohe, Oahu are illustrated in Table 2 (Haraguchi in Hawaii DBEDT 1990). Although these temperatures are likely to differ somewhat from temperatures in the designated sanctuary, the general monthly trends can be expected to be similar.

The depth of the mixed layer varies from 50 m to 140 m (Chave and Miller 1977; Wyrtki et al. 1967). The thermocline extends well beyond 200 m (100 fathoms) and has been reported to extend to depths between 275 m to 365 m in the offshore region (U.S. Environmental Protection Agency 1980). Stratification is weakest in the winter months and strongest in the summer.

Specific water chemistry data for the sanctuary area, particularly the inner area between the islands of Lanai, Molokai, Maui, and Kahoolawe, have not been located. However, based on studies conducted in comparable water depths and distances from shore, it is believed that the water chemistry of the outer edge of the sanctuary is more oceanic than coastal in character. The persistent trade winds, tides, and exceptionally strong currents between and adjacent to the islands encourages maximum mixing and dispersion of nearshore waters. Major inputs from the local land masses are likely to be episodic and may be negligible along the borders of the sanctuary. General approximations of the water chemistry based on measurements taken at a nearshore site off Oahu (Chave and Miller 1977), suggest that dissolved oxygen is high, perhaps supersaturated in the surface waters, ranging from 5.4 ml/L at the surface to 5.7 ml/L at 100 m.

TABLE 2.2. HAWAIIAN WATER TEMPERATURES BY MONTH

Month	*Temperature ° F* Mean maximum	*Temperature ° F* Mean minimum
January	74.7	71.1
February	75.6	70.3
March	76.5	71.8
April	77.7	73.0
May	79.5	74.7
June	81.1	77.7
July	81.1	78.3
August	81.9	79.2
September	81.9	78.4
October	81.1	77.2
November	79.3	74.5
December	75.9	71.4
Annual	78.6	74.8

Source: Hariguchi in: Hawaii Department of Business, Economic Development & Tourism 1990.

At 300 m depth off Oahu, these values decreased to 5.0 ml/L. A similar distribution pattern for pH was noted off Oahu, in December, 1976, where values in the surface waters averaged 8.1 and increased to 8.2 between 25 m and 50 m depths. A decrease of 7.9 was noted at 300 m. The pH values were markedly lower at the same site during April, 1977. Values of pH averaged 7.6 at the surface, increasing to 7.7 between 100 m and 150 m depth, and then decreased to 7.6 at 400 m. In sea water, pH generally ranges from 7.5 to 8.4.

Analyses for silver, cadmium, chromium, and copper were conducted in 1976 and 1977 at the proposed south Oahu Dredge Spoil Site. Each of these elements was below the minimum detection limit of 1 ug/liter. Lead and nickel were below detection limits of 5 ug/liter and 4 ug/liter, respectively. Analyses for mercury and zinc gave abnormally high values. The samples were believed to have been contaminated, and therefore omitted from further consideration. No trace metal samples have been taken at the site since 1977.

OCEANOGRAPHY

Coastal current measurements off the Hawaiian Islands (Wyrtki et al. 1969; Chave and Miller 1977) suggest a mean velocity less than 20 cm/sec in most cases, however, extreme variability is the rule, not the exception. Water circulation around the islands is driven by a combination of forces including tides, the West Wind Drift, circulation of the Eastern Pacific Gyre, and local wind and eddy systems. The latter have been extensively studied by University of Hawaii oceanographers (Wyrtki et al. 1967; Wyrtki et al. 1969; Wyrtki 1970; Patzert 1970; and Patzert et al. 1970). The main Hawaiian Islands are marked by variable current directions and velocity and the presence of well developed eddies (University of Hawaii, 1983. Figure 2.3).

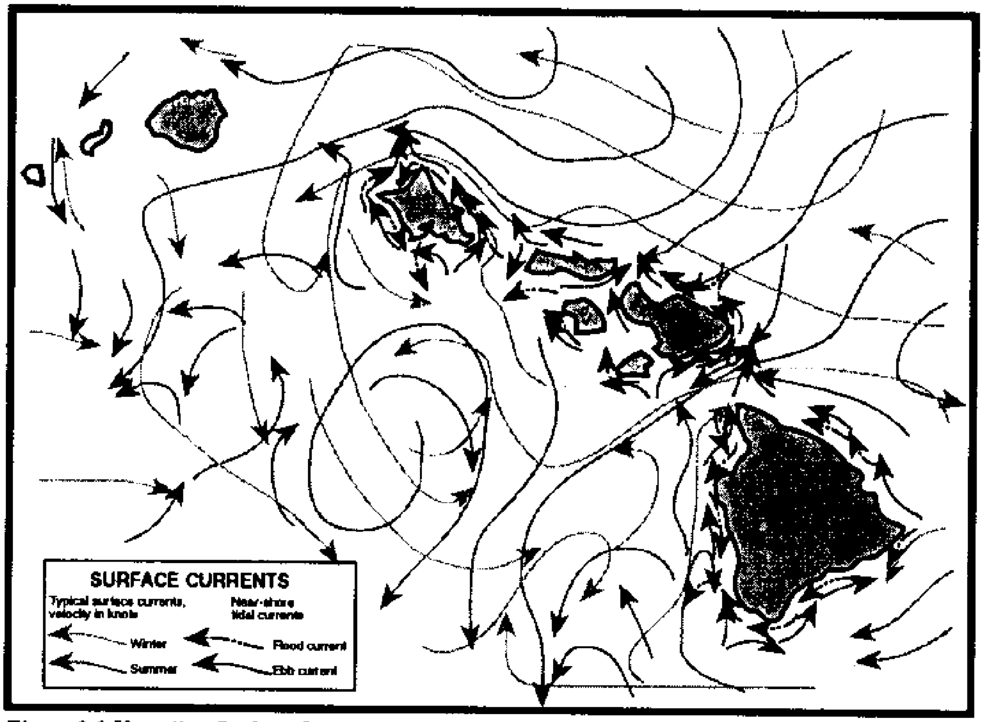

Figure 2.3 Hawaiian Surface Currents

According to Wyrtki (1970), the ocean circulation around the Hawaiian Islands is dominated by eddies with diameters ranging from 50 km to 150 km. Most of the eddies are cyclonic and are present during all seasons, and the flow in them is nearly geostrophic. The volume transports have been calculated to be as large as 8 million m^3/sec. Surface currents around eddies have been measured in excess of 100 cm/sec (Patzert 1970). The eddies are relatively shallow and are concentrated in the upper 150 m, well within the depth ranges of the sanctuary. Flights with airborne radiation thermometers, attempted to map the horizontal distribution and movement of eddies over time by measuring cold spots that form in the center of cyclonic eddies (Figure 2.4) (Wyrtki 1970). These measurements identified periods of cooler water between Maui and Kahoolawe (Figure 2.5) (Wyrtki 1970); however, it was unclear if these periods were the result of eddies or more likely reflected cool water advecting through the channel between Hawaii and Maui. The nearest to shore that eddies have been measured is 40 km (Patzert 1970). Upwelling has been noted in the central portion of the cyclonic eddies, reflecting a doming character, and temperature differences of as much as 1° C have been recorded between the central dome of the eddy and the outer edges for cyclonic eddies (Figure 2.4) (Wyrtki 1970). The cool water reported from the center of the eddies may also reflect cooling by evaporation due to strong winds

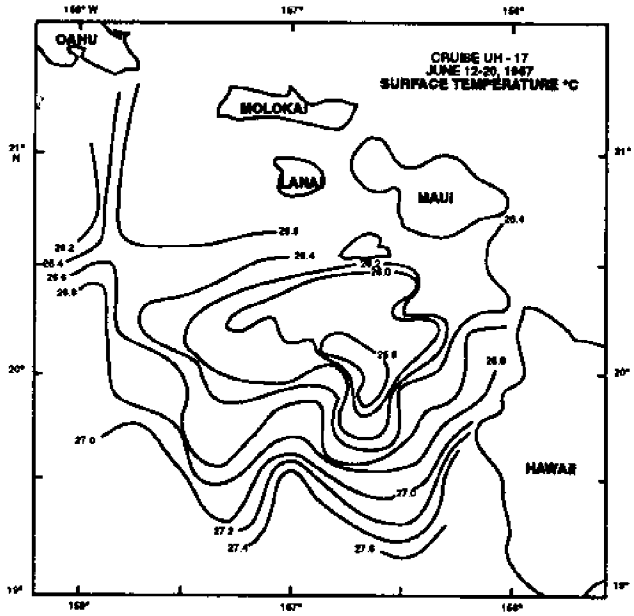

Figure 2.4 Sea Surface Temperature

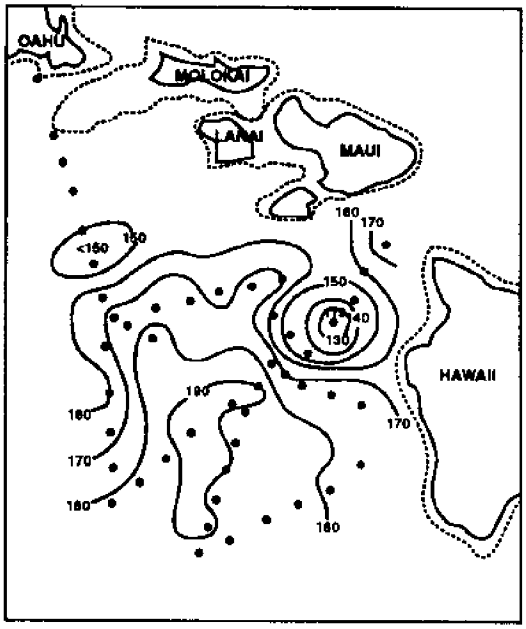

Figure 2.5 Depth of 20° Isotherm

(Wyrtki 1970). Anticyclonic rotation results in an accumulation of the lighter water around the rotational axis (Figure 2.5) (Patzert 1970). The magnitude of the thermal doming is approximately equal to the depression of the anticyclonic eddies in a shallow surface layer of 100 m depth. At greater depths, the anticyclonic depression is less pronounced and has a broader horizontal extent. It should be noted that to date, none of the research on eddies has included the area between the islands of the sanctuary. It is unclear if the eddies persist between the islands or if the wind and resulting current patterns are so modified by the island "shadow-barrier" effects as to eliminate the oceanic component of the eddy close to shore.

SUMMARY

While there may be many unique or unusual features found within the designated sanctuary boundaries, those pertinent to physical oceanography seem to focus on two very distinctive characteristics: bathymetry and eddy circulation. The bathymetry of the area, bound by Maui, Molokai, Lanai, and Kahoolawe, along with the extension of the shallow Penguin Bank southwest of Molokai, represents a unique, semi-enclosed, shallow protected sea in the midst of an expansive ocean. There is almost no information in the published literature as to the specific characteristics of this interisland area. In addition, consultation with leading physical oceanographers at the University of Hawaii, Drs. R. Dixon Stroup and Pierre Flament, have further confirmed the lack of recent oceanographic research in this area. It appears that many oceanographers examine the benthic conditions or ocean circulation around the islands, but relatively few research the conditions between the islands of the designated sanctuary in detail. The possible exception is Ed Noda and Associates Ocean Engineering firm and Seafloor Surveys, International, Inc. who in 1989 and 1990, recorded current measurements and bathymetry of the interisland area, under a contract with Hawaiian Electric Co. Unfortunately, the data are not available due to proprietary concerns.

There are a number of papers by Wyrtki, Patzert, and others previously cited that discuss ocean currents and the eddies that are so prominent around the islands. The published literature indicates that previous studies did not include areas within 40 km of the interisland area.

RECOMMENDATIONS

General physical oceanographic information on the nearshore environment seaward to the 100-fathom isobath is not available. Furthermore, the oceanographic data for waters on the periphery of the four-islands region outside the 100-fathom isobath is limited and somewhat dated. Although it may be true that bathymetric surveys are unlikely to change over a period of 20 years or so, it would be useful to have a more detailed bathymetric survey of the interisland area using the now available side scan sonar systems. This information, along with sub-bottom profiling, might offer insight into the topography that could influence small-scale current systems, sediment types and transport, and ecosystem characteristics and their relation to the distribution or migration patterns of whales within these shallow waters.

In summary, it is recommended that the area of the sanctuary be divided into a system of grids. Within this grid, a systematic survey of the key physical parameters, such as water chemistry, currents, temperature, and bathymetry, would be conducted, in order to integrate the physical and biological characteristics of the areas to identify common denominators. Finally, the concern with non-point source pollution and the discharge from municipal sewer systems (not to mention the runoff from urban and commercial areas) poses yet another potential problem to the semi-enclosed, nearshore waters of the sanctuary. Studies to identify and track terrigenous-based water pollutants into the nearshore areas should also be conducted.

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CHAPTER 3
NEARSHORE MARINE COMMUNITIES

DATA SOURCES

The overview of nearshore marine communities relies on data from a number of sources. The primary sources are peer-reviewed literature, including journal articles, and theses and dissertations from the University of Hawaii. The second source of information is "grey literature" that includes information in environmental impact statements. Because of the often inaccurate reporting by newspapers, this source has been completely avoided in the preparation of the status of nearshore marine communities in the proposed sanctuary.

GENERALIZATIONS ON THE ECOLOGY OF HAWAIIAN REEF SPECIES

The Hawaiian Islands are among the most isolated in the world. This isolation has played a major role in the development of the archipelago's shallow marine communities. The origin of most Hawaiian inshore marine species is from the Indo-West Pacific Faunal Region (Gosline and Brock 1960; Maragos 1977; Kay 1979; Bailey-Brock 1987), the center of which is in the region of the Malaysian Peninsula and the Philippine Islands. With distance and isolation from this source, many species common elsewhere on Central Pacific reefs are absent in Hawaii. This reduction or attenuation in species with distance from the source has resulted in a proliferation of species (i.e., endemics) in many of the taxa that have successfully colonized the islands (Zimmerman 1948). Some groups such as the reef fishes are represented by a large percentage (29%) of endemic species (Gosline 1955; Randall 1987). Briggs (1974) attributes the high degree of endemism among marine organisms in Hawaiian waters to a long, stable climatic history as well as to the considerable geographic isolation. Endemism in the Hawaiian marine fauna is almost entirely restricted to the species and subspecies level of the taxonomic hierarchy (Kay 1977). Endemic species comprise about 20% of the mollusks (Kay 1967), 20% of the shallow-water asteroids and ophiuroids (Ely 1942) and 40% of the Alpheid shrimps (Banner and Banner manuscript).

Because of the isolation and northerly geographic setting (resulting in relatively low water temperatures), the shallow Hawaiian marine fauna is considered to be depauperate. There are about 450 species of inshore fishes (Gosline and Brock 1960; Randall 1980) and 40 species of corals (Maragos 1977) in Hawaiian waters. Many of the shallow-water invertebrates have a greater diversity of species; the Mollusca are represented by about 1,000 species (Kay 1979), the Polychaeta by about 243 species (Bailey-Brock 1987) and the Bryozoa by about 200 species (Soule et al. 1987).

Comparison of the number of shallow-water species of corals, mollusks, echinoderms, and fishes recorded from Hawaii with those found in other island groups to the south of the Hawaiian Islands illustrates the attenuation. In Hawaii, there are 15 genera of corals and 53 genera in the Federated States of Micronesia (Maragos 1977), Kay (1967) records about 1,000 species of mollusks in Hawaii and 2,500 species in the Ryukyu Isands, 90 echinoderms are known from Hawaii and 345 from the Philippines (Clark and Rowe 1971), 450 species of fishes are known from Hawaiian inshore waters, and over 1,000 species from shallow-water habitats in the Federated States of Micronesia and vicinity (Myers 1989).

In general, benthic marine habitats are considered in three distinctive zones: littoral, sublittoral, and the deep sea. This discussion focuses on the first two zones only. The littoral zone is often subdivided into a littoral fringe where marine and terrestrial organisms co-exist but marine forms dominate, and the eulittoral zone where marine species adapted to or requiring alternating conditions of submersion and emersion are found (Lewis 1964). In the Hawaiian Islands, the tidal range is only about 1 m; thus, the eulittoral zone is not usually very extensive. Impinging waves may modify the extent of the eulittoral zone by effectively submerging shoreline areas that are usually above the high-water mark thereby obscuring otherwise clear zonation.

If the proposed sanctuary encompasses marine resources from the shoreline seaward, it will include about 388 km of coastline in Maui County (Maui, Molokai, Lanai, and Kahoolawe Islands). This coastline represents about 32% of the state's total coastline resource (DBEDT 1992). Hawaiian coastlines are quite varied ranging from sand beaches to the world's highest sea cliffs along the north side of Molokai (Sterns 1966; Macdonald et al. 1990). Numerous geological processes, including recent lava flows into the sea, subsidence, uplifting, and weathering with subsequent deposition of materials, have all contributed to the formation of our Hawaiian coastlines (Wentworth 1938, 1939). In addition, there are biological processes that fix calcium carbonate such as corals and coralline algae as well as the physical accretion of this material creating limestone benches which add to the diversity of our shorelines.

Water depth, substratum type, inputs such as fresh-water from land and exposure to waves, all affect the diversity of the biological communities that develop in any given location. In general, these factors all contribute to the zonation of species that is encountered at the interface and subtidal regions along our coasts. Kay (1977) provides an excellent general account of the zonation of shallow Hawaiian marine habitats, which is given in its near entirety below. For this discussion, Hawaiian nearshore habitats are divided into shoreline and subtidal ecosystems.

SHORELINE ECOSYSTEMS

The littoral fringe is that area of the shoreline fringed by the seaward edge of maritime vegetation, composed primarily of naupaka (*Scaevola*), hau (*Hibiscus*) and sea heliotrope (*Messerschmidia*) in Hawaii. The zone is above the reach of the waves and tides but is markedly affected by salt spray. Two regions are distinguishable: an upper region that is often localized in occurrence and characterized by broken limestone or basalt boulders, and a lower region of more or less continuous rocky substrate of cemented limestone or basalt (Emery and Cox 1956). In the upper region where boulders are covered by a canopy of maritime vegetation and the undersides are characterized by conditions of high humidity, at least six species of mollusks and one isopod are commonly found. Seaward of the boulder region the shoreline is dominated by two littorine species, one of which is from the Indo-West Pacific and the other is endemic to Hawaii. Both of these species require access to the ocean in order to complete their life cycles. Just seaward of this, but above the reach of the waves, a common nerite (pipipi, *Nerita picea*) and two grapsid crab species are found.

Where basalt outcrops extend seaward from the shore, extensive areas of water-leveled benches, vertical cliff faces, and boulder beaches are prominent features of the coastline on all the high islands. The shoreward portions of benches and beaches are part of the littoral fringe, but the seaward sections are alternately exposed and immersed by tides twice daily and scoured by waves seasonally. On basalt benches the highest level of wave action is marked by a line of the alga akiaki (*Ahnfeltia concinna*). Below the *Ahnfeltia* is a variety of frondose algae that covers the substratum with increasing density on approaching the sea. This section is, in turn, succeeded seaward by a broad band of pink coralline algae (*Porolithon*), and the interface between the shore and the sea is marked by a mix of other algal species. The dominant mollusks seaward of the akiaki are the opihi (*Cellana exarata*), and in the *Porolithon* zone the larger yellow-foot opihi, *Cellana sandwicensis* are found as well as the single urchin, *Colobocentrotus atratus*. The frontal slope of the substratum is riddled with borings from sea urchins (*Echinometra oblongata* and *E. mathaei*) as well as from a number of mollusks. Two species of blennies (including the paoo or *Istiblennius zebra*) are found in this habitat.

The pattern described represents the broadest expression of eulittoral zonation found in Hawaii, and it is variously modified on vertical cliff faces, and in sheltered coves and bays. On vertical cliff faces, the *Ahnfeltia* zone and the succeeding frondose algal zone are absent, with the littorines and nerites of the littoral fringe merging directly into the *Porolithon*-encrusted zone. In sheltered coves and bays, especially where there are intrusions of brackish ground water, the native Hawaiian oyster (*Ostrea sandvicensis*) will encrust vertical surfaces between the littoral fringe and the subtidal. Where sufficient coverage of water occurs, there is an assemblage of fishes that forage over this substrate including herbivores such as the amaama or mullet (*Mugil cephalus*), the kupipi (*Abudefduf sordidus*), carnivores such as the papio (various species of the family Carangidae), aholehole (*Kuhlia sandvicensis*) and a number of wrasses or hinaleas (Labridae).

Calcareous or carbonate shorelines are dominant features of the coastlines of all the major islands except Hawaii. Solution benches are one form of the calcareous or carbonate shoreline. Topographically, solution benches resemble atoll reef flats, consisting of sea level platforms extending from 1 m to 30 m seaward from the shore. The benches are separated from shore by a raised, sharply pitted limestone zone and a nip (an indentation at the base of the vertical section). Seaward of the nip, the flat-topped surface is densely matted with an algal turf. At the sloping outer edge, calcareous algae and to a lesser extent, corals, contribute to the structure of the bench. Because of its height above sea level, the surface of the bench may be exposed at low spring tides for periods of as long as four hours.

The biota of calcareous shorelines is distinguished from that of basalt shorelines by its cover of thick algal turf. In and among the turf are numerous small invertebrates including polychaete worms, mollusks (cones, cowries, miters) and sea urchins. Both the flora and fauna are conspicuously zoned. The pools of the pitted zone, which are in effect the littoral fringe, are inhabited by small littorines and fishes including the paoo (*Istiblennius zebra*) as well as juveniles of several fish species (mamo - *Abudefduf abdominalis*, kupipi - *A. sordidus*, aholehole - *Kuhlia sandvicensis)*. In deeper depressions on the bench that permanently hold water, a much greater diversity of invertebrates and fishes will be found.

Tide pools occur on sea level basalt outcrops, some are formed by depressions in the water-leveled benches, and others are formed by massive boulders fronting the sea and on the benches of calcareous shorelines. Physical conditions in marine pools vary with exposure to the sea. Tide pools that are farthest from the sea undergo striking variations in temperature and salinity, whereas those at the seaward edge exhibit essentially marine conditions. The most exposed pools are characterized by sand substrates bound by cyano-bacterial mats. Few marine species are found here because of the extreme conditions; among those present are several species of mollusks, crabs, and fishes. Seaward pools are progressively more densely turfed with a variety of algae, and the diversity of mollusks, polychaetes, crustaceans, echinoderms, and fishes increases. Many of these seaward pools serve as a nursery habitat for a number of marine fishes including the aholehole (*Kuhlia sandvicensis*), the mamo (*Abudefduf abdominalis*), kupipi (*A. sordidus*), manini *Acanthurus triostegus*), and kumu (*Parupeneus porphyreus*).

Sandy beaches form another distinctive shoreline in the high islands. In general, sandy shorelines are characterized as low, sloping beaches backed by a wall or raised coral platform. Sand is composed of calcareous remnants from foraminifera, mollusk shells, echinoderm, and coralline algal fragments except on Hawaii, where beaches are composed of black sand and olivine (Moberly *et al*. 1965).

Hawaiian beaches may be subdivided into three zones:(1) an upper beach including the vegetation line; (2) a mid-beach between the high-tide line and the vegetation line, its extent dependent on slope and tide; and (3) the lower beach that is continuously awash by waves. The biota of sandy beaches is associated with both sand grain size and beach slope. The biota of the upper beach is characterized by amphipods, isopods, and ghost crabs which burrow in the area (Fellows 1966). Ghost crabs are also found in the mid beach slope area and the lower beach slope is characterized by the mole crab (*Hippa pacifica*), spionid polychaetes and four species of the gastropods (*Terebra* spp.; Miller 1970).

Fronting many of these different shoreline types are fringing reefs. In general, Hawaiian reefs are not as well developed or diverse as reefs of other Pacific islands, again due to the relative isolation of the archipelago and its geographic position at the northern extreme of coral reef development; thus, water temperature serves to retard coral growth and development. More than one-half of the shoreline of the older islands of the chain (i.e., Kauai, Oahu, Molokai, Lanai, and Maui) is fringed by coral reef. The reefs are wide, shallow platforms extending as much as 300 m seaward from the shore. The reef platforms are typically subtidal, usually between depths of 1 m to 3 m below mean sea level, although occasional sections may be exposed at low spring tides. The reef flats are predominately sand, coral rubble, and coralline algae. Crustose coralline algae are the dominant reef builders on Hawaiian reefs with coelenterate corals being relatively unimportant in the overall fringing reef habitat (Littler 1973). Coral growth is probably best developed along the frontal edges of the reef flats or in adjacent (seaward) deep water areas.

Reef flat assemblages are perhaps the most diverse of those occurring along Hawaiian shorelines partly because of the extended period of time they are submerged. Reef flats have a variety of habitats including solid substrates of calcareous algae and corals, stands of frondose algae, rubble, and sand patches. Because of the variety of habitats, the distribution of reef organisms is patchy; where there are sand patches, infaunal organisms such as mollusks, echinoderms, and polychaetes occur; where there is rubble or living coral, a multitude of other species including fishes are found.

Often estuaries are found where freshwater streams enter the ocean. Estuaries are defined as river valleys inundated by marine waters and receiving freshwater input on the landward side; estuaries may also occur as the tidal portions of streams. In the proposed sanctuary, Cox and Gordon (1970) note the following areas with estuarine characteristics: Molokai: Halawa Stream and Bay, Pelekunu Bay and the fishponds of South Molokai; Maui: Maliko Bay, Kahului Harbor, Kahakuloa Bay, Honokohau Bay, Honolua Bay, and the estuarine bays of the northeast coast of east Maui including Honomanu, Makaiwa, Waipio, Hoolawa, Pilale, and Kuiaha.

Estuarine ecosystems support an endemic fauna of about 38 species. Most of these species are euryhaline and most are derived from marine rather than fresh water ancestors (Timbol 1972). Typical estuarine endemic fishes include the oopu (*Awaous genivittatus*), oopu nakea (*A. stamineus*), aholehole (*Kuhlia sandvicensis*), and the mollusk, the hihiwai (*Neritina granosa*). Estuaries are also the primary habitats of a few highly sought-after food species such as the introduced Samoan crab (*Scylla serrata*), and they are the nursery for a number of inshore marine fishes such as the amaama (*Mugil cephalus*), awa (*Chanos chanos*), kaku (*Sphyraena barracuda*), aholehole (*Kuhlia sandvicensis*), and papio (several species of the family Carangidae). Many estuaries in Hawaii are now affected by the invasion of exotic species such as the Tahitian prawn (*Macrobrachium lar*) which tend to replace the native biota.

Although estuaries do not comprise a large, well defined ecosystem type in the boundaries of the proposed sanctuary, they remain an important habitat type. Despite low rainfall along much of the coastline of the proposed sanctuary (e.g., west Maui), many small, intermittent streams may serve as important nursery habitat albeit, the availability of this habitat is transitory. Related to the usual estuarine habitat are mangroves. Mangroves were introduced on Molokai in 1902 and on Oahu in 1922. On both islands there are several developed stands that now exhibit many of the characteristics attributed to mangrove swamps in other tropical areas, but the Hawaiian stands lack the extensive flora and fauna of typical large mangrove stands because of their recent development (Walsh 1963). Recent attempts have been made to control and otherwise remove mangroves from wetland areas (e.g., Kaloko-Honokohau National Historical Park on the Kona coast, the Nuupia Ponds Wildlife Management Area on Mokapu Peninsula, Oahu) where they are eliminating open water habitat that serves as critical foraging grounds for threatened and endangered waterbird species such as the kukuluaeo or Hawaiian Stilt (*Himantopus mexicanus knudseni*).

SUBTIDAL ECOSYSTEMS

In addition to coral communities associated with fringing reefs, corals extend subtidally to depths of at least 50 m in Hawaiian waters, although the greatest development of these reefs is at depths from a few meters down to about 30 m. Prime examples of coral community development may be seen on submarine surfaces of recent lava flows off the coast of Maui and in the waters between Maui and Molokai. Coral communities are well developed around the islet of Molokini where commercial dive tours thrive. As discussed, coral communities are better developed where they are protected from high wave activity; thus, the leeward (western) coasts often have well-developed examples; however, coral communities are a characteristic of all subtidal areas with appropriate hard substratum around all of the islands.

Hawaiian coral communities show a zonation that is related primarily to wave exposure and indirectly to depth. The three assemblages are described below.

A *Pocillopora meandrina* assemblage is associated with coastlines where there is considerable wave action and a basalt boulder or limestone/lava pavement in depths from about 1 m to about 12 m; occasionally the *P. meandrina* assemblage will be found down to depths of about 30 m. *Pocillopora meandrina* is one of the first coral species to colonize new substrates whether they are lava (Grigg and Maragos 1974) or from anthropogenic sources (concrete, etc., Brock unpublished). This coral species is dominant in the shallow waters at Molokini Islet and at many sites around Lanai, Kahoolawe, and Maui islands. The *P. meandrina* assemblage is often interspersed with other species of corals such as *Porites lobata* and *Monitopora verrucosa*, soft zoanthid corals such as *Palythoa tuberculosa* and *Zoanthus* spp., and the sea urchins *Echinometra*, wana or *Echinothrix* and *Tripneustes*.

More than 50 species of fishes are routinely encountered in the *Pocillopora meandrina* zone (Hobson 1974, Gosline 1965). Included in this group are moray eels or puhis (Muraenidae); squirrelfishes or alaihis and mempachis (Holocentridae); aholehole (*Kuhlia sandvicensis*); aweoweo (*Priacanthus cruentatus*); upapalus (Apogonidae); nenue (*Kyphosus bigibius*); commercially important goatfishes including moano (*Parupeneus multifasciatus*), weke (*Mulloides flavolineatus*), kumu (*Parupeneus porphyreus*), and occasionally the munu (*P. bifasciatus*) fishes (Pomacentridae); wrasses or hinaleas (Labridae); palukaluka (*Scarus rubroviolaceus*); surgeonfishes including the api (*Acanthurus guttatus*), manini (*A. triostegus*), maikoiko (*A. leucoparieus*), pakuikui (*A. achilles*), maiii (*A. nigrofuscus*), maiko (A. nigroris), black kole (*Ctenochaetus hawaiiensis*), kole (*C. strigosus*), maneoneo (*Zebrasoma velifrum*), umaumalei (*Naso lituratus*) and kala (*N. unicornis*); gobies and blennies (Gobiidae and Blenniidae), and a number of smaller species. Other species often encountered in the *Pocillopora meandrina* zone include the omilu (*Caranx melampygus*), papios (family Carangidae), lai (*Scombroides lysan*), amaama (*Mugil cephalus*), nehu (*Stolephorus purpureus*) as well as needlefishes and halfbeaks (Belonidae and Hemiramphidae).

Just seaward and slightly deeper of the *Pocillopora meandrina* assemblage is the zone dominated by *Porites lobata*. Where wave activity is not significant, *Porites lobata* usually grows as a rough hemisphere attaining sizes in excess of 4 m in diameter. This species lays down annual growth bands much like a tree thus the age of individual colonies may be determined (Knutsen et al. 1972). *Porites lobata* has a radial growth of about 1 cm/yr and will attain an age of close to 200 years (Grigg 1982). In bays where wave activity may be light, the zonation of *Pocillopora meandrina* and *Porites lobata* may be less obvious; in these situations, *P. lobata* may be much more abundant than *P. meandrina*. *Porites lobata* is successful in populating almost any consolidated area from shallow depths down to 30 m but will modify its growth form in response to physical conditions of the environment (Maragos 1972). Where there is surge, the coral is usually flat and strongly encrusting; in deep or more protected waters, the coral occurs as a large lobate hemisphere. A number of other coral species are found in the *P. lobata* assemblage including *P. meandrina*, *Montipora verrucosa*, *M. patula*, *M. verrilli*, *M. flabellata*, *Porites compressa*, and a host of lesser species (*Fungia scutaria*, *Leptastrea* spp. *Cyphastrea* spp.).

The diversity of fishes encountered in the zone of *Porites lobata* is greater than that seen in the *Pocillopora meandrina* zone. The difference in diversity may be related to the greater depth and diversity of habitats available in this zone. Gosline (1965) reports 90 species from this biotope; Hobson (1974) notes that most species seen in his study of coral reef fish communities of the Kona, Hawaii coast were present in this coral rich habitat. Brock (1990a; 1992a,b,c; 1993a,b,c) has recorded more than 60 species of fish from the biotope in which *Porites lobata* dominates on Oahu, Maui, and Hawaii Islands.

In general, seaward of the *Porites lobata* zone or biotope is the biotope of *Porites compressa* whose dominated assemblages are usually found at depths below 8 m to 10 m down to about 30 m. *Porites* *compressa* colonies form fragile thickets that may cover hundreds of square meters of substratum. Because of its delicate structure, *P. compressa* is usually found in deep water or is situated in locations that are relatively protected from the impact of storm waves. Protected locations include bays as well as the leeward (west) coasts of the larger islands (here West Maui). Again, many of the shallow-water invertebrates and fishes recorded from the Hawaiian Islands are found in this zone. These species are listed in the many taxonomic works that have been prepared for our Hawaiian fauna and flora. Most of the commercially important inshore fishes and invertebrates are encountered in the biotope of *Porites compressa* and much of the fishing effort today is focused in the biotopes of *P. lobata* and *P. compressa.*

DISTURBANCE TO HAWAIIAN SHALLOW WATER ECOSYSTEMS

Disturbance on coral reefs comes from many sources including those that are natural (such as storm waves or storm water runoff) and those caused by human activities. Coral reefs are subjected to varying degrees of disturbance which affects the observed structure of the communities. (Structure refers to the composition and abundance of species in the local area). Some of the greatest impacts on coral reefs occur to the hermatypic corals which are sessile as adults and are among the most visible components present. Usually where the frequency of disturbance is low, coverage of the hard substratum by corals is high but the diversity of species will be low; at the opposite end of the spectrum, where the frequency of disturbance is high, a low coverage but higher diversity in the coral assemblage will result. The greatest diversity of corals will be found in areas where disturbance is intermediate (Grigg and Maragos 1974; Connell 1978; Grigg and Dollar 1990); thus, intermediate levels of disturbance result in high diversity coral assemblages. This disturbance may come from a variety of natural and anthropogenic sources.

With respect to impacts on reefs, interest is frequently focused on corals. In their sessile adult phase, corals must be able to withstand the perturbation or die; thus the corals found in any given locality represent the environmental history (i.e., impact(s) that have occurred) of the area. Corals through their growth often provide much of the habitat heterogeneity present in reef systems. It has been experimentally demonstrated that the diversity of species is greater in topographically complex environments (Brock 1979). Greater habitat complexity results in the presence of more shelter space for fishes. Numerous studies have shown that appropriate space and cover are important to the local abundance of fishes on coral reefs (see review by Sale 1977). The standing crop of coral reef fishes is often related to the degree of substratum relief or complexity. Thus, areas of sand flats typically have lower standing crops of fishes (mean about $4 g/m^2$) than do areas of complex coral cover and shelter where estimates range up to $190 g/m^2$ (Brock 1954; Risk 1972; Brock and Norris 1989). Thus, disturbance or perturbation that impacts corals will indirectly impact all of the other reef resources that are in some way dependent on those corals.

Natural Disturbance

Natural perturbation on coral reefs can range from trivial event causing minor impacts to major storm events that may impact large areas. These impacts from natural sources may include intense storm events (Stoddart 1963, Maragos *et al.* 1973), volcanic eruptions (Umbgrove 1930), large-scale El-Nino events (Glynn 1985), episodes of massive sedimentation (Hopley 1982), population explosions of the coral-feeding crown-of-thorns starfish (*Acanthaster planci* Chesher 1969; Endean 1976), all of which may cause large-scale mortality in coral communities. Often, the impact to corals may be partial or intermediate to varying degrees as is often the case with disease (Antonius 1985), predation (Robertson 1970), low tides (Loya 1976), low temperature (Shinn 1972), volcanic activity (Pearson 1981), and red tides and earthquakes (Stoddart 1969).

The magnitude of impact to coral communities is related to the intensity of the impact as well as to the frequency with which it occurs and whether this frequency exceeds the time period necessary for recovery in the coral community to occur. On temporal scales of 5 to 50 years, the most important natural source of disturbance in Hawaii is from storm-generated surf. In Hawaiian waters, surf has a well-known annual cycle: the north shore winter swell and the summer south swell both of which impinge on coral communities.

Imposed on this normal circumstance is the infrequent high surf that is generated by occasional storm events such as hurricanes.

Because the Hawaiian Islands are situated in the tropics near the northern boundary of coral distribution, the cooler water translates into usually slow growth for Hawaiian corals. Age studies (Knutsen *et al.* 1972, Grigg 1982) show that most Hawaiian corals do not have a high growth rate; thus, the impact of a high-wave event may be evident in a coral community for many years following that event (Dollar 1982). The slow growth characteristics mean that storm events do not have to occur and impact a coral assemblage with much frequency to maintain the community in an early successional stage. Recovery of coral communities on the western Hawaii coast has been estimated to require from 20 to 50 years (Grigg and Maragos 1974).

Many studies have documented the catastrophic impact that hurricane-generated waves have on coral reefs (Stoddart 1963, 1965, 1969; Maragos et al. 1973; Dollar 1982). The impact from hurricanes on coral communities may be quite "patchy" leading to a mosaic of destruction (Brock unpublished). Hurricane Iniki struck the Hawaiian Islands in September 1992 and caused severe damage to coral communities along the southeast to western shores of the main island. In the Lahaina area, impact to coral communities was patchy (Brock, personal observations) as it was along the south shore of Lanai (Brock 1993d).

Wave disturbance has probably been one of the major factors in shaping coral communities in the Hawaiian Islands including the area of the proposed sanctuary. Coral assemblages in wave-sheltered habitats will have high coverage but relatively low diversity and those assemblages exposed to occasional wave impact will be "held" at an early successional stage and will frequently show greater diversity. Coral communities in early successional (subclimax) stages can be expected to recover to these early stages relatively quickly following their disturbance.

Impacts that have occurred to coral reefs on greater geological time scales include changes in sea level. Reef assemblages appear to have survived successfully by recovery at new depths faster than die-off has occurred. Similarly, natural sedimentation and runoff have impacted coral reefs since their inception. Local impacts occur from these natural sources and will continue to occur in the future. The arid nature of much of the coastal lands on west Maui, Molokai, Lanai, and Kahoolawe means that vegetative cover is often sparse. During heavy rainfall events, runoff occurs carrying terrigenous material to the sea. This evidence is very apparent along the south Molokai shoreline where a large fraction of the beach materials is obviously of terrigenous origin. Indeed, Brock (1992d) found that about one-third of the sand from samples collected along the south coast of Lanai is composed of basalt which is either derived from runoff or *in situ* breakdown of basalt. Most of this arid coastline is not developed; thus, the terrigenous component is from natural sources.

Anthropogenic Disturbance

There are numerous human-induced disturbances that occur on coral reefs. Some of these anthropogenic stresses are more widespread than are others. Important forms of human disturbance include (1) sedimentation from erosional runoff due to land use practices (e.g., stream channelization, dredging, etc.), (2) pollution due to point and non-point sources that cause eutrophication or mortality by chemical poisoning, (3) the discharge of heated effluents due to electrical generation, (4) the impact of overfishing, and (5) the introduction of exotic fishes. There are other sources of anthropogenic stress on coral reefs that may cause more serious impacts than these problems, but the damage is usually more localized. Examples include dynamite fishing and coral mining which do not occur in Hawaiian waters.

Sedimentation

The impact of increased sedimentation is probably the most common and serious anthropogenic influence on coral reefs (Grigg and Dollar 1990). Sediments may be generated *in situ* by blasting and dredging for channel and harbor construction (Sheppard 1980), or they may come from land. Dredging not only increases the local sediment load but destroys benthic communities in the path of the dredge. Banner (1974) reported that 29% of the reefs in Kaneohe Bay, Oahu were removed by dredging in 1939. Sediment loading can also result from terrestrial activities that increase erosional runoff. In Hawaii, agriculture and urbanization may contribute to this loading. Impacts to Hawaiian reefs by sedimentation have been documented by Banner (1974) and in the Caribbean by Dodge *et al.* (1974) and Rogers (1985).

The effects of sediments on corals has been reviewed by Johannes (1975), Dodge and Vaisnys (1977), Bak (1978), and Brown and Howard (1985). Complete burial of corals will result in mortality but quantitative field data demonstrating negative impacts with lesser sediment loading are rare (Dodge and Vaisnys 1977). The input of sediments and their subsequent re-suspension are natural events on coral reefs, thus most corals tolerate some level of sedimentation. Many coral species remove sediment from their surfaces by tissue distension or ciliary action (Yonge 1931). Most quantitative studies have found that impacts due to sedimentation are transitory (Sheppard 1980; Marsalak 1981a; Rogers 1983) or are almost nonexistent (Dollar and Grigg 1981; U.S. Army Corps of Engineers 1983).

A major agricultural crop in many lowland areas is sugarcane. Part of the cycle in sugar production requires the burning and removal of the cane, leaving the fields temporarily barren. Heavy rainfall under these conditions may result in runoff carrying sediment to the sea. Today, agricultural practices attempt to minimize the loss of soil. However, sugarcane has been grown in some of these areas for more than a century (e.g., west Maui), and during periods of intense rainfall when these fields were uncovered, soil probably washed into the sea. Despite this, the shallow water communities that are present are those that survived and acclimated to any and all historical impacts; thus, these communities reflect the history of perturbations that have occurred.

The coral reefs surrounding the island of Kahoolawe have received a considerable amount of terrigenous material for many years. Goats were introduced to the island more than 150 years ago and the unsuccessful attempts to ranch on the island contributed further to grazing pressure. Grazing reduced the cover of the xerophytic vegetation, exposing the soil to erosion due to rain and wind (Environmental Impact Study Corp. 1979). The goats have now been removed from the island and without this source of perturbation, vegetative cover should increase. The reefs surrounding the island have been subjected to terrigenous inputs for more than 100 years. These reefs have been recently surveyed by members of the Hawaii Institute of Marine Biology and the National Marine Fisheries Service. Despite the high sedimentation over the years, many reefs around Kahoolawe appear to be in a healthy state (Dr. Paul. Jokiel, Hawaii Institute of Marine Biology pers. comm. 1993).

Sewage

Sewage introduced into coral reef habitats may result in stress through oxygen depletion, emission of toxic contaminants and sedimentation by high particulate loading. The effect of sewage pollution on coral reefs has been reviewed by Pastorek and Bilyard (1985). Sewage may contain significant amounts of toxic material or daughter products from pesticides, heavy metals, or chlorine. High biochemical oxygen demand from the sewage coupled with the generation of hydrogen sulfide could impose toxic effects. In general, Hawaii has little industrial waste which could serve as a source of toxic materials that are discharged into the domestic waste system.

To date, most of the studies relating to the impact of sewage on coral reefs show that sewage serves as a nutritional source that stimulates and favors certain components of the benthic community over other species. In general, the detrimental effects of nutrient subsidies on coral reefs are caused by shifts in the competitive advantage of species for space on the bottom (Marsalak 1981b, Smith et al. 1982); thus, algae and suspension/particulate feeding organisms are favored on Hawaiian reefs receiving sewage effluent (Dollar 1979; Smith et al. 1982).

It should be noted that sewage discharged in Hawaii is primarily domestic and has little in the way of toxic contaminants. Also, placement of the discharge terminus in areas where circulation is high translates into rapid advection, mixing, and dilution of the materials.

Sewage is discharged into coastal injection wells rather than discharged at sea in Maui County. Outlying areas are served by cesspools or septic tanks; thus, the concern related to sewage may be through the input of materials via non-point sources. Again, because these materials have little in the way of toxic components (pesticides, heavy metals, or other contaminants), they probably serve as a nutritional subsidy as has been found around shallow Hawaiian point source outfalls above. However, recent events regarding algal "blooms" off of west Maui have been attributed to leakage from west Maui sewage injection wells.

Thermal

Many tropical marine organisms reside in waters that have temperatures close to their upper lethal limit (Edmondson 1928); thus, if additional thermal inputs are made, the potential for impact exists. Field studies of anthropogenic thermal enrichment are limited to the effects of heated effluent used to cool generators in power plants. Where effluent temperatures rise sufficiently and circulation is low, mortality in benthic communities occurs. Studies at Kahe Point, Oahu found mortality in corals where temperatures were elevated 4° to 5° C above ambient and the discharge terminus was on the shoreline (Jokiel and Coles 1974). When the discharge terminus was moved to a point well offshore into water about 4 m deep, the deleterious effect disappeared because of rapid mixing and advection (Coles 1984).

Presently, the cooling water used for the Kahului Generating Facility is drawn from coastal wells utilized as a coolant and discharged at the shoreline of Kahului Bay fronting the plant. Permit agencies require annual monitoring of the benthic communities in the zone of mixing (ZOM) for change. These studies, which have occurred primarily over the last three or four years, have found little negative impact from the discharge (Hawaiian Electric Co. and B.P. Bishop Museum 1975; Brock 1992e; 1993e). A known impact of this discharge is the attractiveness the warm surface water layer in the vicinity of the discharge terminus has to the threatened green turtle (*Chelonia mydas*). Apparently, green sea turtles are attracted to the discharge at night where they forage (Balazs et al. 1987).

Introduced Species

The introduction of exotic species may be considered one of the greatest threats to the native biota of insular areas. As noted above, Hawaii has a unique biota that has undergone tremendous speciation due to the relative isolation of the archipelago. The Hawaiian Islands have received more introductions than any other area of Oceania (Maciolek 1984). The introduction of species that are competitively superior to native species may result in the displacement of native forms. Many of the exotic species prey on native species (Maciolek 1984) and may serve to completely eliminate endemics in aquatic systems (Bailey-Brock and Brock 1993).

The impact of exotic species introduction is often not readily apparent. Perhaps one of the most interesting is the known introduction of at least one species of marine macroalgae that is presently causing an algal bloom off west Maui (Lahaina-Kaanapali area). Brock (1992f) provided a discussion of the situation which is summarized below.

Since 1989, at least two major "bloom" events of macroalgae have occurred in the waters offshore of Lahaina. The first of these was in late summer-early fall 1989, and the second occurred during the same period in 1991. A number of algal species have been involved, but the two most important have been *Hypnea musiciformis* and *Cladophora sericea*. The bloom of *Cladophora* has occurred in more offshore waters, apparently commencing as an epiphyte on *Halimeda opuntia*, which is found on the broad sand/rubble flats offshore of Lahaina/Kaanapali area from about 15 m to more than 30 m in depth. The *Cladophora* attains some size and then breaks off and is rafted by currents both parallel to shore as well as into the beach. *Hypnea* on the other hand, is usually found attached to hard substratum close to the shoreline in areas adjacent to intermittent stream mouths; it too, may be broken free by waves and carried onto the shore.

The genus *Cladophora* has been responsible for algal blooms elsewhere. In the near land-locked Herrington Sound Bermuda, *Cladophora prolifera* has become the dominant space occupier over the last 25 years (Lapointe and O'Connell 1989) and in another near land-locked body of water, Peel Inlet in Western Australia, *Cladophora albida* has taken over much of the benthos there (Sewell 1982). In both of these instances, the data suggest that input of nutrients (i.e., nitrogen and phosphorus) triggered the development of *Cladophora* assemblages which have persisted. It should be noted that both bodies of water are almost completely land-locked, a situation very different from the open coastline fronting Lahaina and Kaanapali.

More than $1 million in federal and state funds have been appropriated to address the algal bloom problem in west Maui. The most widely accepted hypothesis to these "blooms" is that of increased nutrient loading from runoff or from the Lahaina Wastewater Treatment Plant injection well system. Studies in which dye was placed into the injection wells at the Lahaina Wastewater Treatment Plant and traced in the ocean have been unsuccessful, suggesting that the injection wells are not a major source of nutrient input. The episodic nature of the appearance of *Cladophora* in the waters offshore of Lahaina/Kaanapali suggests that the mechanism(s) that trigger it are likewise episodic. One working hypothesis is that occasional input of high-nutrient water from land, via drains and intermittent streams following periods of high rainfall, may be the source of "fuel" that fosters the growth of this alga. However, if this were the source of nutrients, the thick algal growth that is present in the shallow water fronting existing drains (i.e., Mahinahina, Honokowai) would likewise take advantage of these nutrients and probably rapidly strip them from the water column. The offshore surface and bottom nutrient concentrations that have been measured as part of environmental impact studies both during dry (Brock 1989, 1992f) as well as following heavy rain (Brock 1990b), suggest that the nutrients are stripped out before getting very far offshore under high rainfall conditions. During dry conditions, nutrient concentrations in nearshore waters are low. The confinement of primary growth *Cladophora* to more offshore areas suggests that the stimulus for growth is not land-derived (e.g., pollution emanating from the shoreline); if it were, we would expect the greatest growth (and abundance) to occur adjacent to land. If the nutrient source is from sewage via the injection well system, *Cladophora* should occur in continuous high abundance because the generation of sewage is a continuous event and any "leak" of material to the marine environment would likewise be continuous.

Besides the hypothesis that land-derived nutrients are responsible for the explosive growth of these algal species, there are other ideas. Among these are a decline in the abundance of grazing species that feed on these algal species, which has resulted in these algae becoming very abundant or, these algal species may be new to the Hawaiian Islands and, like many introductions, go through an explosive growth phase before coming into "equilibrium" with the habitat.

There is little evidence to support the decline in grazing pressure hypothesis. Both qualitative observations as well as quantitative transects conducted before bloom conditions for environmental impact studies (Niemeyer et al. 1976; Brock 1986; Brock 1987; Brock 1988a; 1988b; Brock and Norris 1987) suggest that the abundance of grazers has changed little along the Lahaina/Kaanapali coastline over the last 10-15 years (Brock 1989, 1992f).

Perhaps the most viable of the alternative hypotheses is that these algal species represent the recent introduction of "weedy" or ecologically aggressive species that have not come into equilibrium in this new environment. These species may be competitively superior space occupiers relative to many of the indigenous and native species when the ecological conditions are favorable. It is known that *Hypnea musiciformis* is a recent introduction that first appeared during the 1970s (Balazs et al. 1987). Previous to the 1989 bloom, *Cladophora sericea* was unknown in the Hawaiian flora. It is interesting to note that since the 1991 bloom, *Cladophora* has not made a significant reappearance in the west Maui area.

Overfishing

There are few data in Hawaii that show the relationship between fishing pressure and changes on coral reefs. Commercial catch statistics are available, but they do not include information on effort, and the recreational catch is not monitored. It is assumed that the recreational catch of inshore resources is large and overshadows the commercial activity. Both the anecdotal and catch information suggest that commercially important inshore species have declined significantly in the last 50 years (Shomura 1987). Reasons suggested for these declines include changes brought about by pollution, natural storm events, habitat alteration and overfishing (Anon 1987). The relative impact of these perturbations is dependent on location; in some localities declines may have resulted primarily from one impact, whereas in others, impacts may have worked synergistically.

Little quantitative information exists on the effects of fishing on coral reef fish communities (Saila and Roedel 1979) and even less is available on the recovery of such systems following the removal of fishing over ecologically relevant time and spatial scales. In the Hawaiian Islands, less than a dozen marine life conservation districts (MLCD's or marine parks) have been established to preserve the resources in those areas. The impact of these conservation efforts on the marine resources remains largely unknown. In the Philippines, one small coral reef preserve was maintained for a 10-year period at Sumilon Island. Studies showed that under protective management, fish community structure was significantly different in the preserve relative to control sites. Significantly higher yields were made by fishermen working reefs adjacent to the preserve probably due to emigration of fish out of the reserve (Russ and Alcala 1988).

Many of the commercially desirable inshore species are important predators in the reef fish community. The northwestern Hawaiian Islands reef fish communities have been protected from fishing under federal jurisdiction (the Northwest Hawaiian Islands Wildlife Refuge) since 1909. If these communities are equivalent to fish communities in the main Hawaiian Islands without fishing pressure, a simple comparison of community structure points out a number of striking differences. One of the most obvious differences is the abundance of large jacks or ulua (e.g., Carangidae) in the NWHI and the near absence of these large and important predators around the high islands (Hobson 1984). If fishing has reduced the abundance of predators such as ulua, what has been the response of prey populations? It remains unknown what the impact of such predator reductions are on the structure of the remaining fish community.

SITE SPECIFIC STUDIES

More than 600 documents were examined in an effort to bring together the majority of the site specific studies that address the ecology and distribution of inshore marine species around Molokai, Lanai, Kahoolawe, and Maui Islands. From this effort it was found that about 50 studies mention marine resources or their ecology. These studies are listed as an annotated bibliography in Appendix 1. It should be noted that the fieldwork for a comprehensive marine survey by personnel from the Hawaii Institute of Marine Biology and the National Marine Fisheries Service has just been completed for the nearshore resources of Kahoolawe Island. This report is not in preparation (Dr. Paul Jokiel, Hawaii Institute of Marine Biology pers. comm. 1993).

In reviewing the literature presented in Appendix 1 and above, several points emerge:

1. In general, earlier studies do not provide much in the way of quantitative information. Qualitative studies have been so noted.
2. All of the studies noted in Appendix 1 are site specific meaning that they provide information on the abundance and species composition of the marine communities of a given area at that point in time. It is difficult to use this information in any rigorous form; it should be used to provide a general "picture" of the marine communities at that specific location and time.
3. Most of the studies have occurred on Maui and most of those are at sites along the west Maui coastline. This is probably related to the greater amount of development that has occurred on Maui than on the other islands considered here.

4. In general, many of the studies have occurred along the dry leeward coasts of the islands in question. In these settings, the hinterland is often not developed and poorly vegetated (e.g., Lanai and Kahoolawe); thus, when a high rainfall event occurs, considerable terrigenous input to the nearshore marine communities may occur. Where the coastal area has been modified, it is often in agriculture (much of west Maui). Vegetative cover is often greater under agriculture, but these lands are periodically exposed during harvest. Again, this presents a situation that when coupled with heavy rainfall, runoff may carry considerable amounts of terrigenous material to the sea. Many of the studies in Appendix 1 note the large amount of terrigenous material that is either present in the marine environment (mixed in the sand) or comes in following rainfall. Despite this impact, many of the marine communities such as those around much of Kahoolawe and along the south shore of Lanai are considered to be in excellent condition.

5. Although quantitative data is lacking, an examination of older studies and more recent studies suggests that one of the changes in biota is the slow decline in the abundance of commercially and recreationally valuable fishery resources. The causal mechanism(s) for these changes are unknown but may be related to greater fishing effort through time.

RECOMMENDATIONS

The purpose of the sanctuary is to enhance the protection of the endangered humpback whale (*Megaptera novaeangliae*). While in Hawaiian waters, humpbacks do not feed so that their use of nearshore resources lies primarily with the occupation of space for some of the time they are present. Reproductive activities are focused in these shallower areas (i.e., within 100-fathom isobath, Nitta and Naughton 1989). Thus, there is no direct link between the whales and the living marine resources of the coral reefs of the proposed sanctuary but a strong connection probably exists between the quality of these shallower habitats and their use by whales.

The rationale and focus of the recommendations below are based solely on the above literature review of the living marine resources found in waters less than 100 m in depth within the boundaries of the proposed sanctuary. These recommendations are:

1. If the inshore waters are to be considered in the sanctuary, then a strong justification for their inclusion must be made.
2. Any justification for the sanctuary including inshore waters that relies on the inshore resources will need considerable further study, because our knowledge of the status of these resources is inadequate.
3. This study shows that there is a dearth of information with respect to (a) the status of the nearshore marine resources in the proposed sanctuary, (b) the mechanism(s) responsible for changes to these resources are poorly understood, and (c) the degree to which human utilization of these resources occurs is unknown. In order to make responsible decisions regarding the development of a sanctuary that would encompass the nearshore marine resources, more information and research is needed.

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APPENDIX 3.1

Annotated bibliography of site specific environmental surveys conducted in the nearshore marine waters of Maui, Molokai, Lanai, and Kahoolawe listed by island. At the end of the appendix are a series of reports by the University of Hawaii Marine Option Program for which one copy exists with the Marine Option Program Office on the University of Hawaii Manoa campus.

MAUI ISLAND

1. AECOS, Inc. 1979. Maui coastal zone atlas representing the Hawaii coral reef inventory island of Maui (MICRI) Part C. Prepared for U.S. Army Corps of Engineers, Pacific Ocean Division, Honolulu.

   The atlas provides coastal maps (scale 1 inch = 500 feet) showing general substratum types, bathymetry, major marine resources present (generally commercially important species), and recreational/commercial uses of the area. The charts cover the entire coastline of Maui.

2. AECOS, Inc. 1988. Biological and water quality studies in the marine environment for a proposed marina development at Launiupoko, West Maui, HI. AECOS Rept. NO. 512. Prepared for Sea Engineering, Inc.

   This quantitative study covers the marine communities in the waters between Launiupoko State Park and Puamana. Four biotopes were recognized in the waters fronting Launiupoko from shore to about 7 m in depth. Coral coverage was low due to wave scour of the benthic community and the resulting fish community development was not high due to the general lack of topographical relief. The study did note the relative dominance of macroalgae in the area.

3. Biota. 1973. Environmental impact statement for an underwater observatory near McGregor Point, West Maui. Prepared for Sea Habitat Hawaii, Inc., P.O. Box 2969, Honolulu, HI 96802. Prepared by Biota, 1260 Mokapu Blvd., Kailua, HI 96734.

   This study provides quantitative information on the structure of the marine communities at two locations in the vicinity of McGregor Point, Maui. Mean coral coverage was 37% and 47% at the two stations and *Porites lobata* was the dominant species recorded. The number of fish species ranged from 38 to 41 per census.

4. Department of the Army, Pacific Ocean Division, Corps of Engineers. 1973. Final Environment Statement: Prevention and Mitigation of Shore Damages, Kahului Harbor, Maui. Honolulu, Hawaii.

   The study provides qualitative information only and lacks interpretation of findings and impacts. The extent of fishing in the harbor varies with the seasonal abundance of fish. Makiawa, akule, hahalalu, manini, aholehole awa, papio, and mullet are all noted as being found in the harbor. The construction activity will cause turbidity and some disturbance to fish and other marine life. Fish will probably move away from the construction area while benthic organisms are expected to recolonize after completion of the project.

5. Department of the Army, Pacific Ocean Division, Corps of Engineers. 1973. Preliminary Draft Environmental Statement: Kahoma Stream Flood Control Project Maui, Hawaii.

   The study provides qualitative information only and lacks interpretation of findings and impacts. The study lacks biological information. The study notes that since 1879 there have been 19 damaging floods in the Lahaina area. During periods of short, intense rainfall, flash flooding occurs resulting in high velocity flows that transport debris downstream into the nearshore environment. Coral growth has been subjected to considerable stress by siltation in areas close to these intermittent stream mouths. Realignment of Kahoma Stream by channelization along with a debris basin and sill should reduce sediment transport during flood conditions.

6. Environment Impact Study Corporation. 1977. Revised Environmental Impact Statement for the Lahaina seawall, Lahaina, Maui, Hawaii. Prepared for Hawaii Design Associates, Inc., Honolulu.

The marine community is qualitatively described. Text mentions seeing *Pocillopora meandrina* and *Porites lobata* as well as *Ulva* and *Acanthophora* in the shallows fronting Lahaina. Fish seen include manini (*Acanthurus triostegus*), hinalea (*Thalassoma duperrey*), and butterfly fishes (*Chaetodon* sp.). The study lacks intepretation and analysis of findings.

7. Environmental Impact Study Corp. 1980. County of Maui Department of Water Supply, environmental impact statement for the Lahaina Water Treatment Plant, Lahaina, Maui, Hawaii. Job 35-MW-33.

This report provides only a short commentary on the species that may reside in the streams around Lahaina and makes no mention of marine biota.

8. Environment Impact Study Corp. and Muroda & Associates, Inc. 1981. Environmental Impact Statement for Makena Road, Makena, Maui, Hawaii.

This study provides quantitative information on the coral and fish communities present in the areas fronting Makena Beach, Maui (raw data).

Six stations were established at distances from 10 m to 150 m from shore in waters from 1 m to 7 m deep. Coral cover ranged from 9% to about 60% and at least 12 species were recognized. Sixty-seven species of fishes were encountered over all stations.

9. Environmental Consultants, Inc. 1976. Marine environmental reconnaissance study for proposed Lahaina small boat harbor, Maui, Hawaii. Prepared for Department of the Army, U.S. Army Engineer Division, Pacific Ocean.

This study is quantitative in nature and covers water quality, nearshore current patterns and marine biology in the area fronting Launiupoko. Six quantitative marine biological stations found coral coverage to range from less than 10% to about 50%. The fish communities were better developed in areas where corals flourished.

10. Fish and Wildlife Service. 1993. Draft Fish and Wildlife coordination act report Maalaea Harbor for light-draft vessels Maalaea, Maui, Hawaii. Prepared for U.S. Army Corps of Engineers, Pacific Ocean Division, Honolulu. U.S. Fish & Wildlife Service, Pacific Islands Office, Honolulu.

This report discusses the reef fronting Maalaea Harbor down to a depth of 25 ft. The study presents qualitative information only. Checklists of the species encountered are given. The study recorded 66 species of fishes, 8 species of corals, 29 species of mollusks, 8 crustaceans, and 10 echinoderms present on the reef flat.

11. State of Hawaii, Department of Transportation, Harbors Division. 1977. Revised Environmental Impact Statement: Administrative Action for Bulkhead and Other Improvements at Kahului Harbor, Kahului, Maui, Job H.C. 3046.

The study provides qualitative information only and lacks interpretation of findings and impacts. The study was conducted in Kahului Harbor, Maui. Mullet (*Mugil cephalus*), akule (*Trachurops crumenophthalmus*), and opelu (*Decapterus pinnulatus*) were reported to be common. Small solitary coral heads of *Montipora* sp. appeared to be dying at that time. Erosion and turbidity due to runoff from grading were noted as being potentially significant.

12. Hawaii State Division of Aquatic Resources. 1977. State-wide marine research and surveys, survey of fish and habitat. Oahu and Maui. Job Progress Report Project No. F-17-R-1.

This study provides quantitative data on fish censuses conducted in Honolua, Makuleia, and Napili Bays on the West Maui coast. Also included are fish census data from Molokini Islet. A total of 82 species of fishes were recorded in the Honolua Bay and Makuleia Bay area and 47 species were observed at Napili Bay. Within the Honolua and Makuleia Bay area (six transects made), the number of fish species observed at each station ranged between 39 and 57, whereas the biomass ranged from 72 to 383 lbs/acre and averaged 206 lbs/acre. At the two stations in Napili Bay, an average of 32 species and a mean biomass of 147 lbs/acre were recorded. The study at Molokini found 75 fish species on the transects.

13. Hawaiian Electric Co., Inc. and B.P. Bishop Museum. 1975. A survey of the marine benthos in the vicinity of the Kahului generating station, Maui, Hawaii. Hawaiian Electric Co., Environmental Department Rept. No. NV-61.

    This study presents quantitative data on the composition of marine communities in the waters fronting the Kahului generating facility situated on Kahului Bay, Maui. The survey examined the community structure of benthic species (macroinvertebrates and algae) present in the Kahului generating facility zone of mixing (ZOM). A total of 46 stations were surveyed for algae, and 15 stations were examined for invertebrates. Statistical analysis was applied with reference to abundance and diversity and the effect of power station discharge.

14. Helber, Hastert, & Kimura, Planners. 1987. North Beach Kaanapali: Final Environmental Impact Statement. Prepared for: Amfac Property Development Corporation and Tobishima Pacific, Inc.

    This report contains quantitative information regarding water quality, ocean currents and biological communities in the area offshore of the old Kaanapali airstrip. Five biotopes were recognized in the study area: the beach biotope, the shallow massive limestone biotope, the shallow coral biotope, the *Porites* biotope and the biotope of sand and rubble. Coral communities are well developed in the deeper, more offshore biotopes and coverage may exceed 70%. Fish communities are similarly well-developed.

15. Kinzie, R.A. III. 1972. A survey of the shallow water biota of Maalaea Bay, Maui. Prepared for Environmental Systems Department, Westinghouse Electric Corp.

    Quantitative survey techniques were used in this survey for Maalaea Bay and Molokini Islet. This report is currently unavailable.

16. Lum, Francis C.H. 1976. Honolua Watershed Project, Maui County, Hawaii: Final Environmental Impact Statement. U.S. Department of Agriculture, Soil Conservation Service, Honolulu, Hawaii. USDA-SCS-EIS-WS-(ADM)-75-1(F)HI.

    The study provides qualitative information only and lacks interpretation of findings and impacts. Fish found along this coastline represent the most common species that are found in Hawaiian waters such as *Acanthurus triostegus, A. nigrofuscus*; *Chaetodon miliaris, C. ornatissimus*; *Parupeneus multifasciatus, P. bifasciatus*, and *Thalassoma duperrey*. Sediment movement away from the coast is inhibited by natural reef barriers and offshore currents. The coastal environment of Honolua is degrading due to silt mixing with beach and offshore sands. During normal rainfall, suspended sediment colors nearshore waters for two to four weeks. The use of desilting basins in the streambed will decrease sediment transportation to the coast, thereby improving the habitat for marine life and offshore reef populations.

17. County of Maui. 1983. Lahaina wastewater treatment plant expansion draft environmental impact statement. County of Maui, State of Hawaii.

    This EIS provides no information about the marine communities fronting the Lahaina Wastewater Treatment Plant.

18. M&E Pacific, Inc. 1979. Environmental Impact Statement for the Kihei Boat Launching Ramp Facility at Keawakapu, Maui, Hawaii. Prepared for: Water Transportation Facilities Division, Dept. of Transportation, State of Hawaii, Contract No. 8427, Job H.C.4053.

The study provides qualitative information only and lacks interpretation of findings and impacts. Although the nearshore waters appear shallow and turbid, 16 species of coral and eight species of invertebrates were identified. Individual colonies of *Pocillopora meandrina* often measured 30 inches in diameter (editor's note: this is probably an error). Live coral coverage was estimated at 5%-20% within the immediate project site. A major factor that influences coral coverage is the movement of sand and damage from sand abrasion. Greater coral growth occurred on irregular hard substratum elevated above the sand than on adjacent flat bottom.

19. McCain, J.C. 1975. Marine environmental investigations near the Kahului generating station, Maui, Hawaii. Hawaiian Electric Company, Inc., Environmental Department Rept. No, NV-62.

An environmental survey of the Kahului Generating Station, Maui (zone of mixing) examining intertidal fish and zooplankton. Two fish species, *Acanthurus triostegus* and *Thalassoma duperrey* were examined for heavy metals. A comparison was made between the tissue samples taken near the Kahului Generating Station and those of fish taken at control sites and near other Hawaiian power plants. Sorting records identify zooplankton in adjacent waters.

20. Neighbor Island Consultants. 1974. A draft environmental impact statement implementation of the proposed Seibu Makena master plan, Makena, Maui, Hawaii. Prepared for Seibu Real Estate Company, Ltd.

This report contains quantitative information regarding the fish and benthic community structure at 18 sites covering the waters offshore of the Makena-Ahihi Bay area. Marine surveys were conducted at nine stations along the coast. Each station included a shallow (depth 2 m-4 m) and a deep (depth 8 m-9 m) survey. Area covered ranged from 40 m-600 m offshore and up to 9 m in depth. Raw data for corals, urchins, substratum, and fish censuses are contained in the appendix with tables providing percent coral coverage and fish density and diversity. Sixteen species of corals were reported with *Pocillopora meandrina* being most conspicuous in shallow water, *Porites lobata* abundant at intermediate depths, and *Porites compressa* frequently dominating deeper water assemblages. A total of 101 species of fish were reported.

21. Oceanic Institute. 1975. Proposed boat launch ramp facility, Mala Maui. Environmental impact statement. Harbors Division, Hawaii State Department of Transportation.

This study contains some quantitative information with respect to water quality parameters but most of the biological information is qualitative in nature. The study describes the marine communities in the vicinity of Mala Wharf, Lahaina, Maui. Some information is presented on the zooplankton in the area and a list of fish species seen is included.

22. Pacific Planning and Engineering, Inc. 1992. Final Environmental Impact Statement for the Hana Ranch Country Club, Hana, Maui, Hawaii. Prepared for: Keola Hana Maui, Inc.

The study provides qualitative information only with respect to the marine environment. The nearshore communities have developed in response to a high-energy environment with coral coverage ranging from very low to 15%. The dominant coral is *Pocillopora meandrina*. A total of 46 fish species were identified, with the most abundant fish being the maiko (*Acanthurus leucopareius*). The upper intertidal is dominated by the alga *Ahnfeltia concinna* and *Pterocladia capillacea* and *Amansia glomerata* dominate the intertidal zone. Section report suggests that the open coastal nature of the marine environment will reduce the opportunity for adverse impacts by the high degree of mixing that occurs.

23. Park Engineering, Inc. 1973. Final environmental impact statement for construction of sewage collection system and waste water reclamation plant Lahaina, Maui, and Hawaii. Prepared for the Department of Public Works, County of Maui.

This EIS provides no information about the marine communities fronting the proposed Lahaina Wastewater Treatment Plant.

24. PBR Hawaii (1990) Lahaina Master Plan Project Final Environmental Impact Statement. Prepared for State of Hawaii, Housing Finance Development Corporation, Department of Budget and Finance.

This study provides quantitative information on marine biology and water quality conditions in the area from Mala Wharf to Kaanapali, West Maui. Twelve stations were established to quantitatively sample pertinent water quality parameters and the marine macrobiota. The water chemistry studies show that ground water causes a slight elevation in some water chemistry parameters. The report provides water chemistry data following a 3.4 inch rainfall event. The marine community analysis noted three biotopes present with the biotope of diverse high coral coverage being biologically, the most interesting. The study noted that these communities appear stable and have persisted under conditions of occasional storm water discharge (with sediment) and ground water input.

25. R.M. Towill Corporation. 1982. Revised Environmental Impact Statement for Improvements to the Maalaea Harbor, Maalea, Maui.

The study provides qualitative information and presents the results of the information collected by the U.S. Fish and Wildlife Service that was presented in entry no. 28.

26. Sam O. Hirota, Inc. 1980. Revised Environmental Impact Statement, Kihei Drainage Project, County of Maui. Prepared for Department of Public Works, County of Maui. Sam O. Hirota, Inc., 345 Queen Street, Honolulu, HI 96813.

This study does not present any quantitative information on the marine communities offshore of Kihei, Maui. It reiterates the results of several other early studies done in the Maalaea-Kihei-Makena area; this recapitulation is broad and qualitative.

27. Tetra Tech, Inc. 1993. Preliminary assessment of possible anthropogenic nutrient sources in the Lahaina District of Maui. Prepared for U.S. Environmental Protection Agency Region 9, Hawaii State Department of Health, County of Maui. Tetra Tech, Inc., Lafayette, Calif.

The objectives of this report are to (1) identify directions for future research, (2) make preliminary estimates of the magnitude of nutrient sources and the fractions reaching the ocean and (3) identify data gaps and recommend field programs to fill these gaps. This study determined that the largest amounts of nitrogen and phosphorus applied to the Lahaina District were from agriculture. Nutrient releases into the Lahaina District coastal waters were also estimated. Sugarcane, the sewage treatment plant effluent, and pineapple were estimated to release annually 200,000, 150,000, and 76,000 lbs of nitrogen, respectively. Phosphorus inputs to the coastal waters were estimated to be largest for the wastewater treatment plant (130,000 lbs/yr), followed by pineapple (6,500 lbs/yr) and sugarcane (4,200 lbs/yr).

28. United States Army Corps of Engineers. 1980. Maalaea Harbor for Light-Draft Vessels, Maui, Hawaii. General Design Memorandum No. 1.

This study presents both qualitative data and a small amount of quantitative information on the structure of marine communities. The study provides a list of marine species seen in the vicinity of Maalaea Harbor and considers the area seaward from the harbor to about 5 m in depth. Three 20 m long transects for the censusing of fishes were carried out and these results are presented.

29. U.S. Army Engineer District, Honolulu. 1975. Final environmental statement maintenance dredging activities in the state of Hawaii. U.S. Army Engineer District, Honolulu, Hawaii.

Report provides only general comments about the fisheries in offshore dredge spoil dump sites. No quantitative information is given with respect to biological components.

30. U.S. Army Engineer District, Honolulu. 1992. Draft supplemental environmental impact statement for Maalaea Harbor for light-draft vessels Maui, Hawaii. Prepared for Department of Transportation, State of Hawaii. U.S. Army Engineer District, Honolulu.

This draft EIS provides a qualitative summary by NMFS regarding resident green turtle populations in the vicinity of the proposed harbor improvements. The U.S. Fish & Wildlife Service includes a section on qualitative observations made on the marine communities in the vicinity of the harbor and the macroalgae in the area were recorded in a checklist.

31. U.S. Army Engineer District, Department of the Army. 1981. Supplemental Information Report to the Final Environmental Statement for the Kahoma Stream Flood Control Project.

The study provides qualitative information only and lacks interpretation of findings and impacts. Kahoma Stream discharges onto a shallow limestone reef covered by silt and an algal mat. Genera common on this flat include *Enteromorpha* sp., *Ulva* sp., *Padina* sp., *Gelidium* sp., *Spyridia* sp. The nearshore waters are turbid, resulting from drainage of forest reserve lands, sugarcane, commercial, and residential lands. Corals of the reef flat are *Pocillopora meandrina*, *Montipora verrucosa*, and *Porites lobata*. A small estuary extends upstream providing habitat for juvenile fishes: aholehole (*Kuhlia sandvicensis*), mullet (*Mugil cephalus*) and the goby (*Eleotris sandwicensis*). The manini (*Acanthurus triostegus*), hinalea (*Thalassoma duperrey*), and the maomao (*Abudefduf abdominalis*), occur farther offshore from the stream mouth.

MOLOKAI ISLAND

32. Department of the Army, Pacific Ocean Division, Corps of Engineers. 1971. Final environmental statement: Kaunakakai Harbor maintenance dredging, Molokai, Hawaii. U.S. Army Corps of Engineers, Honolulu.

The study provides only qualitative information; biological data are provided.

33. Department of the Army, Pacific Ocean Division, Corps of Engineers. 1976. Final environmental statement: flood control project, Kapaakea, Molokai, Hawaii. U.S. Army Corps of Engineers, Honolulu.

This study provides only qualitative observations on the marine community offshore of Kapaakea, Molokai. The study notes that the reef flat is about 4,000 ft wide and most of it consists of a mud flat serving as habitat for *Halophila* sp. and numerous shrimp and crab burrows.

34. Hawaii Planning Design and Research. 1978. Marine environment and water quality surveys at Kaunakakai, Molokai, Hawaii. Prepared for U.S. Army Corps of Engineers, Pacific Ocean Division.

This study is quantitative and covers marine biology, circulation patterns and water quality conditions for the area offshore and fronting Kaunakakai, Molokai. An environmental survey of the marine environment was conducted at Kaunakakai Harbor, Molokai. Water quality samples were obtained from eight stations (ranging 0 m-180 m in depth). Six quantitative stations were chosen to sample the major benthic communities present in the region west of the project site. Fishes were sampled using visual survey techniques (depth ranging 30 cm-15 m). Quantitative data provided in tables for water quality (nutrients, bacteria, salinity), invertebrates, algae and fish. The shallow reef areas serve as a breeding area for commercially important adult fish and a nursery ground for juveniles including mullet (*Mugil cephalus*), papio (Carangidae), weke (*Mulloides flavolineatus*), and aholehole (*Kuhlia sandvicensis*).

35. Manoa Mapworks. 1984. Molokai Coastal Resource Atlas. Prepared for U.S. Army Corps of Engineers, Pacific Ocean Division, Honolulu.

This atlas provides coastal maps (scale 1 inch = 500 feet) showing general substratum types, bathymetry, major marine resources present (generally commercially important species) and recreational/commercial uses of the area. The charts cover the entire coastline of Molokai.

LANAI ISLAND

36. Belt Collins & Associates. 1990. Manele: Golf course and golf residential project, Lanai, Hawaii. Draft Environmental Impact Statement. Prepared for Lanai Company, Inc.

This study is quantitative and covers the areas of marine biology and water chemistry for 10 stations along the south coastline of Lanai. The EIS reports on the first (baseline) field effort that has become a quarterly sampling program (ongoing) for this coastline. The marine communities are diverse along this coast and appear to be impacted by infrequent storm waves (causing wave scour) and siltation from the mouths of intermittent streams following heavy rainfall. The water chemistry of the nearshore waters shows very little ground water input and the water quality is typical of exposed Hawaiian coasts.

37. Hawaii State Division of Fish and Game. 1973. Marine survey off the Hulopoe-Manele Bay area, Island of Lanai. Division of Fish and Game Report, Department of Land and Natural Resources, State of Hawaii.

This report provides quantitative information on the fish community structure in the Hulopoe-Manele Bay, Lanai.

Fourteen transects were conducted; each transect was 40 ft wide by 250 yd long. The number of species ranged from 33 to 60 and averaged about 48 species per station. Estimates of standing crop ranged from 92 to 504 lbs/acre and averaged 182 lbs/acre. The report recommends that a MLCD be established at Hulopoe-Manele.

38. Oishi, F.G. 1990. Intertidal and subtidal algae, coral, and macroinvertebrates at the Manele-Hulopoe Marine Life Conservation District, Lanai. Department of Land and Natural Resources, State of Hawaii.

This study provides quantitative information on benthic community development (i.e., corals and benthic algae) on four transects established in the Hulopoe-Manele MLCD. Ten species of corals were encountered in the transects and the author noted that occasional wave impact is probably an important element in structuring the marine communities of the MLCD. The study noted a paucity of macrothalloid algae in the area. The conclusion was that the marine communities appeared to be relatively undisturbed.

KAHOOLAWE ISLAND

39. Department of the Navy. 1972. Final environmental impact statement Kahoolawe Island target complex, Hawaiian archipelago. Department of the Navy, Honolulu.

This study provides no information regarding marine resources surrounding the island except to say (page 18): "The species of marine life in the waters surrounding Kahoolawe are presumed to be the same as those surrounding the other main islands". No individual inventories are available from any of the main islands.

40. Environmental Impact Study Corp. 1979. Environmental impact statement military use of Kahoolawe Training Area, Hawaiian archipelago. Prepared for the Department of the Navy. Environmental Impact Study Corp., Honolulu.

This EIS presents quantitative and qualitative observations regarding the marine resources around Kahoolawe. The quantitative data are for coral coverage, sea urchin abundance, and commercially

important inshore fish species. Fish data collection techniques are unusual in that they were gathered by an experienced diver who speared all of the commercially important fish that he could during a 0.5 hr session. The report presents qualitative descriptions of various sites around the island. Also included are data on sediment types, currents, and water clarity.

MARINE OPTION PROGRAM, UNIVERSITY OF HAWAII STUDENT REPORTS:

41. Akaka, L., C. Baldwin, B. Magruder, and M. Nagata. 1976. Kahoolawe Reef Fish Survey, May 15-16, 1976. Marine Option Program, University of Hawaii, Honolulu.

    This report provides a species list and relative abundances of fish for several inshore habitats at Papakaiki, Kahulani, Titcum-East, Titcum-West, Black Rock, and Twin Sands on Kahoolawe. The data are qualitative.

42. Ambrose, E., K. Takahashi, D. Regan, K. Crozier, B. Akiona, A. Lee, W. Dudley, and S. Maynard. 1988. Nearshore Baseline Survey of Olowalu, Maui, Hawaii. Marine Option Program, University of Hawaii, Honolulu.

    This study established four transect sites offshore of Olowalu for sampling fishes, invertebrates, coral, and algae. Five coral species composed 82% of the coral coverage and 24 species of algae were recorded. The fish census noted 74 species with the most abundant being *Ctenochaetus strigosus, Acanthurus nigrofuscus,* and *Thalassoma duperrey.* A creel survey sampled 21 fishermen and found that most were fishing with rod and reel, spear, and handpoles.

43. Anzai, G.A., G. Akita, L. Boucher, R. Fantine, T.Y. Kobayashi, G. Muraoka, H. Price, S. Takenaka, and L. Torricer. 1979. Marine Option Program data acquisition project: Papohaku Beach, Molokai, and Molokini Island, Maui. Sea Grant College Program, University of Hawaii, Honolulu. Working Paper No. 39.

    The methods used in these inventories were quantitative. At Papohaku Beach, Molokai 19 transects were established to ascertain the effects of the early phases of coastal resort/urban development on the marine biota. The most notable changes were the large amount of terrigenous material in the ocean and declines in coral and fish abundance. The data were compared to those collected in 1974 in the same location; the comparative analysis showed declines in commercially desirable fish species.

    The Molokini Islet study established nine transects at depths from 7 m to 18 m. Substrate type and coverage by corals and/or algae were recorded as were the biomass of commercially valuable fish species.

44. Bass, P., and L. Teshima. 1985. A baseline survey of Ahihi Bay. Marine Option Program, University of Hawaii, Honolulu.

    This quantitative survey of Ahihi Bay, Maui established five transect sites from the shore to a depth of 8.5 m. Dominant coral species present included *Porites lobata* and *Pavona varians*; *Porolithon gardineri* was the most common algal species seen. A total of 66 fish species were censused and *Ctenochaetus strigosus, Zebrasoma flavescens, Thalassoma duperrey, Acanthurus triostegus,* and *Stegastes fasciolatus* composed 55% of the total count.

45. Bigelow, K., K. Alspach, R. Lohle, T. McDonough, P. Ravetto, C. Rosenfeld, G. Stender, and C. Wong. 1989. Assessment of the mangrove ecosystem of West Molokai, Hawaii with additional site surveys of Moanui Beach Park and Ualapue Fishpond. Marine Option Program, University of Hawaii, Honolulu.

    The objectives of this environmental survey were to (1) assess the relationship between the mangrove forest and adjacent fishponds and coral reefs west of Kaunakakai, (2) to inventory the marine resources offshore of Moanui Beach park and (3) carry out a survey of Ualapue Fishpond. The survey of the mangroves, fishponds, and coral reefs found that the presence of the mangrove forest reduced the amount of land-derived sediment arriving to fishponds and coral reef areas. The Moanui Beach Park survey

provided quantitative and qualitative information on the status of the marine resources offshore of the park. The assessment of Ualapue Fishpond determined that it was in relatively good condition with some encroachment of mangroves and with restoration, it could again be productive.

46. Harr, R., L. Anderson, S. Ebersole, B. Ebersole, K. Sakuma, P. Ramos, W. Jones, J. Sylvester, and S. Maynard. 1991. Molokini Survey Project Final Report July 23-30, 1987. Marine Option Program, University of Hawaii, Honolulu.

This survey quantitatively examined the fish, coral, and macroinvertebrate populations at Molokini; special emphasis was placed on determining the impact that anchor damage may have on the coral community. In total 110 species of fishes were recorded. Anchor damage was apparent but was difficult to quantitatively ascertain.

47. Kawamoto, K.E., D.A. Bulseco, and T.Y. Kobayashi. 1981. The effects of siltation upon the nearshore marine environment of Kahoolawe. Marine Option Program, Univesity of Hawaii, Honolulu.

This quantitative study established six stations along the northwest shoreline of Kahoolawe. Biological data on fishes, corals, other invertebrates, and algae were collected. Results found that the substratum was, on the average, covered by silt (64%), live coral (17%), and hard substratum (19%). The dominant coral in the areas examined was *Porites lobata*. 35 species of algae were present with the corallines dominating the substratum. The dominant algal species were those characteristic of high energy environments. In total, 126 species of fishes were recorded and 65% of the fishes censused were planktivores. Fish biomass estimates are also provided.

48. Oishi, F. 1975. Papohaku Beach Survey Data Acquisition Group, June 24-25, 1974. Sea Grant College Program, University of Hawaii, Honolulu. Working Paper No. 14.

This study focused on an inventory of the marine resources in the Papohaku area of Molokai. Six transects were established to sample fish and algae present in the area. The fish biomass data were quantitative, however, most information was qualitative.

49. Orcutt, A., G. Lelesch, P. Bass, D. Bauer, J. Hodge, W. Jones, R. Nevins, C.Wilburn, and M. Grimes. 1988. A Coastal Resource Inventory of the Lopa-Naha, Lanai Coastline. Prepared for Lanai Company, Lanai City, Lanai. Marine Option Program, University of Hawaii, Honolulu.

This study provides an inventory of marine resources in the Lopa to Naha section of Lanai. Quantitative information was collected for fish, macroinvertebrates, algae, and corals at three locations along this coastline. At each station, six 100 m long transect lines were established parallel to the shore and spaced 50 m apart. The transect lines commenced at the shore and continued to about 300 m offshore. Marine communities were found to be well developed at most sites.

50. Sanderson, S.L., and A.C. Solonsky. 1980. A Comparison of Two Visual Survey Techniques for Fish Populations. Marine Option Program, University of Hawaii, Honolulu.

This quantitative environmental survey was conducted at 33 sites in five areas (Palaau, Moanui, Halawa Valley, Keawanui, and Ilio Point) on Molokai. Coral, algal, and fish dendrograms were developed to determine the similarity patterns among these sites. In general, the biological parameters clustered according to the area in which they were located. With the exception of Keawanui, each of the areas can be considered a distinct habitat from the others.

51. Tarr, A.B., and K.K. Yamase. 1980. Marine Option Program Data Acquisition Project: Papohaku Beach, Molokai, March, 1978. Marine Option Program, University of Hawaii, Honolulu.

This report analyzes data collected from preconstruction, construction, and post-construction periods at Papohaku, Molokai. The report provides quantitative data for the post-construction phase of the program.

The results of this analysis showed that during construction, high sediment input (via wind) occurred and some commercially valuable fish species decreased during construction then increased following completion of the project.

52. Torricer, L.L., G. Akita, G.A. Anzai, L. Boucher, R. Fantine, T.Y. Kobayashi, G. Muraoka, H. Price, and S. Takenaka. 1977. Marine Option Program Data Acquisition Project: Honolua Bay, Maui. Marine Option Program, University of Hawaii, Honolulu.

Sixteen transect sites were surveyed in the Honolua Bay area (depth range from 1 m to 14 m). Six bottom types were identified with *Porites lobata* being the most important coral species. 31 algal species were encountered and 76 species of fishes were censused. The reef flat habitat contained the highest abundance of fish followed by the reef face habitat.

CHAPTER 4
CETACEANS IN HAWAIIAN WATERS

DATA SOURCES

With the exception of spinner dolphins and seasonally resident humpback whales, there has been a lack of systematic research on Hawaii's resident cetacean species. Literature pertaining to humpback whales is considerably larger and is summarized in a separate section. The presence of other cetacean species has been documented incidentally in surveys of other species, primarily humpback whales (Shallenberger 1981). In many cases, these sightings have been unpublished and are based on personal communications. For example, Dan McSweeney has conducted considerable privately funded research on pilot whales (*Globicephala macrorhynchus*) and sperm whales (*Physeter catodon*) off the leeward coast of Hawaii (Eugene Nitta, National Marine Fisheries Service pers. comm. 1993), however, none of his work has been published.

PROTECTION, LEGISLATION, AND MANAGEMENT

All marine mammals within the U.S. and territorial waters are currently protected by the Marine Mammal Protection Act of 1972, as amended. The National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) is charged with the interpretation and administration of this act. Humpback whales are also protected by the Endangered Species Act of 1973, as amended, and have been protected by an international whaling moratorium since 1966. Humpbacks are further protected in Hawaiian waters by anti-harassment regulations that are enforced by NMFS (Federal Register 1987). These regulations established a minimum approach distance of 100 yds for all Hawaiian waters and a minimum approach of 300 yds for the waters within Maalaea Bay, Maui and portions of Lanai coastal waters. Violators are subject to fines or imprisonment or both. The NMFS recently published the final draft of the Humpback Whale Recovery Plan (NMFS 1991) that reviewed all pertinent literature and established objectives for population management (for a more detailed review of protection/management issues, see Chapter 8).

1993 Marine Mammal Survey

Previous surveys in Hawaii reported only on the locations of humpback whales (Herman and Antinoja 1977; Rice and Wolman1978; Herman et al. 1980; Baker and Herman 1981), thus, until recently, there were no data from systematic surveys which included Odontocete species. The most extensive marine mammal survey performed to date in Hawaiian waters was conducted during February and March, 1993 as part of a baseline assessment designed to detect the impact of the ATOC transmission on resident marine mammal species (Mobley et al. 1993; Forestell et al. 1993). Acoustic Thermometry of Ocean Climate (ATOC) was designed by Walter Munk and his associates at the Scripps Oceanographic Institute to detect global warming trends using low frequency sound. A series of four aerial surveys was conducted during 1993 primarily to assess the abundance and distribution of humpback whales, though locations and group compositions of all marine mammal species seen were also documented. The surveys were designed to conform to line transect techniques, which permit abundance estimates to be projected from sighting data (e.g., Burnham, Anderson, and Laake 1980).

Surveys during the 1993 series were conducted from single-engine overwing aircraft equipped with radar altimeters and global-positioning system devices (GPS). These instruments were used to determine the location and altitude of the plane and, when combined with the sighting angle, to determine the position of marine mammal pods by use of a clinometer. Precise distance estimation is an essential ingredient of abundance estimation.

Unlike previous surveys in Hawaiian waters, the majority of the 1993 effort was concentrated in waters deeper than 100 fathoms (see Figure 4.1). Effort was distributed as follows: less than 100 fathoms- 23%, 100-1,000 fathoms- 42%, greater than 1,000 fathoms- 35%.

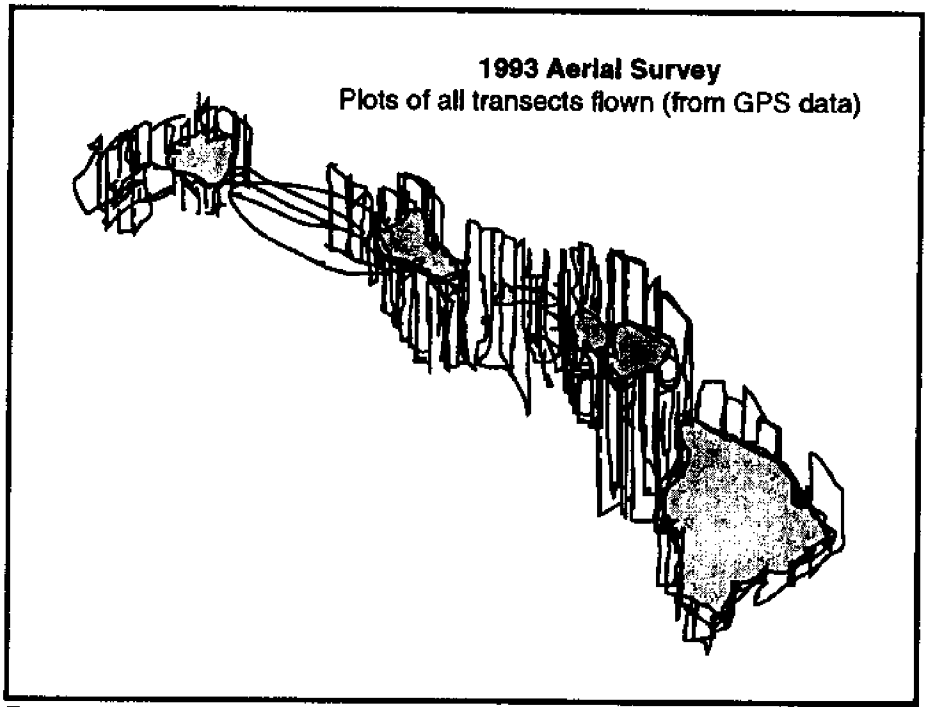

Figure 4.1

CETACEAN SPECIES RESIDENT IN HAWAII

The order Cetacea (dolphins and whales) consists of two suborders: Odontocetes (toothed cetaceans) and Mysticetes (baleen whales). Generally, a useful distinction between them is one of size since the great whales are all Mysticetes, with the exception of the sperm whale, an Odontocete.

Shallenberger (1981) identified 24 species of cetaceans (five Mysticete and 19 Odontocete species) in Hawaiian waters on the basis of stranded specimens or field observations (see Table 1). Nitta (1988) documented all cases of stranded cetaceans recorded between the years 1936 and 1988 which comprised 17 of these species. From both sets of data it is clear that of the Mysticete species, only the humpback whale (*Megaptera novaeangliae*) can be considered seasonally resident. Sightings of the remaining four Mysticete species (Bryde's, finback, minke, and right whales) were so rare as to be considered anomalous.

Of the Odontocete species shown in Table 4.1, five were identified on only one or a few instances and are similarly designated as anomalous. The remaining 14 species are designated as rare, uncommon, or common in order of increasing occurrence. Of the eight species of Odontocetes identified during the 1993 surveys of Hawaiian waters (see Figure 4.2), four were found within the 100-fathom limit (spinner dolphins, spotted dolphins, bottlenosed dolphins, and false killer whales) and thus would likely fall within the jurisdiction of the current proposed marine sanctuary boundaries. It should be noted, however, that because most of the species listed in Table 4.1 are wide-ranging, other Odontocetes would likely be found within the proposed sanctuary limits as well. Data from Shallenberger (1981) concerning these four species are summarized below. Additional pertinent data from the 1993 aerial surveys are also included.

Bottlenosed Dolphins

Pacific bottlenosed dolphins (*Tursiops gilli*), typically larger and more powerful than their Atlantic counterparts (*T. truncatus*), are found throughout the Hawaiian archipelago including the northwestern

TABLE 4.1. CETACEAN SPECIES FOUND IN HAWAII WITH RESULTS OF 1993 AERIAL SURVEYS *

Common (Scientific) Name	Observations	(fathoms) Frequency	Depth of '93 sightings <100	>100
MYSTICETES:				
Fin whale (*Balaenoptera physalus*)	stranding (1)	Anomalous		
Bryde's whale (*B. edeni*)	field obs (few)	Anomalous		
Minke whale (*B. acutorostrata*)	field obs (1)	Anomalous		
Humpback whale (*Megaptera novaeangliae*)	field obs (many)	Common	yes	yes
Right whale (*Balaena glacialis*)	field obs (1)	Anomalous		
ODONTOCETES:				
Sperm whale (*Physeter catodon*)	field obs (many)	Uncommon	no	yes
Bottlenosed dolphin (*Tursiops gilli*)	field obs (many)	Common	yes	yes
Spinner dolphin (*Stenella longirostris*)	field obs (many)	Common	yes	yes
Spotted dolphin (*Stenella attenuata*)	field obs (many)	Common	yes	yes
Striped dolphin (*Stenella coeruleoalba*)	stranding (13)	Rare		
Rough-toothed dolphin (*Steno bredanensis*)	field obs (many)	Common		
Common dolphin (*Delphinus delphis*)	field obs (1)	Anomalous		
Whitesided dolphin (*Lagenorhynchus obliquidens*)	field obs (1)	Anomalous		
Risso's dolphin (*Grampus griseus*)	field obs (2)	Rare		
Pygmy sperm whale (*Kogia breviceps*)	stranding (8)	Uncommon	no	yes
Dwarf sperm whale (*Kogia simus*)	field obs (1)	Anomalous		
Killer whale (*Orcinus orca*)	stranding (1)	Anomalous		
False killer whale (*Pseudorca crassidens*)	field obs (many)	Common	yes	yes
Pygmy killer whale (*Feresa attenuata*)	field obs (many)	Uncommon		
Melon-headed whale (*Peponocephala electra*)	field obs (many)	Uncommon		
Pilot whale (*Globicephala macrorhynchus*)	field obs (many)	Common	no	yes
Goosebeaked whale (*Ziphius cavirostris*)	stranding (2)	Rare	no	yes
Densebeaked whale (*Mesoplodon densirostris*)	field obs (1)	Rare		
Bottlenose whale (*Hyperoodon ampullatus*)	field obs (1)	Anomalous		

* Table adapted from Table 1 of Forestell & Brown (1992) that was based primarily on Shallenberger (1981). Stranding results are for period 1936–87 as taken from Nitta (1987). Results of 1993 survey were added from unpublished data. Frequency is noted in decreasing magnitude as follows: common, uncommon, rare, and anomalous.

The sighting data of Shallenberger (1981) are at odds with the stranding data of Nitta (1987) for striped dolphins (*Stenella coeruleoalba*). Striped dolphins were noted as "rarely observed" by Shallenberger but were listed by Nitta as the species with greatest frequency of stranding. The source of this discrepency is unclear.

islands. Shallenberger (1981) notes they are found mostly along the edges of banks or shelves, usually along the 50- or 100-fathom isobaths where upwelling from deep water occurs. Pod sizes typically range from single individuals and small groups of three to 10 animals to large groups of 100 or more individuals (Shallenberger 1981). They feed on numerous species of fish, squid, shrimp, and other crustaceans (Leatherwood 1975; Leatherwood, Caldwell, and Winn 1976). Bottlenosed dolphins adapt readily to captivity and a number of them have been kept and bred successfully at Sea Life Park and other oceanaria.

Groups of bottlenosed dolphins were sighted on five occasions during the 1993 survey in waters ranging from less than 100 to more than 1,000 fathoms (see Figure 4.2). The mean observed pod size was 15.4 individuals.

False Killer Whales

False killer whales (*Pseudorca crassidens*) are found throughout the world's temperate to tropical oceans, but are found most often in tropical and subtropical waters (Shallenberger 1981). Their habitat ranges from

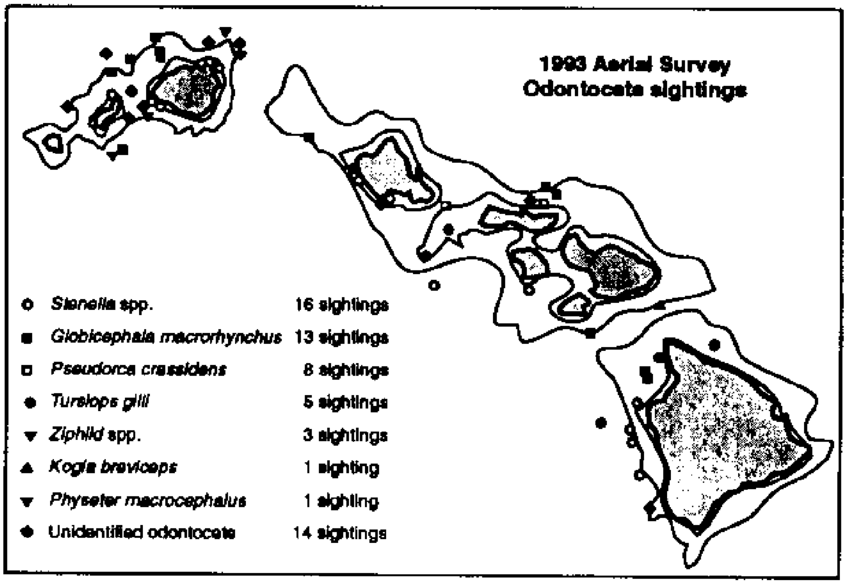

Figure 4.2

shallow (<100 fathoms) to deep water (>1,000 fathoms) and their distribution appears to be related to concentrations of prey. They typically travel in large pods, often exceeding 100 individuals, and frequently swim in broad formations, a possible mechanism for finding food. Squid beaks have been found in their stomach contents and they have been observed feeding on mahimahi (*Coryphaena hippurus*) and yellowfin tuna (*Thunnus albacares*) (Shallenberger 1981). Like bottlenosed dolphins, false killer whales have been shown to readily adapt to captivity and have been kept for relatively long periods at Sea Life Park and other oceanaria.

Eight Pseudorca groups were sighted during the 1993 aerial surveys in waters ranging from less than 100 to 1,000 fathoms. Mean pod size was 28.6 individuals.

Spinner Dolphins

Spinner dolphins (*Stenella longirostris*) are members of the genus Stenella that includes spotted dolphins (*S. attenuata*), striped dolphins (*S. coeruleoalba*), and the Clymene dolphin (*S. clymene*). Spinners, so named because of their tendency to "spin" while breaching or leaping from the water, are found throughout the tropical Pacific, Atlantic, and Indian Oceans (Baker 1987). In Hawaii, they are located throughout the island chain and show distributional patterns related to physiography, prey distribution, sea state, water depth, bottom topography, and turbidity (Norris et al. 1985). They are commonly found in large groups consisting typically of 50–100 individuals, though larger groups have been seen (Shallenberger 1981).

Spinner dolphins have been intensively studied by Norris and his students, particularly near Hawaii Island (Norris and Dohl 1980; Norris et al. 1985; Ostman and Driscoll 1991; Wursig, Cipriano, and Wursig 1991). Spinners typically show predictable home ranges, foraging at night for food in deep water (400 m-2,000 m) where the deep scattering layer (DSL) rises closer to the surface than normally occurs during daylight hours. Prey species for the Hawaiian spinners are not as well documented as for other regions but are believed to include at least two species of squid (*Abralia estrostrica* and *A. trigonura*) and several species of fish (particularly mycophids) (Shallenberger 1981). During the day they typically return to bays and inshore regions to rest and socialize and to avoid predation by pelagic sharks (Norris and Dohl 1980; Wursig, Cipriano, and Wursig 1991). Spinner dolphins were positively identified on eight occasions during the 1993 survey series in waters between 100-1,000 fathoms in depth. Mean pod size was 50 individuals. Six additional observations were designated as *Stenella* species that were likely to have been either spinner or spotted dolphins. These occurred in waters ranging from less than 100 fathoms to greater than 1,000 fathoms.

Spotted Dolphins

Spotted dolphins (*Stenella attenuata*) are common in Hawaiian waters and are frequently confused with spinner dolphins since they are similar in size and habitat. Most of what is known about spotted dolphins is derived from the eastern tropical Pacific and Japanese waters due to their association with the purse seine tuna industry. Spotted dolphins and related species have been inadvertently slaughtered as a result of purse seine fishing practices in these regions.

Spotted dolphins are typically found in the leeward coastal waters and offshore banks of all Hawaiian Islands, as well as channel regions. Shallenberger (1981:53) writes, "Due to the normally large herd size and the frequencies of observation, it is likely that spotted dolphins are the most numerous Hawaiian cetacean (in terms of numbers of individuals)". Similar to spinner dolphins, spotted dolphins have their own characteristic aerial behaviors including very high jumps, long low jumps, and tail walks (Shallenberger 1981). Shallenberger noted that very little research has been performed on this species in Hawaiian waters.

During the 1993 aerial survey, spotted dolphins were positively identified in just one case, a group of five individuals, in waters less than 100 fathoms. It is likely that there were more spotted dolphins among the six *Stenella* species sightings described in Chapter 3.

Odontocete Prey Species

What little is known of the feeding habits of Odontocete species in Hawaii has been gleaned from examinations of stranded specimens, occasional field observations, and from generalizations based on more extensive literature for other regions. Shallenberger noted that a significant portion of the diet of smaller Hawaiian cetaceans is made up of epipelagic and mesopelagic fish and squid. Primarily, this includes myctophid fish, some of whom migrate at night to within 200 m of the surface, and several species of squid which also show vertical diurnal migrations, including *Abralia trigmura* and *A. astrostica*. Shallenberger underscores the importance of squid to Odontocete diets by noting that virtually every stranded specimen examined contained squid beaks in its stomach contents. The myctophid species of fish are also commonly found in Hawaiian cetaceans (Shomura and Hida 1965). Local fish species of likely importance include: opelu (*Decapterus pinnulatus* and *D. maruadsi*) and akule (*Trachurops crumenophthalmus*). Shallenberger reported that larger cetaceans have been observed eating mahimahi (*Coryphaena hippurus*), yellowfin tuna (*Thunnus albacares*), and skipjack tuna (*Katsuwonus pelamis*). These species are all commercially important and their relative availability can be assessed using catch statistics (Shallenberger 1981).

Predators

Information relevant to Odontocete predation has been primarily anecdotal (Shallenberger 1981). Sharks have been observed to feed on live cetaceans in other oceans (e.g., Leatherwood, Evans and Rice 1972; Leatherwood et al. 1973) but, according to Shallenberger (1981), have not been observed doing so in Hawaiian waters. Accounts exist of unidentified cetacean remains in the stomach contents of tiger sharks (*Galeocerdo covieri*) harvested in Hawaii, but it is not known whether the animals were alive or dead when eaten. Additional indirect evidence of shark attacks on cetaceans occur in the form of crescent-shaped scars on the bodies of living specimens. Hawaiian cetaceans are also frequently seen with the small circular scars characteristic of "cookie cutter" sharks (*Isistius brasiliensis*). These small bites generally heal and are not known to be fatal.

Odontocete Distribution Trends

Eighty-one percent of the Odontocete pods sighted during the 1993 aerial surveys were found in waters deeper than 100 fathoms (Figure 4.2). Thirty-eight percent of the sightings were in the vicinity of Kauai and Niihau. Interestingly, the areas favored by humpback whales, the four-islands (Maui, Lanai, Molokai, and

Kahoolawe), and Penguin Bank regions (Figure 4.3) showed the lowest incidence of Odontocete sightings. The *Stenella* species, in particular, showed a tendency to locate along the 100-fathom isobath, as described by Shallenberger (1981).

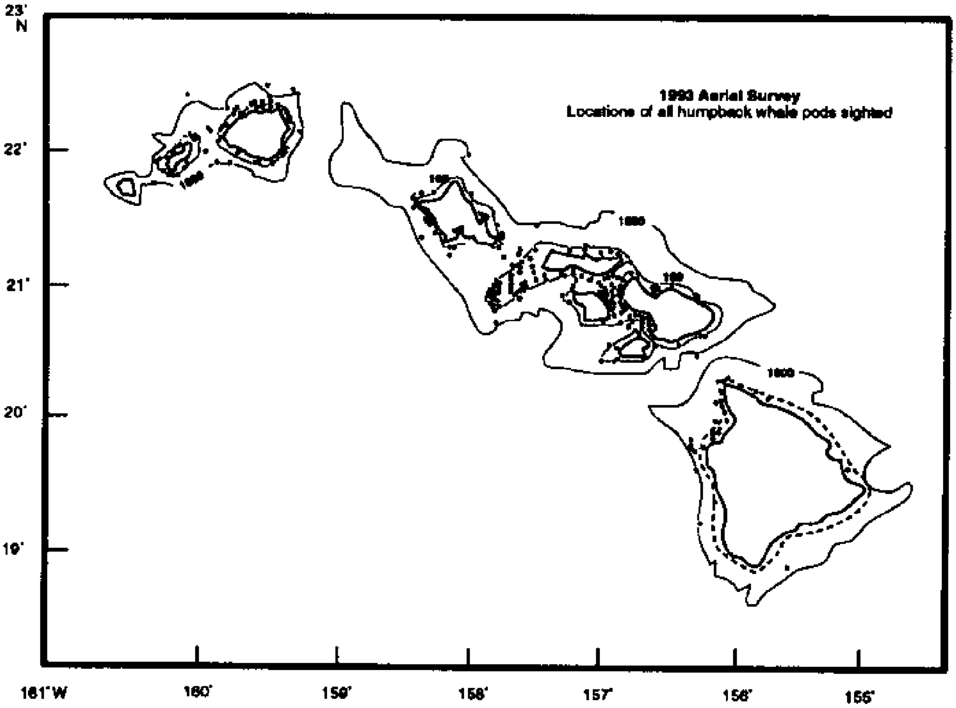

Figure 4.3

NORTH PACIFIC POPULATION OF HUMPBACK WHALES

Humpback whales migrate each year from summer coastal feeding grounds in high latitudes to breeding and calving grounds near islands or shallow banks in low-latitude waters. Populations of humpback whales are found in most of the world's oceans, but intensive twentieth-century whaling reduced their numbers to a small fraction of their original abundance. The size of the north Pacific population was estimated earlier to be approximately 10% of the species' pre-whaling abundance (Rice 1978; Wolman 1978). Prior to the 1970s, most of the information concerning the natural history of humpback whales came from harvested specimens primarily in the southern oceans (e.g., Chittleborough 1954, 1955; Dawbin 1966). During the past two decades the focus of research has shifted to field studies of free-ranging specimens aided by the use of natural markings on the flukes to identify individuals. Analysis of photographs of these natural markings (primarily variations of black and white pigment found on the ventral surface of the flukes) have contributed substantially to our understanding of the population structure, social ecology, and reproductive patterns of this species (see review in Perry et al. 1988).

The structure of the north Pacific population of humpback whales is poorly understood. Kellogg (1929), using the observations of early whalers, suggested that humpback whales in the north Pacific were divided into an American and Asian stock. He proposed that the Asian stock wintered in tropical waters south of Japan and traveled north to feeding areas in the Sea of Okhotsk and along the Kamchatka Peninsula. The American stock was thought to breed in the waters off the west coast of Mexico and travel northward along the coast of North America to feeding grounds in the Gulf of Alaska, the Bering Sea, and near the Aleutian Islands. At that time, there was no evidence of exchange between the American and Asian stocks. Recently, however, Darling (1991) reported a resight of a humpback whale seen in the waters surrounding Ogasawara, Japan, as well as the island of Kauai. Recent analyses of humpback whale songs recorded in the wintering grounds off Mexico, Hawaii, and Japan also support the possibility of cross-Pacific exchange (Helweg et al. 1993) since some "themes" (recurring features of song) were found common to all three wintering regions.

The Hawaiian wintering grounds were apparently not known to Kellogg, nor to other authors discussing the north Pacific humpback whales (e.g., Nishiwaki 1966). The Hawaiian grounds have been studied intensively only since the mid-1970s (e.g., Herman and Antinoja 1977; Tyack 1981; Darling, Gibson, and Silber 1983; Glockner and Venus 1983). Herman (1979) proposed that the whales may have "arrived" in Hawaiian waters possibly no earlier than the mid-1800s. Among other evidence, Herman noted the fact that there is no specific word for humpback whale in the Hawaiian language and no mention of the existence of Hawaiian humpback whales in the logs of European whalers (despite the use of Lahaina and other ports for stocking whaling ships) until the mid-nineteenth century. If true, this hypothesis might explain the lack of awareness of Kellogg and other earlier authors concerning the seasonal residence of humpback whales in Hawaiian waters.

More recent photographic identification data, focused primarily on the habitats in the central and eastern north Pacific, have revealed patterns of exchange between southern wintering areas in Hawaii and Mexico, and northern feeding areas in the waters surrounding the Farallon Islands off the central California coast, southeastern Alaska, and western Gulf of Alaska (Perry et al. 1988). In contrast to migration from winter to summer regions, cases of movement from one summer feeding area to another are rare. Based on these patterns of movement, Baker and others (1986) proposed that humpback whale groups in the north Pacific are best described as "structured stocks" that consist of several feeding herds which intermingle to breed on one or more wintering grounds.

Humpback Whales in Hawaiian Waters

Other authors have noted the tendency for humpback whales to congregate in shallow-water banks and island areas during the winter breeding season (Chittleborough 1965; Herman and Antinoja 1977). Because humpback whales are presumably not feeding during the winter breeding season (Dawbin 1966; Tomilin 1967), this shallow-water preference is not likely based on prey availability. Other authors have conjectured that: (1) shallow, inshore waters offer greater protection from predators such as sharks, which is of particular concern for calves (Baker 1985); or (2) warmer waters require less of an expenditure of metabolic energy, which is particularly important during a period of fasting (Brodie 1975). Hawaii affords large expanses of relatively shallow water (less than 100 fathoms) and thus is well suited as a breeding habitat.

Humpback whales are found in Hawaiian waters throughout the winter-spring season with peak abundance occurring approximately between mid-February and mid-March (Baker and Herman 1981; Herman, Forestall, and Antinoja 1980; Forestell and Mobley 1991). The social behavior of the whales while on the wintering grounds is presumably related to reproduction, since calves are born during the winter season and gonadal activity in both males and females increases in the winter months (Chittleborough 1954, 1955; Nishiwaki 1959). It appears that the mating system is polygynous or promiscuous (Mobley and Herman 1985), characterized by complex acoustic displays (e.g., 'song'), and vigorous physical competition among males. Female humpbacks generally give birth to a single calf at two- to four-year intervals (Baker, Perry, and Herman 1987; Glockner-Ferrari and Ferrari 1984; Clapham and Mayo 1988), although some females may give birth two years in a row. The calf remains with its mother for approximately one year (Chittleborough 1954). Current rates of neonatal mortality are unknown but of great importance to assessments of the rate of recovery of the species (Perry, Baker, and Herman 1990). Mother-calf pairs are frequently accompanied by a third whale, an "escort" (Herman and Antinoja 1977). The escorts appear to be consorting with the mother in order to mate with her, and intense aggression among escorts and "intruding" whales has been observed (Tyack and Whitehead 1983; Baker and Herman 1984; Mobley and Herman 1985). Although not all females ovulate post-partum, enough may do so to warrant the attention of males (Herman and Tavolga 1980; Tyack 1983). Humpback whales generally are difficult to sex in the field, however, in those cases where discrimination has been possible, singers and escorts have proven to be males (Glockner-Ferrari and Ferrari 1984; Baker and Herman 1984).

Long, complex "songs," first identified by Payne and McVay (1971) and by Winn and Winn (1978) are heard throughout the humpback's winter grounds. The singer is normally a lone whale, but singers have also been observed to stop singing and join with cow-calf pairs, and sing while escorting (Tyack 1981; Darling, Gibson, and Silber 1983; Frankel et al. 1989; Helweg et al. 1993). Concurrent singing by many whales may be a form of communal display by males (Herman and Tavolga 1980) which, in addition to other functions, may help to synchronize ovulation in females with the presence of mature males (Baker and Herman 1984). Sound-playback experiments have indicated that song probably functions as an advertisement rather than an attractant because playbacks of song rarely produced approach by whales. Other sounds that may indicate the presence of a female (Alaskan feeding call and Hawaiian social sounds) were more likely to cause whales to approach the playback source (Tyack 1983; Mobley, Herman, and Frankel 1988). Current studies of humpback song by Frankel and others (1989) modeled on the procedures developed by Clark, Ellison, and Beeman (1986), utilize a linear array of hydrophones to track vocalizing whales (singers) by their sounds (Frankel et al. 1989). Recent findings from acoustic-array work suggest that the initial distance between singers is one determinant of whether other singers will increase, decrease, or maintain their separation distance (Helweg et al. 1993). These results indicate that maintaining spacing among males is one function of song, as first suggested by Winn and Winn (1978), and that the biologically effective distance of song is approximately 6 km (Frankel et al. 1991). Based on a review of accumulated evidence it has been proposed that a dual function of song is that it serves to establish spacing among individual singers and as a means of advertisement to females (Helweg et al. 1993).

Abundance Estimates

Of the known wintering and summering areas of humpback whales in the north Pacific, the Hawaiian Islands are considered to contain the largest seasonally-resident population. Earlier shipboard surveys of the coastal waters of the Hawaiian Islands by the NMFS during the winter seasons of 1976–79 (Rice 1978; Wolman 1978) produced estimates of between 550-790 whales (mean estimate 650). More recently, mark and recapture techniques have been applied to analyses of fluke identification photographs that estimated 1,407 whales (95% confidence limits 1,113 and 1,701) as having visited the Hawaiian Islands during a four-year period, from 1980 to 1983 (Baker and Herman 1987; NMFS 1991). Because these estimates were produced using different abundance estimation techniques, they are not directly comparable and, therefore, cannot be relied on to suggest population increase.

Mobley and Bauer (1991), comparing sighting rates of pods seen in the winter seasons of 1977–80 with those seen in 1990 using identical methods, found significant increases across the 10- to 13-year period. The authors concluded that either there had been an increase in the size of the north Pacific population, or that a greater proportion of the north Pacific population is wintering in Hawaiian waters.

Aerial surveys performed during the 1991 season by Forestell and Mobley (1991) using modified line transect methods, estimated that 1,584 whales were present in coastal Hawaiian waters on the peak date for that season (Feb. 22, 1991). This survey series, however, was limited primarily to waters within the 100-fathom isobath.

The results of the 1993 survey series yielded an abundance estimate of 669 whales, with a 95% log-based confidence interval of 536-835 (C.V. = 11.3%) (Mobley et al. 1993). This estimate refers to the number of animals that were likely to be at the surface at the time of survey, but does not reflect the number of whales below the surface (Note: line transect models of abundance estimation assume the g(0) or probability of detection on the transect line to be 1, which is not true for cetaceans since they spend much of their time underwater). Shore station results taken from a sample of over 600 surfacings from the north shore of Kauai (1993 ATOC Marine Mammal Research Project, unpublished data) show whales to be at the surface 19% of the time. Thus, the corrected population estimate is roughly 3,500 whales, although this estimate may vary pending more reliable estimates of whale surface time.

Distribution Trends

Earlier aerial surveys conducted during the 1977–80 winter seasons (Herman, Forestall, and Antinoja 1980; Baker and Herman 1981) suggested that the majority of humpback whales were found in the shallow waters (<100 fathoms) of the major Hawaiian Islands, though extensive surveys in deeper waters were not conducted. Analyses of pod locations in the four-islands and Penguin Bank regions revealed that whales were not distributed homogeneously throughout the 100-fathom isobath but were generally found in more shallow water (modal depth=27 fathoms), (Forsyth, Mobley and Bauer 1991). More recent surveys have concentrated in waters exceeding 100 fathoms (Figure 4.1) and have found 73% of all humpback whales within the 100-fathom isobath (Mobley et al. 1993) (Figure 4.3). The fact that 27% of all sightings were in deep waters suggests that past surveys, with efforts concentrated in waters less than 100 fathoms, may have underestimated the number of whales present.

The earlier surveys (1977-80) showed wintering humpback whales to be concentrated in the waters of the four-islands and Penguin Bank regions. The majority of pods containing calves were also found in these areas (Figure 4.4). A comparison with the 1990 aerial survey results showed that these regions were still preferred by adults and calves, but revealed substantially increased sighting rates around the islands of Niihau and Kauai (Figure 4.5). The 1993 aerial survey results (Figure 4.3) support the findings of earlier surveys with regards to the preference of wintering humpback whales for various island regions. Arranged in order of decreasing sighting rate they are as follows: Penguin Bank, four-islands region, Kauai/Niihau, Hawaii and Oahu.

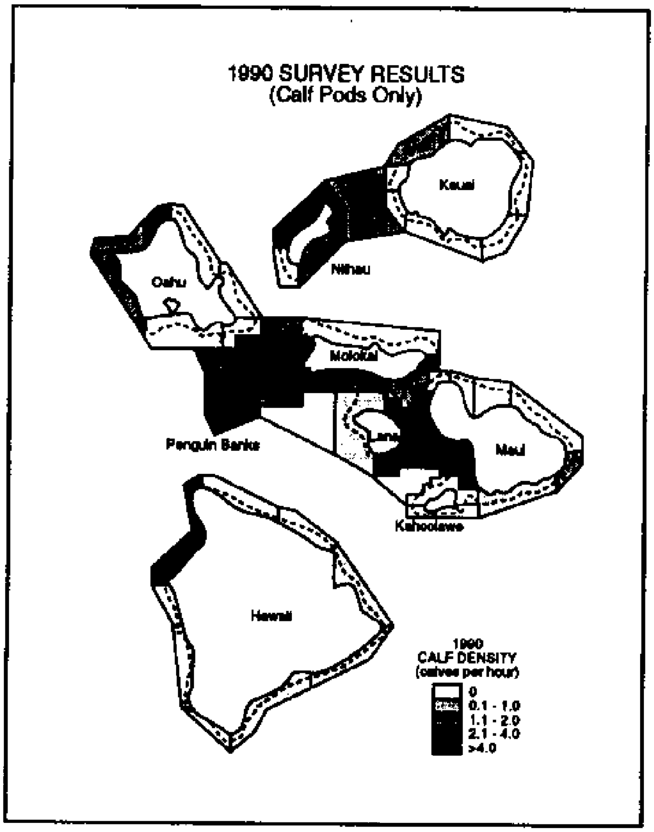

Figure 4.4

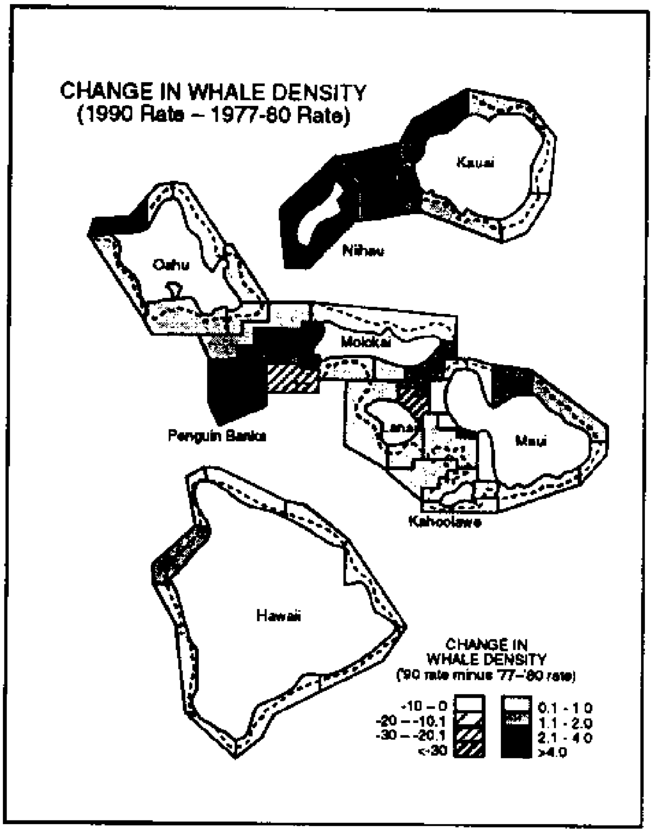

Figure 4.5

Preferred Cow/Calf Grounds

During the 1990 aerial survey series, all of the pods sighted were orbited to determine pod composition. For this reason, the 1990 results provide a more reliable indication of the number of calves present in recent years, as well as the regions preferred by pods with calves (Figure 4.4). Of the 361 whale pods observed (where pod composition could be confirmed), 79 (22%) contained calves. Sixty-eight percent of all calf pods observed were seen in the four-islands and Penguin Bank regions. Based on these data, Mobley and Bauer (1991) described these regions as preferred calving grounds, probably because of the greater expanses of available shallow water (less than 100 fathoms).

Effects of Low-Frequency Sound

The effects of low-frequency sound (LFS) on marine mammals have come under intense scrutiny recently. Frequencies less than 100 Hz are of particular concern owing to their long-distance propagation characteristics, potentially carrying across entire ocean basins given sufficient amplitude. Presumably, vessel effects on the behavior and distribution of whales are mediated by the emission of LFS.

Most of what little is known about LFS effects comes from investigations of oil industry-related noise. Malme et al. (1985) investigated the effects of air guns and playbacks of drilling platform sounds among other oil industry-related noises and found no clear evidence of humpback whale avoidance of the sound source at exposure levels up to 172 dB (re: 1uPa) for the air gun source and up to 116dB (re 1uPa) for continuous sound from industrial noise playback. For other Mysticete species, avoidance of such anthropogenic sounds has been detected at exposure levels of approximately 115 dB to 120 dB (Malme et al. 1984 for gray whales; Richardson et al. 1991 for bowhead whales). Projects such as the ATOC Marine Mammal Research Program currently underway, promise to expand our knowledge of the effects of LFS on humpback whales in particular.

The smaller Odontocete species are probably less affected by LFS. Johnson (1966) showed very poor sensitivity of captive bottlenosed dolphins to frequencies less than 100 Hz. Specie differences in sensitivity are quite possible, however.

SUMMARY

1. A total of 24 cetacean species (five Mysticetes; 19 Odontocetes) have been observed in Hawaiian waters, though only 15 with any regularity (Shallenberger 1981). Of the Mysticetes, humpback whales are the only species with more than incidental occurrence.

2. Since humpback whales presumably do not feed while in Hawaii, the primary forces affecting their behavior and distribution while wintering in Hawaiian waters are those associated with reproductive success. The primary forces affecting the behavior and distribution of Odontocete species are associated with the availability of prey species.

3. Based on the 1993 aerial survey results, four Odontocete species were identified as occurring in shallow coastal waters along the major Hawaiian Islands, thus potentially falling under the jurisdiction of the sanctuary. These species include bottlenosed dolphins (*Tursiops gilli*), false killer whales (*Pseudorca crassidens*), spinner dolphins (*Stenella longirostris*), and spotted dolphins (*Stenella attenuata*).

4. The 1993 survey results indicated Odontocete species to be particularly abundant in the waters surrounding Kauai and Niihau. They were less abundant in the four islands (Maui, Kahoolawe, Lanai, Molokai) and Penguin Bank regions, however, where humpback whale densities are greatest.

5. Comparison of results from earlier aerial surveys (1977–80) with recent surveys using identical methods (1990) suggest that the number of humpback whales wintering in Hawaiian waters may be increasing.

Additionally, abundance estimates from surveys performed between 1977–93 have shown a consistent pattern of increase.

6. Humpback whales generally prefer shallower waters than Odontocete species. Of the 403 groups of humpback whales sighted in 1993, 73% were in waters less than 100 fathoms. Only 19% of the 58 Odontocete groups sighted were in these shallow depths.
7. The combined aerial survey results show clear preferences of humpback whales for different island regions. Ranked in decreasing order of sighting rate (pods/hr of survey), the regions are as follows: Penguin Bank, four islands region, Kauai and Niihau, Hawaii, and Oahu.
8. Humpback whale pods with calves show clear preferences for the shallow waters of the four-islands and Penguin Bank regions. This preference has been stable for 15 years of surveys.

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CHAPTER 5
OTHER THREATENED AND ENDANGERED SPECIES

DATA SOURCES

This chapter examines turtles, seabirds, and the Hawaiian monk seal within the designated boundaries of the Hawaiian Islands Humpback Whale National Marine Sanctuary. A listing of threatened and endangered species in Hawaii and the Pacific islands was obtained from the U.S. Fish and Wildlife Service. Information concerning turtles and monk seals was obtained from the National Marine Fisheries Service's (NMFS) Honolulu Laboratory, and information on seabirds was obtained from the Hawaii Audubon Society. Additional information was gathered from books, peer reviewed journal articles, and "grey" literature found at the University of Hawaii's Hamilton Library and the NMFS Service's library. This information was supplemented with personal communications with experts. George Balazs of NMFS provided information concerning threatened and endangered sea turtles in Hawaii; William Gilmartin of NMFS contributed information on the Hawaiian monk seal; and Dr. Sheila Conant, Department of General Science, University of Hawaii, provided information on Hawaii's endangered birds.

SEA TURTLES

Five species of marine turtles are known to inhabit the waters of the Hawaiian Islands: green sea turtle (*Chelonia mydas*), hawksbill sea turtle (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), and the olive ridley (*Lepidochelys olivacea*) (Des Rochers 1992). Leatherback, loggerhead, and olive ridley turtles are not known to nest in the Hawaiian Islands and are rarely seen in Hawaiian waters (Balazs 1978). Hawksbills nest on the main Hawaiian Islands primarily on several sand beaches on the island of Hawaii and on the east end of Molokai (Hawaiian Sea Turtle Recovery Team 1992). The green sea turtle is the most commonly found turtle throughout the Hawaiian Island chain. More than 90% of the breeding and nesting of green turtles occurs at French Frigate Shoals in the Northwestern Hawaiian Islands (NWHI), although a substantial population resides and returns to the waters within Maui and Kauai Counties.

Hawksbill Turtles

The hawksbill turtle is listed as endangered under the Endangered Species Act of 1973 (U.S. Fish and Wildlife Service 1992). Information on the life history and ecology of hawksbill turtles in the Hawaiian Islands is lacking although these sea turtles were well known to the pre-contact Hawaiian people (Hawaiian Sea Turtle Recovery Team 1992). The Hawaiians did not value the hawksbill as a food item possibly because of its periodic toxicity due to the turtle's dietary habits. According to Balazs (pers. comm. 1993) no more than 15 nesting sites are recorded each year. The nesting period extends from July through November (Hawaiian Sea Turtle Recovery Team 1992). The most consistently used nesting sites are Kamehame Point on Hawaii and at the river mouth of Halawa Valley on Molokai. The NWHI appear to be unfavorable breeding and nesting grounds for the hawksbill turtle.

Green Sea Turtles

The green sea turtle, listed as threatened under the Endangered Species Act, is a long-range migrant breeder that spends most of its life foraging and resting in nearshore benthic habitats (Balazs, Forsyth, and Kam 1987). Historically, green sea turtles nested on beaches throughout the archipelago but rarely outside the NWHI today (Des Rochers 1992). The breeding season at French Frigate Shoals, which is the main nesting area within the NWHI, lasts for about five months from May through September (Hawaiian Sea Turtle Recovery Team 1992).

There are numerous sightings of green sea turtles in the waters off Maui County including Honokowai, Maliko Bay, Olowalu, Kahului Bay, and Palaau Bay on Molokai. Between 1948 and 1973, the island of Maui reported the highest percentage of commercial captures of sea turtles (Balazs 1980). Today, many turtles return to Kahului Bay possibly for the warmer waters necessary to increase their metabolism (Balazs 1980). Palaau may provide a possible habitat for the green turtle in deeper waters.

Kahoolawe and Lanai have only occasional and rare sightings of the green sea turtles, although they may have served as popular nesting grounds for green sea turtles in the past. Polihua Beach on Lanai, is the most documented area for green sea turtles on the main Hawaiian Islands; however, there have been no recent observations or sightings of sea turtles at Polihua, perhaps as a result of human use and erosion along the shoreline (Balazs 1980). According to Balazs (1984), though, Polihua Beach may serve as the best possibility for any future experimental restocking of sea turtles. The largest population of green sea turtles is located near Lanai at Keomuku and Kuahua (Balazs 1984). The U.S. Fish and Wildlife Service (1989) reports that green sea turtles have been seen in the off-shore waters of Kauai and are known to nest in the sandy bays along the coast of Kilauea Point.

There is insufficient data to estimate the historical number of green sea turtles in the Hawaiian Islands. Surveys of nesting turtles at French Frigate Shoals since 1973 provide an estimate of 750 total mature female green turtles (Hawaiian Sea Turtle Recovery Team 1992). Because 90% of all green sea turtle nests are found on French Frigate Shoals, the total female population is probably less than 900 throughout the Hawaiian Islands.

Green turtles feed primarily on benthic algae which is generally restricted to shallow depths. They have been reported to feed on 56 species of algae and nine species of vertebrates (Des Rochers 1992). Green turtles have been known to bask or rest on beaches (Balazs, Forsyth, and Kam 1987) although terrestrial basking is rare among sea turtles and has been exhibited by only a few populations of green sea turtles in the Pacific. In Hawaii, the basking behavior seems to be limited to beaches in the NWHI (Balazs, Forsyth and Kam 1987).

Most adult green turtles reside in the nearshore waters of the main Hawaiian Islands due to the abundance of preferred marine vegetation, the availability of suitable habitat for resting, and the presence of oceanic currents that carry juveniles towards the main islands (Balazs, Forsyth, and Kam 1987). Major resident areas are at depths greater than 20 m but generally not exceeding 50 m. These areas (Figure 5.1) include: Kau and North Kohala Districts (Hawaii); Hana District and Paia (Maui); north and northeastern coastal areas bordering the Kalohi and Auau Channels (Lanai); south coastal areas between Kamalo and Halena (Molokai); Kailua and Kaneohe Bays, northwest coast from Mokuleia to Kawailoa Beach (Oahu); Princeville, Na Pali Coast, and the south coast from Kukuiula to Makahuena Point (Kauai) (Des Rochers 1992).

Interim Turtle Recovery Plan

The NMFS is preparing a turtle recovery plan as required by the Endangered Species Act of 1973. An Interim Hawaiian Sea Turtle Recovery Plan, prepared by a team of scientists appointed by NMFS in 1985, was issued as an Administrative Report of the Southwest Fisheries Center in 1992 (Hawaiian Sea Turtle Recovery Team 1992). The interim plan addresses the recovery of hawksbill, green, leatherback, and olive ridley turtles. The plan recommends actions to reduce factors causing the decline of these turtles including human take, predation, disease, and habitat alteration of both the marine and terrestrial environment. Many recommended actions outlined in the interim plan, such as public education to eliminate turtle harassment, and maintaining the natural habitat, fit within the objectives of the sanctuary program.

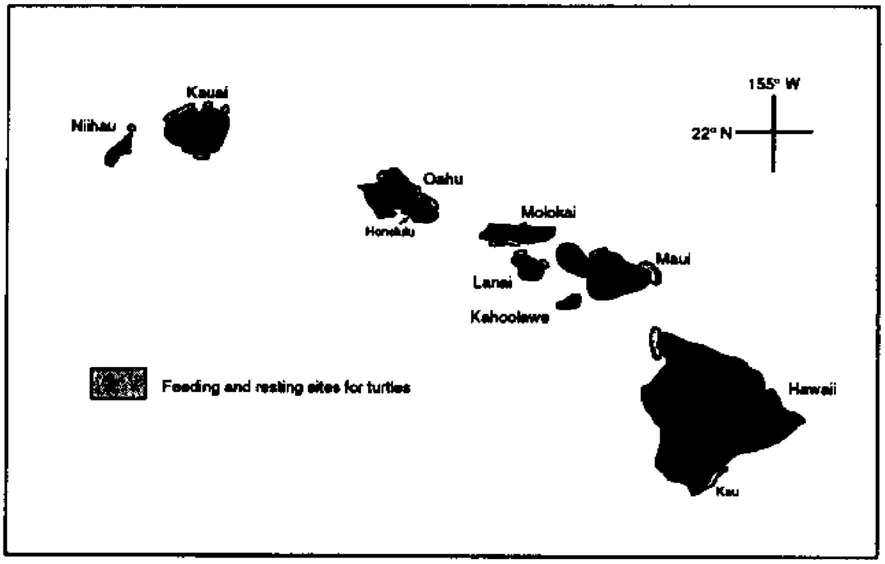

Figure 5.1 Feeding and Resting Sites for Green Sea Turtles

SEABIRDS

Before the arrival of the first Polynesians in the Hawaiian Islands, there were as many as 110 species of endemic birds throughout the archipelago. Between the time of the arrival of the first Polynesians and the arrival of Captain Cook in 1778, an estimated 40 species may have already been extinct (Hawaii Audubon Society 1989). Since the arrival of the Europeans in the Islands, another 22 species have become extinct (Hawaii Audubon Society 1989). The dramatic increase in the number of extinctions has been due to the introduction of foreign plants and animals by recent arrivals.

Today, 22 marine birds can be found throughout the Hawaiian chain, mainly in the NWHI (Hawaii Audubon Society 1989). Of the 30 species of native Hawaiian birds listed as endangered or threatened by the U.S. Fish and Wildlife Service, only one is commonly found in the vicinity of the designated sanctuary, the Hawaiian dark-rumped petrel (*Pterodroma phaeopygia sandwichensis*).

The Hawaiian dark-rumped petrel has been observed on the islands of Kauai, Lanai, Hawaii, and Molokai. Once Oahu's most numerous seabird, the dark-rumped petrel is mainly confined to the Haleakala Crater on Maui (Berger 1981). There are barely 400 to 600 pairs of petrels in the Hawaiian Islands (Sheila Conant, pers. comm. 1993). These marine birds return during their breeding season (March-October) to nest at elevations between 7,200 and 9,600 feet, the only bird species in Hawaii that nests at such high altitudes (Sheila Conant, per. comm. 1993). Petrels spend most of their time at sea, feeding on squid, fish, and crustaceans. They come ashore only to nest and raise their young. It is possible that Maui and the other Hawaiian Islands are merely a stop-over for breeding and nesting. No observations have been conducted.

HAWAIIAN MONK SEAL

Breeding populations of the Hawaiian monk seal, *Monachus schauinslandi* occur almost exclusively in the NWHI. Data on the size and distribution of the Hawaiian monk seal population prior to 1950 are lacking (U.S. National Marine Fisheries Service 1991), although it is estimated that the population at that time was about 3,500 (Altonn 1991). Since 1957, the population has declined by 60%, and today there are approximately 1,200 individuals (Gilmartin, pers. comm. 1994). The Hawaiian monk seal is listed as an endangered species under the Endangered Species Act.

The exploitation of the Hawaiian monk seal began shortly after 1814, when the Russian explorer Lisianski reported that he observed them in the NWHI (Hiruki and Ragen 1992). The monk seal served as a valuable source for oil, pelts, and food for sealers and sailors. Commercial activity and most incidental taking ended by the late 1800s after seal populations had been decimated (Hiruki and Ragen 1992). Most, if not all, taking by humans stopped once the seal was listed as an endangered species.

Since Lisianski's exploration, there have been two major population declines in the monk seal's history. One, in the 1800s, as a result of extensive sealing and the second, between the 1950s and 1970s primarily due to human disturbance of the seal's breeding areas (U.S. National Marine Fisheries Service 1991). The latter period resulted in a 50 to 60% reduction of the seal population (Ragen 1993). Birth count monitoring began in 1983 at the breeding islands. From 1983 to 1988 the number of recorded births increased from 162 to 224. In 1989, the count decreased, and in 1990 only 143 births were observed — the lowest number of births ever recorded (U.S. National Marine Fisheries Service 1991; Altonn 1991).

Monk seals are extremely sensitive to human activity and disturbances and are rarely seen in the main Hawaiian Islands. Seal births were observed on Kauai in 1988 and on Oahu in 1991 (Gilmartin, pers. comm. 1994). Monk seals have also been reported basking along the beaches of Maui (Tanji 1992, 1993). Both incidents verify that the main Hawaiian Islands continue to serve as temporary resting grounds for the monk seal. A list of monk seal sightings reported to the NMFS in the main Hawaiian Islands since 1985 is contained in Table 5.1 and a listing of sightings in 1993 is contained in Table 5.2

TABLE 5.1. MONK SEAL SIGHTINGS IN THE MAIN HAWAIIAN ISLANDS, 1984–93

Reported to the National Marine Fisheries Service.

Year	*Kauai*	*Oahu*	*Maui*	*Molokai*	*Lanai*	*Kahoolawe*	*Hawaii*
1984	1	9	-	9	-	-	-
1985	1	2	3	1	-	-	-
1986	3	10	5	-	5	1	5
1987	35	13	-	-	-	-	1
1988	31	11	1	1	-	1	-
1989	45	11	2	1	-	-	-
1990	6	19	3	2	-	1	1
1991	1	39	7	-	1	2	1
1992	2	37	6	1	-	1	4
1993	3	14	7	1	-	-	6

Source: National Marine Fisheries Service

Monk Seal Recovery Plan

The National Marine Fisheries Service completed a monk seal recovery plan in 1983 as required by the Endangered Species Act (Gilmartin 1983). The objectives of the plan were to (1) identify and mitigate the natural factors causing the decline in the seal populations; (2) characterize seal habitat; (3) assess monk seal populations; (4) document and mitigate effects of human activity; (5) implement appropriate management actions leading to conservation and recovery; and (6) develop educational programs. The plan outlines the tasks necessary to meet the objective and assigns the tasks to appropriate federal and state agencies. The NMFS appointed a recovery team of marine scientists to monitor the implementation of the plan. The Monk Seal Recovery Team continues to meet regularly to review research findings and advise NMFS on monk seal research and recovery activities (U.S. National Marine Fisheries Service 1991).

TABLE 5.2. REPORTED 1993 MONK SEAL SIGHTINGS IN THE MAIN HAWAIIAN ISLANDS

Month	*Location*	*# Sightings*
January	Kona Coast, Hawaii	1
January	Kihei, Maui	1
January	Maalaea Bay, Maui	1
February	Waimea Bay, Oahu	1
February	Haleiwa, Oahu	1
February	Kihei, Maui	2
February	Kaena, Oahu	1
February	Kau, Hawaii	1
March	Maalaea Bay, Maui	1
March	Kaena, Oahu	1
March	Kaneohe, Oahu	1
March	Hauula, Oahu	1
March	Laie, Oahu	1
April	Kaena, Oahu	1
May	Anahole, Kauai	1
June	Haleiwa, Oahu	1
June	Chun's Reef, Oahu	1
July	Kaena, Oahu	2
July	Kaaluwalu Bay, Hawaii	1
August	Milolii, Hawaii	1
September	Apua Pt, Hawaii	1
September	Kaupo, Maui	1
September	Hana, Maui	1
October	Kau, Hawaii	1
November	Kipu Kai, Kauai	1
November	Kapaa, Kauai	3
December	Kawaikapu, Molokai	1
December	Ewa Beach, Oahu	1

Source: National Marine Fisheries Service 1993

Implications for the Sanctuary

The dark-rumped petrel, *Pterodroma phaeopygia sandwichensis*, and the Hawaiian monk seal, *Monachus schauinslandi*, are infrequent users of the designated sanctuary. The leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), and olive ridley (*Lepidochelys olivacea*) sea turtles are infrequent visitors to the Hawaiian Islands. Protection efforts may be enhanced by research and public education efforts funded by the NOAA's Sanctuary and Reserves Division, but the designated sanctuary is not considered the prime habitat for these animals. The sanctuary's management regime may include actions recommended in the interim turtle recovery plan and any subsequent recovery plan for the dark-rumped petrel.

The situation is somewhat different for the threatened green sea turtle (*Chelonia mydas*) and the endangered hawksbill sea turtle (*Eretmochelys imbricata*). Both of these turtles are found within the designated sanctuary. The hawksbill nests on beaches in Maui County and the green sea turtle forages throughout Maui and Kauai

Counties. Protection and recovery of these two species may be considerably enhanced by their inclusion into the sanctuary. The interim recovery plan for these two species lists several actions which could be implemented in a sanctuary management regime.

RECOMMENDATIONS

1. Methods for the protection of sea turtles and monk seals populations are covered in respective recovery plans.* NOAA's Sanctuaries and Reserve Division may wish to incorporate the management strategies recommended in those recovery plans as part of the management regime of the Hawaiian Island Humpback Whale National Marine Sanctuary.

*The Interim Hawaiian Sea Turtle Recovery Plan is reported in a NMFS Administrative Report. A Pacific-wide recovery plan is still in the preparation stage.

2. The Sanctuaries and Reserve Division and the State of Hawaii may wish to consider including the hawksbill and green sea turtles for management within the designated sanctuary. These turtles are considered either threatened or endangered under the Endangered Species Act of 1973 and are found in the areas within the designated sanctuary boundaries. The green sea turtle's foraging and resting ranges include areas around Maui and in the waters off Kilauea Wildlife Refuge on Kauai. The hawksbill turtle is known to nest on beaches in Maui.

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CHAPTER 6

TRADITIONAL USES OF THE MARINE ENVIRONMENT

DATA SOURCES

The information presented in this section relies primarily on literature obtained from the University of Hawaii's Hamilton Library Pacific Collection and the Bernice Bishop Museum Library. A number of articles were found in peer-reviewed journals and theses and dissertations. The primary source of information is "grey" literature, including agency-commissioned studies and conference papers. Interviews were also conducted with Hawaiian informants on Lanai and Oahu.

Island	*Informant*	*Date*
Lanai	Mr. Sol Kahoohalahala (resident) Mr. Sam Kaopuiki (resident) Ms. Elaine Kaopuiki (resident)	September 20, 1993
Oahu	Dr. Daviana McGregor Asst. Professor, Ethnic Studies University of Hawaii	September 28, 1993

Additional information was provided by Professor Luciano Minerbi, Urban and Regional Planning, University of Hawaii and staff planner for the task forces on Molokai dealing with self-sufficiency and Hawaiian fishponds.

INTRODUCTION

This section will explore some of the ways Hawaiians interact with the ocean, and how those interactions could impact the proposed Hawaiian Islands Humpback Whale National Marine Sanctuary. Although many other ethnic groups (e.g., Chinese, Japanese, Filipino, Portuguese, and others) have made extensive use of ocean resources, they do not claim special use rights and thus will not be discussed.

HAWAII: BACKGROUND

According to current archaeological evidence, the Hawaiian Islands were most probably settled by Polynesian voyagers sailing from the Marquesas Islands (Kirch 1985). Other scholars who have used archaeological findings such as fishhooks, contend that a second group of Polynesian settlers arrived from Tahiti on an inmigrating wave that lasted from the twelfth to the fourteenth century (Emory and Sinoto 1965). Likewise, Fornander (1878) and Emerson (1893) used Hawaiian oral tradition and mythology to support hypotheses of ancestral connections between Hawaii and Tahiti.

Although it has become standard to use A.D. 750 as the initial or early settlement date for the Hawaiian Islands, newer archaeological evidence places initial settlement at A.D. 300 or earlier (Kirch 1985). In fact, Kirch (1985) states that of a collection of sites shown to have been occupied by A.D. 300-600, "none . . . appear to represent initial colonization". He concludes that the first settlement of Hawaii must have "occurred sometime *before* the fourth to fifth centuries" (emphasis in original).

Estimates of Hawaii's pre-contact population vary greatly, although the most widely-accepted estimate places the pre-contact population of Hawaii between 200,000 and 250,000 people (Schmitt 1971). The 1983 edition of the *Atlas of Hawaii* (University of Hawaii) lists the pre-contact population between 250,000 and 300,000 people. Stannard (1989) disputes these estimates, arguing that the Hawaiian population was more likely in the range of 800,000 individuals and possibly more.

HAWAIIANS: SETTLEMENTS AND SOCIAL PATTERNS

The early Hawaiians arranged their land and seascapes to reflect their ideas of natural and social order. Each island was called a *mokupuni* or *moku*. *Mokupuni* were further divided into *moku-o-loko* [*moku*], such as Ewa or Waianae on Oahu. These interior island divisions were portioned into *ahupuaa*, *ili*, and smaller parcels which were worked and farmed by *ohana*, or extended family units. The *ahupuaa* was the basic socio-economic land unit. Generally, the *ahupuaa* was a pie-shaped segment of land with its apex at the summit of the central mountain ridges of an island and its wider base at the shore and beyond into ocean fishing grounds. An *ahupuaa*'s boundaries were usually delineated by natural features such as a ridge line separating two valleys. Thus, the valley of Kahana constituted one ahu*puaa* of the *moku* of Koolauloa on the northeastern side of the island of Oahu. Hawaii's place names and property laws still reflect these land divisions today.

Within the *ahupuaa*, everyone had access to various resources, from the sea to the upland forests. People living at or near the shore often exchanged fish or nearshore produce for upland products with their relatives who lived farther inland.

Pre-contact Hawaiian society was highly structured and hierarchical according to ascribed social status based on ranking senior and junior lineage. Lilikala Kameeleihiwa has conceptualized the Hawaiian system of social hierarchy as a triangle:

> On each main island, a single *Moi* [King] at the apex of the society served as an intermediary between the *Akua* and the rest of *Ka Lahui* [the Nation]. Several levels of subordinate *alii nui* and *Kahuna Nui* were followed by more numerous and lesser ranking *alii* and *kahuna* who acted as *konohiki*. These people created a buffer between the *Moi* and the vast majority of *makaainana* who made up the foundation of the society.
>
> Those at the top were *kapu*, or sacred, and possessed of *mana* [spiritual and political power]. Those at the bottom were *noa*, common or free from *kapu* and, by extension, without the necessary *mana* . . . to invoke a *kapu* — although even a common fisherman, if successful, had some *mana*. Those in between were on a sliding scale, having less *mana* the farther down the triangle they slipped and the farther away they fell from high lineage (Kameeleihiwa 1992:45–46).

This hierarchical system of social organization ensured that the Hawaiian nation lived in harmony with the spiritual and physical world (Kameeleihiwa 1992:25–26). Within the ancient Hawaiian social and economic systems of hierarchy and land division were the concepts of *malama aina* (caring for the land) and *pono* (harmony, balance). The Hawaiians believed they were related to the land and the *aina* (that which feeds) was their mother, and the plants that sustained them, particularly *kalo* (taro), were elder siblings. This was also true for the sea. Many contemporary Hawaiians continue to live by these precepts, or are turning to this way of constructing the world as a means of recasting their cultural heritage in today's world.

This summary provides only a brief glimpse of the ancestral Hawaiians. It is important to recognize that Hawaiian cultural concepts of resource use such as *pono* and *aloha aina* (love of the land) differ significantly from contemporary western concepts. The challenge for NOAA will be to integrate Hawaiian cultural concepts with contemporary management of the sanctuary.

MARINE AREAS AND RESOURCES OF RELIGIOUS AND CULTURAL SIGNIFICANCE

Hawaiians used the ocean for fishing, aquaculture, trade, transportation, and communication. In addition, the marine waters also figured predominently in religious practices including the worship of personal deities, known as *aumakua*. Each of these areas will be explored below.

Native Hawaiian Subsistence Fishing

Most Pacific island subsistence economies integrated agriculture with the exploitation of reefs, lagoons, and pelagic waters (Kirch 1982). The Hawaiians were adept at exploiting inshore and open-water marine resources. This exploitation included not only finfish, but mollusks, sea urchins, and other invertebrates — including stony coral — for food, tools, and religious offerings (Kirch 1982). In utilizing the sea, the Hawaiians evolved a different set of "use rights" from the Western practices of open access to marine resources. The vestiges of these use rights carry over today and may have a bearing on the management of the proposed sanctuary.

Pre-Contact Jurisdiction (Prior to 1778)

In pre-contact Hawaii, temporal rule of the islands was divided among a number *alii*, or chiefs. Each of these chiefs had, in theory, unrestricted suzerainty over all the resources within his *moku* or districts (Meller 1985). The *ahupuaa*, in which the *moku* was subdivided, "usually had attached to them ocean fishing rights, in some instances not only adjacent to their own shores, but spreading out on each side up and down the coast for many miles" (Cobb 1908). Thus, the *alii* controlled all fishing rights in their jurisdiction.

Managing the *ahupuaa* were the *konohiki* or agents of the *alii*. The *konohiki* collected a portion of the harvest of both land and ocean resources on behalf of the *alii* from the *hoaaina* or tenants and placed limitations on the uses of resources depending on environmental conditions (Meller 1985). Fisheries located outside the *ahupuaa* were also subject to control by the *alii*.

Fishery Rights in the Kingdom of Hawaii (1795 to 1893)

Private fishing rights received official written recognition in 1839 with the passage of the *Act to Regulate the Taxes* which reallocated the right of ownership of fishing grounds to *makaainana*, or common people, and to the *konohiki*, with a portion reserved for the King (Clay et al. 1981). This new regulatory regime recognized the rights of the common people to fish in the nearshore areas while limiting the power of the *konohiki* to keep people from exploiting ocean resources (Meller 1985). Fishery rights of the common people were expanded with the passage of *An Act Granting to the People the Rights of Piscary Now Belonging to the King* in 1851. With this act the King relinquished all rights to open-ocean fisheries to the common people.

This new right of the common people led to the formation of family-based fishing *koa huna*, or fishing grounds, in the open sea (Murakami and Freitas 1987). The locations of these *koa* were usually kept secret within the ohana (extended family) and were passed down from generation to generation (Anders 1987). Although many of these deep sea *koa* locations remain secret and are preserved only through oral traditions, they exist today (Murakami and Freitas 1987). One master fisherman in 1902 could name over 100 *koa* and their locations — places that he had fished since childhood (Kahaulelio 1902).

Fishing Rights After the Overthrow of the Monarchy (1893 to Present)

In 1893, the Kingdom of Hawaii ended when its government was overthrown in an unconstitutional *coup d'état*. Nonetheless, Hawaiian fishing rights remained intact throughout the three stages of government that followed the overthrow of the Kingdom. In the Treaty of Annexation, the Republic of Hawaii ceded absolute sovereignty over the Hawaiian Islands to the U.S.; it was not, however, accepted by Congress. Instead, in the Hawaiian Organic Act of April 30, 1900, Congress conferred power on the Territory of Hawaii and specified that:

> . . . the law of Hawaii not inconsistent with the Constitution or laws of this Act shall continue in force subject to repeal or amendment by the legislature of Hawaii or the Congress of the United States (Section 6) (Iversen, Dye, and Paul 1990).

According to Murakami and Freitas (1987), this section of the Organic Act, the rights of the *konohiki* to the shoreline fishery and the rights of the *makaainana* to the deep-water fishery were carried over from the Kingdom into statehood and are in force today.

The U.S. Congress attempted to extinguish all *konohiki* fishing rights in the Organic Act of 1900. Section nine of the Act provided for a two-year period in which the owners of *konohiki* rights could register claims to a *konohiki* fishery with the Territorial Courts or forfeit all claims to those rights (Meller 1985). Once the claims were filed it was the intent of the federal and territorial governments to acquire all rights to the registered *konohiki* fisheries through condemnation (Clay et al. 1981).

There exists some uncertainty as to the total number of *konohiki* fishing areas and how many were registered before 1903. Meller (1985) estimates that there may have been between 363 and 720 *konohiki* areas in total. The author also notes that opinions vary as to the number of registered areas, from a low of 101 to a high of 144. Because of the discrepancy in the number of registered rights, there is no exact figure as to the number of rights in existence today. Khil (1978) puts the figure at 42, with the majority located on Oahu (Figure 6.1). Meller (1985) mapped the location of the outstanding fishing rights areas for each of the islands. These figures are reproduced here for the islands of Maui, Molokai, Lanai, and Kauai (Table 6.1). There is slight disagreement between Khil's and Meller's accounting of remaining *konohiki* fishing rights areas. Khil lists three outstanding *konohiki* fisheries for Molokai, whereas Meller lists only one. The variation is due to conflicting sources of information.

TABLE 6.1. DISPOSITION OF KONOHIKI FISHERIES

Island	Registered	Condemned	Outstanding
Oahu	59 *	27	26
Hawaii	9	0	9
Maui	26	26	0
Molokai	3	0	3
Lanai	2	0	2
Kauai	9	7	2
Total	**108**	**60**	**42**

*There is a discrepancy among the various sources as to the exact number of registered *konohiki* fisheries for Oahu and Hawaii.

Source: Khil 1978:25.

No attempts were made to extinguish use rights to open-ocean fisheries (those outside the three-mile territorial waters). They were never repudiated, condemned, or canceled by the provisional, territorial, or state governments (Kosaki 1954; Murakami and Freitas 1987). The waters beyond the three-mile territorial seas were considered to be open access waters and not subject to U.S. control under the customary laws of that time (Iversen, Dye, and Paul 1990).

The U.S. assumed management jurisdiction over fishery resources out to 200 miles (the Exclusive Economic Zone or "EEZ"), with the passage of the Fisheries Conservation and Management Act (FCMA) of 1976. The Act is silent on the matter of Hawaiian open-ocean fishing rights. According to customary law prior to the passage of the FCMA, however, coastal residents could assert rights to high seas resources under two legal doctrines: 1) effective exercise of sovereign control, and 2) long and continuous usage. Under these doctrines, Hawaiians may have a claim on preferential rights to resources in the U.S. EEZ.

Subsequent state legislation, including the 1978 amendment to the State Constitution, Article XII, Section 7, reaffirms the rights "customarily and traditionally exercised by . . . descendants of native Hawaiians";

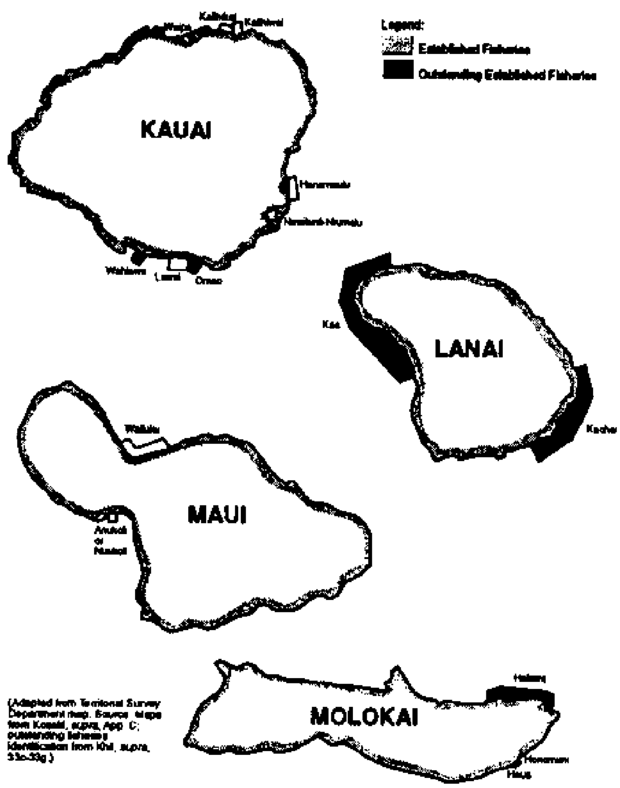

Figure 6.1 Konohiki Fishing Areas

however, no requirements for registration or any legal claim to specific areas were ever made. Thus, determining the specific areas where the *koa huna* are located is problematic.

Recent Development in Subsistence Fishing

A Subsistence Task Force was formed on Molokai in 1992 to discuss the management of Hawaiian homestead lands and adjacent marine areas on the island. The Task Force, which includes members of the community and state and county agencies are discussing among other issues an updated definition of subsistence fishing and how to preserve the option for Hawaiians to return to a subsistence lifestyle. The Task Force has developed a draft plan that includes a proposal for a marine sanctuary in Moomomi Bay and surrounding waters which will allow access to nearshore waters for subsistence fishing (Daviana McGregor, pers. comm. 1993).

Implications for the Sanctuary

The claim of vested rights is very clear in the case of *konohiki* fishing rights, which have been adjudicated and upheld in the courts (e.g., Damon vs. Hawaii 194 U.S. 154, 1904). The claim for vested rights and preferential rights for *koa* fisheries is less certain. The fact that there are no legal boundaries established for the *koa* fisheries "argues against a claim for exclusive, vested fishing rights" (Iversen, Dye, and Paul 1990). However, without a test in the courts addressing the legal basis for or against use rights in areas outside the jurisdiction of the state, any opinion is merely speculative.

The existence of the *konohiki* and the potential existence of the *koa* fisheries have implications for the establishment of a marine sanctuary in Hawaii. The proposed Hawaiian Islands Humpback Whale National Marine Sanctuary covers an area around Maui County that includes both state and federal waters. Included within the boundaries are some of the documented *konohiki* fisheries and potentially some of the *koa* fisheries. Sanctuary management regimes should account for these traditional Hawaiian fisheries.

The Molokai Self-Sufficiency Task Force has not finalized its plans at this time, but the results of their planning effort could impact the development of the sanctuary.

AQUACULTURE

Aquaculture was another important historical use of the marine environment. According to Kikuchi (1973), "fishponds existed nowhere else in the Pacific in types and numbers as in prehistoric Hawaii". Summers (1964) states that marine fishponds are found nowhere else in Polynesia. Indeed, the practice of mariculture may have originated in Hawaii (Costa-Pierce 1987).

Historical evidence indicates that fishponds were introduced on Oahu prior to the thirteenth century by settlers from the Society Islands (Kikuchi 1973). The earliest aquaculture systems were probably composed of natural bodies of water, weirs, dams, fish traps, and artificial fish shelters (Kikuchi 1973). By the fourteenth century, true fishponds were being developed throughout the Hawaiian Islands (Kikuchi 1973).

The Hawaiians built different types of fishponds to take advantage of a range of geographic and aquatic conditions. According to Kikuchi (1973), "the trend was to utilize practically all available bodies of water of some size in the construction and evolution of fishponds". The different fishponds that evolved for use in fresh, brackish, and marine waters have been classified into six main types (DHM 1990).

Type I: *loko kuapa* — a coastal marine fishpond artificially enclosed by a seawall;

Type II: *loko puuone* or *hakuone* — an isolated shore fishpond usually formed by the development of a barrier beach building a single elongated sand ridge parallel to the coast;

Type III: *loko wai* — a freshwater fishpond located inland from the shoreline;

Type IV: *loko ia kalo* or *loko loi kalo* — fishpond that uses an irrigated taro plot as an inland water pond for the raising of fish;

Type V: *loko umeiki* — a fishtrap similar in shape and construction to a *loko kuapa* with many stone lanes leading into areas enclosed by nets; and

Type VI: *kaheka* and *hapunapuna* - a natural pool or a holding pond.

Examples of each of these types are in Figure 6.2

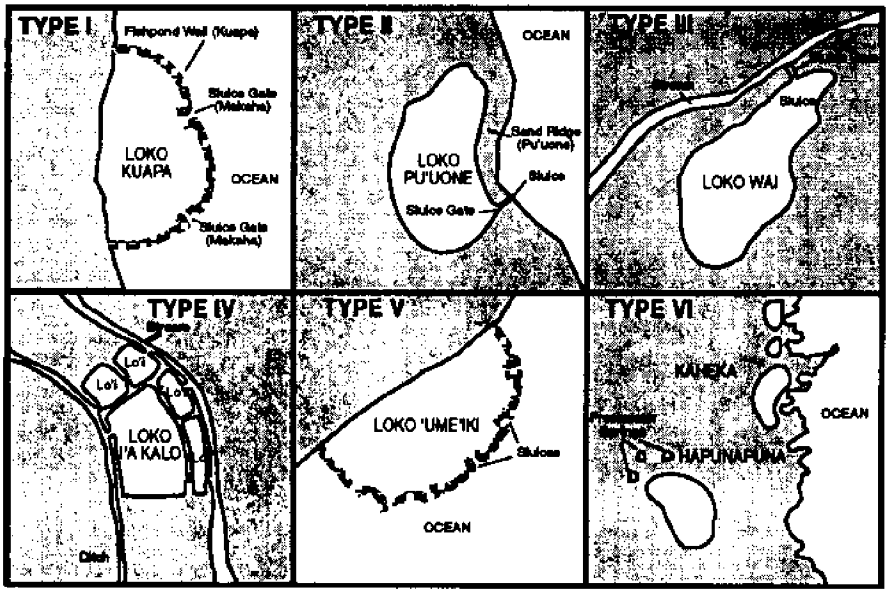

Figure 6.2 Hawaiian Fishpond Types

Estimate of Number and Distribution

Estimates vary as to the number of fishponds that were built in the Hawaiian Islands. Costa-Pierce (1987) estimates there were 360 at the time of European contact; Kikuchi (1973) reports that 449 fishponds were constructed; and DHM Inc. (1990) lists 488 fishponds in its fishpond inventory.

The location and distribution of the type of fishponds throughout the inhabited islands seems to be geographically determined. For example, on the island of Molokai, which has a protected, shallow reef along its southern coastline, more *loko kuapa* were constructed there than anywhere else in the islands (Costa-Pierce 1987). On the island of Hawaii, where the shoreline drops off too precipitously for construction of large walled ponds, inland upstream freshwater ponds were built (Hudson 1932). The type and location of known fishponds are listed in Table 6.2.

TABLE 6.2. FISHPONDS BY TYPE AND ISLAND

Type	*I*	*II*	*III*	*IV*	*V*	*VI*	*II/VI*	*?*[1]	*Total*
Niihau		1							1
Hawaii	21	61	14		1	30	3	8	138
Maui	11	12	7			8		6	44
Lanai	1				3				4
Molokai	44	12	2		13			3	74
Oahu	70	22	78		4			4	178
Kauai		16	13	7				14	50
Total	**147**	**124**	**114**	**7**	**21**	**38**	**3**	**35**	**489**

[1] Unsure of type.

Source: DHM Inc. 1990; Kikuchi 1973.

Productivity and Use

Fishponds were a form of extensive aquaculture functioning with little or no input from pond managers. Costa-Pierce (1987) reported that the Hawaiians added cut grass, mussels, clams, seaweed, and taro leaves to the ponds, presumably to promote the growth of algae for feeding the herbivorous fish. Yields from this type of aquaculture are typically low and Cobb (1902) estimated that the ponds produced 336 kg/ha/yr (about 350 lb/ac/yr). Based on the number of ponds in existence in 1800 and considering that the average size was 15 acres, Apple and Kikuchi (1975) estimate that the fishponds would have produced about seven pounds of fish per person per year based on an estimated population of 266,000.

It is obvious that the fishponds were not meant to provide for the general population's daily needs. The fishponds most likely provided a supplement to the daily diet of fresh-caught fish, taro, and yams. According to most accounts, fishponds were owned by the *alii* and the fish raised in them were reserved for that class (Kikuchi 1973; Apple and Kikuchi 1975; Costa-Pierce 1987). Kikuchi (1973) adds that smaller fishtraps, irrigated taro plots, natural pools, and upland dams provided only occasional yields and were generally relegated for use by the lands' tenants. However, as far as the larger, more productive ponds were concerned, the *alii* kept "sacred and special resources, such as fishponds that produced especially tasty fish, under their direct control" (Costa-Pierce 1987).

Prior to consolidation of the Hawaiian Islands into a Kingdom by Kamehameha the Great in 1810, island chiefs and their courts were very mobile, establishing no European-like capitals. Fishponds were used to supply the local chief whenever he took up residence in a particular area. As chiefdoms were consolidated and courts became fewer but larger in number, fishponds took on an increasingly important political role (Apple and Kikuchi 1975). Any fishpond "in a conquered chiefdom became the personal property of the conquering high chief; whenever feasible, its harvest was used by the chief to help support him and his court" (Apple and Kikuchi 1975). In some cases fishponds themselves were the object of interregional conflicts (Kikuchi 1976). While fishponds probably produced "a relatively low but dependable yield in terms of total needs of the royal establishment, ownership of them increasingly became a symbol of high status within Hawaiian society . . . and was the sign of a powerful chief" (Apple and Kikuchi 1975).

Fishponds Today

With the population decline in the second half of the nineteenth century, much of the Hawaiian integrated farming system fell into disuse and disrepair. Native Hawaiians largely abandoned the practice of extensive aquaculture in favor of a Western-style food consumption pattern and the fishponds were left unmaintained. Coastal development for tourism and for residential purposes in the twentieth century, especially since statehood, has led to the destruction of many of the ancient fishponds.

Apple and Kikuchi conducted a visual survey of the coast of the main Hawaiian Islands and found only the remains of 157 fishponds (Apple and Kikuchi 1975). Of the 157, only 56 could be considered for possible restoration (see Figure 6.3). Table 6.3 is a listing of all the fishponds on the islands of Maui, Lanai, Kauai, and Molokai surveyed by Apple and Kikuchi. Madden and Paulsen (1977) conducted a study of 67 fishponds and found that only 28 were still in sufficient repair to be used for mullet (*Mugil cephalus*) and milkfish (*Chanos chanos*) culture. Costa-Pierce (1987) reported that by 1987 there were seven ponds in use for commercial and subsistence purposes.

On Molokai, a recently formed task force will recommend to the state how to manage the existing fishponds on that island. A study of the fishponds is being conducted by three University of Hawaii faculty members to advise the task force of possible options for restoration, use, and commercialization (Luciano Minerbi, pers. comm. 1993). Study and task force recommendations were not available at the time this report was prepared.

TABLE 6.3. FISHPONDS OF MAUI, LANAI, KAUAI AND MOLOKAI

Name	*Location (Ili, Ahupuaa, TMK)*	*Size (ac.)*	*Type*	*Owner*
MAUI FISHPONDS – HANA DISTRICT				
Haneoo	Haneoo/1-4-08:2 (*Loko-nui*;BPBM 50-Ma-A15-9)	11.2	I	P
Kuamaka	Haneoo/1-4-08:4 (*Loko-iki*;BPBM 50-Ma-A15-8)	1.3	I	P
LANAI FISHPONDS				
Lopa	Kaohai/4-9-03;9 (BPBM 50-La-A1-13)	.8	I	P
KAUAI FISHPONDS				
Kee	Haena/5-9-08:18	3	II	S
Kanoa	Hanalei/5-5-01:2	4	III	P
nameless	Wailua/4-1-03:16	3	II	P
Alekoko	Niumalu/3-2-01:1	32	III	P
nameless	Koloa/2-6-06;2 (*Hoai*; BPBM 50-Ka-B4-15)	4	II	P
nameless	Lawai/2-6-02:1 (*Lawai Kai*)	2	III	P
Nomilu	Kalaheo-kai/2-3-10:2	4	III	P
MOLOKAI FISHPONDS				
Kainaohe	Kaamola/5-6-05:22	17	I	P
Ualapue	Ualapue/5-6-01:1	22	I	S
Kalokoeli	Kamiloloa/5-4-02:14	28	I	S
Kupeke	Kupeke/5-7-06:1	30	I	P
Niaupala	Kaluaaha/5-6-08:8	34	I	P
Alii	Makakupaia/5-4-06:23	27	I	H
Kaope-a-Hina	Kaluaaha/5-7-09:1	19	I	P
Keawanui	Keawanui/5-6-06:8	54	I	P
Pahiomu	Keonokuino/5-5-01:10	20	I	S

TABLE 6.3. FISHPONDS OF MAUI, LANAI, KAUAI AND MOLOKAI continued

Name	*Location (Ili, Ahupuaa, TMK)*	*Size (ac.)*	*Type*	*Owner*
Kihaloko	Ahaino II/5-7-06:22	5	I	P
Kulaalamihi	Honomuni/5-7-04:34	4	I	P
Waihilahila	Kailiula/5-7-06:27	4	I	P
Kanoa	Kawela/5-4-03:23	50	I	P
Kipapa	Keonokuino/5-5-01:8	10	I	S
Kalokoiki	Wawaia/5-6-08:20	6	I	P
Kamahuehue	Kamalo/5-5-02:5	37	I	P
Piopio	Mapulehu/5-7-08:77	17	I	P
Puhaloa	Manawai/5-6-04:29	6	I	P

Source: Apple and Kikuchi 1975

Key: P = Private, S = State of Hawaii, H = Hawaiian Home Lands

Implications for the Sanctuary

Fishponds are an important archaeological feature and a link with Hawaii's past. A number of the fishponds that were judged by Apple and Kikuchi to be repairable are found in coastal areas adjacent to the proposed sanctuary. Complete restoration of the ponds to a productive level may be outside the mandate of the sanctuary's purpose. However, restoration of exemplary fishponds and the development of an educational program revolving around the history, construction, and use may be appropriate.

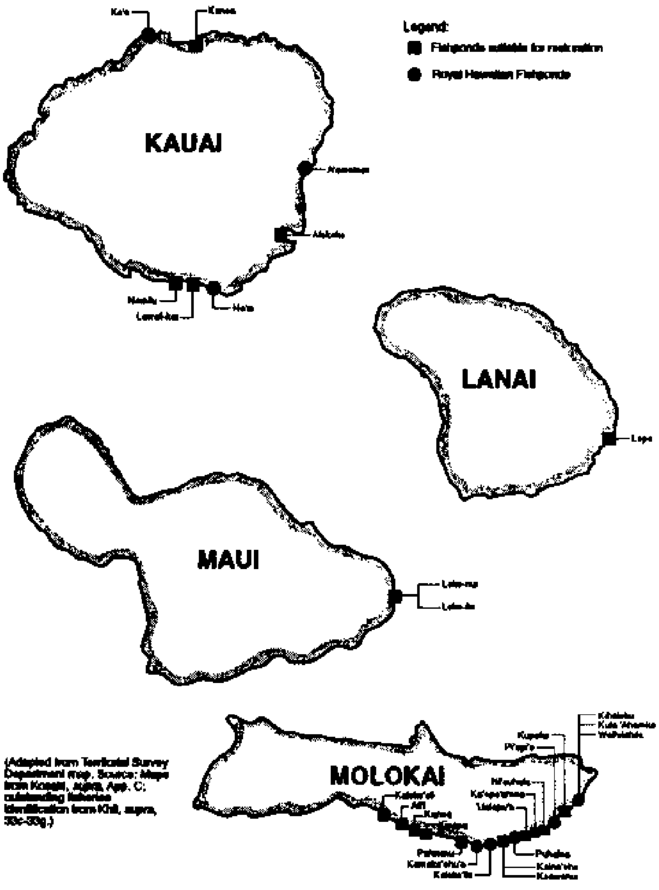

Figure 6.3 Location of Hawaiian Fishponds

INTERISLAND WATERWAYS

The ancient Hawaiians paddled the channel waters in their canoes for food, recreation, trade, communication, and military purposes. The rich history of the islands is full of accounts of mythical demigods and real-life heroes testing their skills on the oceans. Control of Hawaii's channel waterways was an important part of Hawaiian society. This importance is reflected today in modern Hawaii's claim to state ownership of interisland waters (Hawaii State Constitution, Article XV).

Control Over Interisland Waterways

Control of the interisland waterways was an extension of domination of the land by the *alii nui*. The "nature of the dominion exercised over a channel lying between two portions of a multi-island unit was based on Polynesian rather than Western concepts" (Hommon 1975). The Polynesians view the surrounding waters as part of the land. According to Hommon, control of the ocean by Hawaiians was implicit in the control of the islands themselves.

One major difference between controlling terrestrial territories and marine territories is that it is difficult to delineate boundaries in the water and to fortify or garrison it against invasion. Thus, the Hawaiians perhaps did not leave evidence of control of the interisland waterways as they did on land. Control of the waterways, including interisland channels, was expressed in limitations imposed on (1) sea travel, (2) exploitation of marine produce, (3) rare goods, and (4) trade with Westerns (Hommon 1975).

One form of limitation on sea travel was the *kapu pule*. The *kapu pule*, as reported by Bell (1929), could last anywhere from one to eight days, during which time only the fishing canoes of the *alii nui* were allowed in the water. Bell noted that breach of this observance was punishable by death. Limitations on exploiting marine fisheries is well noted in the literature. Titcomb (1972) notes, for example, that while there was a *kapu* placed on *aku* (skipjack tuna) for a six-month period, there was an open period for *opelu* (mackerel scad), and vice versa. Hommon (1975) points to a number of instances where the *alii nui* had exclusive access to rare goods. Rare goods, such as whale teeth found along the beach (the Hawaiians did not hunt whales), became the property of the local chief. The right to own "whale bone and ivory was strongly identified with the power and prerogatives of the *alii nui* as head of the government" according to Hommon. Finally, the *alii nui* controlled trade with westerners by placing a *kapu* on bartering until the chief was present to oversee the barter (Ralston 1984).

Hommon summarizes that "ancient Hawaiian government officials, and the *alii nui*, in particular, exercised legal control over many aspects of the use to the surrounding ocean". In theory, these controls extended across each of the interisland waterways.

Interisland Waterways: Uses and Routes

Use of the interisland waterways by Hawaiians prior to the establishment of the Kingdom were plotted by Hommon based on data from ethnohistoric literature (Figure 6.4). Based on records of 50 voyages, including 108 interisland legs, four channels were more heavily travelled: 1) between Hawaii and Maui; 2) between Maui and Molokai; 3) between Molokai and Oahu; and 4) between Oahu and Kauai. Most travel took place between adjacent islands, indicating that longer trips to distant islands were broken up into trips to intervening islands.

According to Hommon, there were 38 different routes used by the Hawaiians in the 50 voyages he analyzed. The largest number were between the northern section of Hawaii Island and the eastern end of Maui. Not surprisingly, for the period in which these voyages were recorded, the *alii nui* from these areas were the most dominant. Hommon's analysis shows that interisland travel was frequent for both peaceful and bellicose purposes. Although his database is small, it does show that the Hawaiians utilized the interisland waterways quite frequently and along established paths.

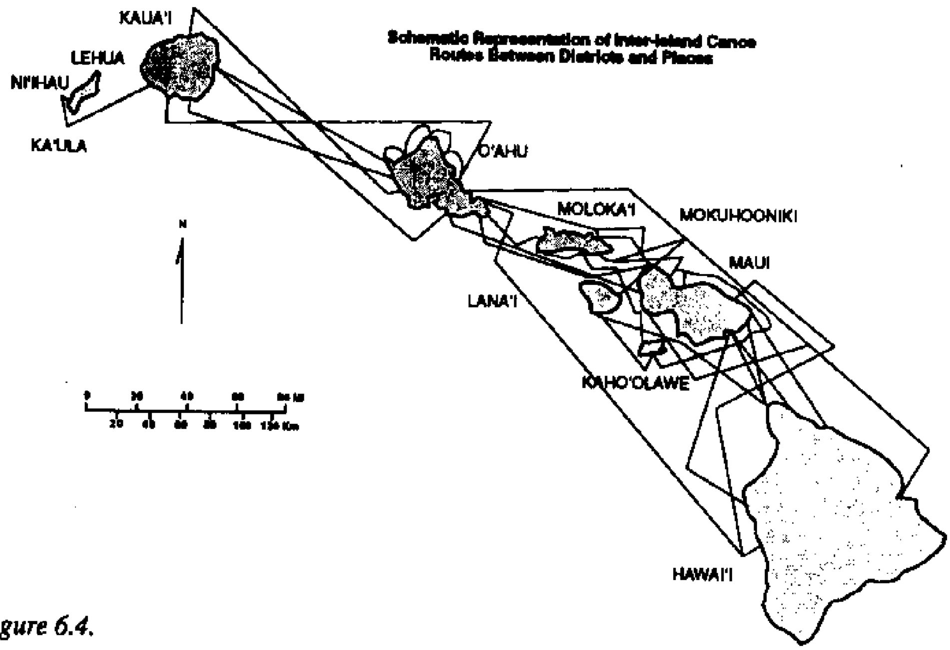

Figure 6.4.

Hawaiian Canoes

The Polynesians came to Hawaii from the Marquesas and also later from the Society Islands in large ocean-going canoes. In Hawaii, canoe building was a highly developed art form. Malo (1951) states that building canoes was a religious affair. Holmes (1993) reports that "... virtually every step in canoe making, from determining whether undertaking such a project was propitious in the first place to the final launching, was steeped in ritual or ceremony designed to appease the gods and solicit their aid in guarding against accidents and problems".

Hawaiians utilized canoes for fishing, recreation, and communication between islands. Holmes states that "in ancient Hawaii, excelling at canoe racing was exceedingly important", though it was probably very different from canoe racing today. The design of the canoe was different depending on its use or station. The common fisherman constructed single-hulled vessels with an outrigger lashed to one side for stability. The larger double-hulled vessels were the province of the *alii*. These larger vessels were 30- to 40-feet long and were reported to hold, on average, 40 to 50 men (Hommon 1975).

Implications for the Sanctuary

The state claims the interisland waterways as part of its territorial waters. The claim is based on historical use of these waters by the Hawaiian people; however, because the creation of the sanctuary is a cooperative arrangement between the state and federal government, this claim to sovereignty over the interisland waters should not pose a threat to the sanctuary. The sanctuary as delineated in legislation is located primarily in state waters.

Extensive use of the interisland waterways was enjoyed by pre-contact Hawaiians. Although there are now few canoes outside of those used for the sport of racing, a recent renaissance in the art of building and sailing these vessels is taking place. These canoes may be paddled through sanctuary waters, and NOAA may need to consider how their passage will be guaranteed.

RELIGIOUS TIES TO MARINE AREAS

The Hawaiian culture, conditioned by an animistic philosophy of life, viewed humankind as being in harmony with nature. Hawaiians, according to Beckwith and Luomala (1970), "worshipped nature gods, and these gods entered to a greater or less extent into all the affairs of daily life". She continues, "[m]uch that seems to us wildest fancy in Hawaiian story is to him [the Hawaiian] a sober statement of fact as he interprets it through the interrelations of gods with nature and with man" (Beckwith and Luomala 1970). Just as the sea was an extension of the land, beliefs about the spirit world were an extension of the real world.

Many of Hawaii's myths and legends relate to the sea. In the legend of Ai Kanaka, the priest Kamalo is wronged by the Moi of Mapulehu and seeks retribution from the shark god Kauhuhu. In turn, Kamalo is instructed to collect a number of red fish to prepare as an offering on the day that Kauhuhu comes to deal out punishment to the offender (Forbes 1907). In other stories, the Hawaiian deities are appeased by sacrifices of white fish, red fish, eels, or other sea creatures.

One of the supreme Hawaiian deities, Ku, takes the form of Kuula or Kuula-Kai (Ku, or abundance in the sea) as the special deity of fishermen (Beckwith and Luomala 1970). According to legend, Kuula was a man who dwelt in Hana, Maui, and possessed miraculous power in directing and controlling fish (Thrum 1907). Upon his death, Kuula passes into the realm of the deities and his son Aiai begins to build altars to honor his father (Beckwith and Luomala 1970; Titcomb 1972). These altars, known as *koa*, are found along all the major islands. Emory (1969) describes a *koa* on the island of Lanai:

> A typical and authentic *koa* stands at water's edge on the sandy point of Honuaula. The irregular platform of stone and coral is six feet high, surmounted by low altar 6 by 12 feet, littered with shells, fish bones, and fresh crabs. At the back of the *koa* is an enclosure containing pine timbers suggestive of a recent shack.

One can see from Emory's description that this *koa* and some others are still in use today.

An important religious practice connected with marine areas and fishing is the belief in the transmigration of the soul of a dead relative into certain species of fish (or other animals), or the animation of certain species by a departed one's soul. These ancestral personal deities, called *aumakua*, took the forms of sharks, eels, octopus, limpets, or other types of marine organisms (Titcomb 1972; Khil 1978; Kawaharada 1992). The *aumakua* were family guardians that were worshipped with daily prayer and by offerings of food in return for bringing good luck during fishing and other important undertakings (Titcomb 1972). Fishermen would not capture any species that were *aumakua* to their families. Violating the *kapu* against taking one's *aumakua* was thought to bring about severe punishment.

There is probably much more about Hawaiian lore and cultural rituals concerning the sea that are considered important by present-day Hawaiians. Several knowledgeable Hawaiians were interviewed in preparing this section and asked about religious practices. Religion, however, is often of a personal nature and the interviewees were not willing to divulge family practices or traditional learning in this area.

Implications for the Sanctuary

The implications of Hawaiian religious practices on the designated sanctuary are difficult to discern. Hawaiian cultural and religious beliefs were tied to the sea as well as the land. The Hawaiian community has protested land-based development when it involves the modification or destruction of sacred places. The creation of a sanctuary, however, cannot be viewed as a development in the same sense as a road or a resort hotel; thus, the sanctuary may not be in conflict with religious practices of native Hawaiians although insufficient data were collected during this survey to make an adequate determination.

RECOMMENDATIONS

1. Further research should be conducted into the nature of native Hawaiian fishery rights with special attention to the deep sea Hawaiian fisheries, the *koa*. Several organizations, including the Native Hawaiian Legal Corporation, University of Hawaii Sea Grant College Program and Western Fisheries Management Council have researched this issue and their conclusions differ. A definitive study could be initiated by NOAA involving the organization cited above, the Office of Hawaiian Affairs, and the University of Hawaii's Hawaiian Studies Program.

2. NOAA's Division of Sanctuaries and Reserve should participate in the Molokai Self-Sufficiency and Fishpond Task Forces deliberations. These efforts are attempts at community-based management of resources that adjoin or are located in the Hawaiian Islands Humpback Whale National Marine Sanctuary. These efforts are supported by county and state agencies. If the task forces' findings are complementary to the intent of the NOAA Sanctuary, they may be used to form the basis of the management regulations for that area. In addition, NOAA should consider funding similar efforts on Lanai and east Maui if appropriate communities are willing to undertake the process. The results could be a management regime for parts of the Hawaiian Islands Humpback Whale National Marine Sanctuary that are community based and community enforced.

3. Sanctuaries and Reserves Division may consider encouraging state or private owners in fishpond restoration efforts for educational purposes.

4. Determining the effects of Hawaiian religious practices on the Hawaiian Islands Humpback Whale National Marine Sanctuary will require further study. Our attempts at interviewing knowledgeable Hawaiians were met with some amount of reticence. We believe that a more in-depth study of this issue would yield useful information that will enhance NOAA's regulation of the Sanctuary.

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CHAPTER 7

CURRENT AND POTENTIAL USES OF THE DESIGNATED SANCTUARY WATERS

DATA SOURCES

Information was gathered from peer-reviewed journal articles, reports from state and federal government agencies, and discussions with representatives of these agencies. A list of these representatives is provided in Appendix 7.1.

CURRENT AND POTENTIAL USES OF SANCTUARY WATERS

This section describes the current and potential uses of the waters of the designated Hawaiian Islands Humpback Whale National Marine Sanctuary as shown in Figure 1.1. These uses include commercial fishing, beach-going, boating, boardsailing, yachting, kayaking, tour boating, snorkeling, whale watching, jet skiing, parasailing, canoeing, charter boat fishing, shipping, research, waste disposal, ocean thermal energy conversion activities, seabed mining, and the installation of a high voltage underwater cable.

Commercial Fishing

The commercial fishing catch from Maui represents nearly 3% of the state total. Molokai and Lanai each contribute 0.25% and 0.11%, respectively (Table 7.1). Although the catch from these islands is small compared to that of the rest of the state, these fisheries are an important economic activity for resident fishermen. The data in Table 7.1 do not indicate the specific volume of fish caught at Penguin Bank. These catch statistics are based on the commercial landings database maintained by the Hawaii Department of Land and Natural Resources, Division of Aquatic Resources. It should be noted that despite legal requirements to report commercial catches, it is well known that there is considerable non-reporting (Smith, in press).

TABLE 7.1. 1990–91 LANDINGS, SALE, AND VALUE OF THE COMMERCIAL FISHING CATCH FROM MAUI, LANAI, AND MOLOKAI

Island	*Lbs. landed (% of state total)*	*Lbs. sold*	*Value ($)*
Maui	664,697 (2.99%)	537,777	1,212,777
Molokai	55,937 (9.25%)	44,489	132,624
Lanai	24,171 (0.11%)	20,059	45,437
Total	**744,805 (3.35%)**	**602,325**	**1,390,838**

Source: Hawaii Department of Land and Natural Resources 1991.

Penguin Bank, located west of Molokai is noted for its productivity. Fishermen from Oahu as well as Maui county use Penguin Bank. Catch reports from the Penguin Bank area for the calendar years 1991 and 1992 are shown in Table 7.2. These data indicate that 202,144 lbs of all fish were landed in 1991 with a total value of $641,265. In 1992, 157,556 lbs. of all fish were landed from the Penguin Bank catchment area with a total value of $500,010. The data above shows that pelagics, including tunas, billfishes, mahimahi, ono, and others compose about one-half the catch. Benthic fish, including deep bottomfish, accounted for about 40% of the total catch.

TABLE 7.2 MARINE LIFE CAUGHT FROM PENGUIN BANK CATCHMENT AREA BY COMMERCIAL FISHERMEN FOR CALENDAR YEARS 1991–92

	CALENDAR YEAR 1991			CALENDAR YEAR 1992		
	lbs. landed	*lbs. sold*	*value ($)*	*lbs. landed*	*lbs. sold*	*value ($)*
Fisheries	Sum	Sum	Sum	Sum	Sum	Sum
Pelagic	99,351	93,966	160,234	70,569	66,097	113,809
Benthic	78,458	75,402	343,352	67,047	64,324	285,685
Coastal/Pel	176	174	341	266	183	346
Reef	1,897	1,663	3,990	1,015	789	1,912
Other	22,262	22,057	133,348	18,659	18,659	98,258
Total	**202,144**	**193,262**	**641,265**	**157,556**	**150,052**	**500,010**

Source: Hawaii Department of Land and Natural Resources 1993.

In its *1992 Annual Report on Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region*, the Western Pacific Regional Fishery Management Council (WPRFMC 1993) notes that for commercial fishing in the Penguin Bank, Maui/Molokai/Lanai bottom fishing grounds, catch per unit effort over the past several years remains highly variable. A comparison of recent data to information from the 1940s and 1950s indicates a decline in catch per unit effort for individual species. This decline is least apparent in opakapaka and most apparent in ehu (WPRFMC 1993).

Data on state-wide fish catches by gear type indicate that after longlining (which is prohibited within 50 miles from the main Hawaiian Islands), the most effective methods are handlining, trolling, aku pole and line, and net (see Table 7.3).

TABLE 7.3. FISHING METHODS, LANDINGS, SALE, AND VALUE OF CATCH FROM COMMERCIAL FISHING FOR 1991 (6/90–6/91) FOR THE HAWAIIAN ISLANDS

Methods	*lbs. landed*	*lbs. sold*	*value ($)*
Longline	14,150,055	13,872,919	36,316,227
Handline	2,689,274	2,577,860	6,196,570
Trolling	2,936,552	2,516,372	4,431,943
aku pole and line	1,274,451	1,274,385	1,710,584
Net	758,189	707,223	1,171,927
Trap	331,914	328,481	3,317,380
Other	101,212	81,280	208,302

Source: Hawaii Department of Land and Natural Resources 1991.

Nets are most often used along reef faces, on the open coast, and in embayments, both as fixed gillnets and as surround nets. Some bullpen nets are used in areas that are flat and open. There are no trawl fisheries in Hawaii (Smith, in press).

Ocean Recreation

Beaches

Like all the Hawaiian Islands, the shoreline of Maui is heavily used for recreation. Molokai and Lanai are less intensely used because of fewer visitors to these islands. The local population, however, frequently use beaches for sunbathing, shore-fishing, bodysurfing, boardsailing, snorkeling, spearfishing, and other activities. Data on the actual number of these beachgoers is not available. Table 7.4 shows the miles of sandy shoreline on the islands of Maui, Molokai, and Lanai.

TABLE 7.4. MILES OF SANDY SHORELINE AND NUMBER OF SURF SITES ON MAUI, MOLOKAI, AND LANAI

Miles	*Maui*	*Molokai*	*Lanai*
Miles of sandy shoreline	32.6	23.2	18.2
Number of surf sites[1]	212	180	99

[1] (Surfing Education Association, 1971).

Source: Hawaii Department of Business, Economic Development & Tourism 1993).

Recreational Boating

Recreational boating is an important activity in Maui County. As of December 31, 1992, about 11% of the boats registered in the state of Hawaii were in Maui County and 9% in Kauai. Because the population of Maui, Molokai, and Lanai is about 9.1% of the state's total, they have a slightly higher number of boats per capita than the state average. Also, the population of Kauai is about 4.6% of the state's total, so it has about twice the number of boats per capita as the state average. The economic contribution of these recreational boaters has not been determined. Table 7.5 shows the number and location of vessels registered in Maui, Kauai, Molokai, and Lanai.

TABLE 7.5. LOCATION OF STATE-REGISTERED VESSELS KEPT AS OF DECEMBER 31, 1992

	Number of vessels			*Percent of vessels*		
Island	*on water*	*on land*	*Total*	*statewide total*	*on water*	*on land*
Maui	169	1159	1328	9.5%	1.21%	8.29%
Kauai	69	1184	1253	8.97%	0.49%	8.47%
Molokai	16	143	159	1.14%	0.11%	1.02%
Lanai	9	40	49	0.35%	0.06%	0.29%

Source: DLNR-DOBOR, 1993a-c.

In addition, the estimated number of undocumented state registered vessels is: 1,169 for Maui, 1,097 for Kauai, 149 for Molokai, and 54 for Lanai (Hawaii Department of Transportation Harbors 1991).

The capacity of small craft mooring facilities in Kauai, Maui, Lanai, and Molokai are shown in Table 7.6.

Table 7.6. SMALL CRAFT MOORING FACILITIES CAPACITY BY ISLANDS: 1991–92

	State-operated[1]				Non-State[2]	
	Catwalks and piers		Other moorage			
Island	Total	Vacant	Total	Vacant	Slips	Other moorage[3]
Kauai	82	7	36	11	–	51
Maui	46	2	145	5	–	–
Lanai	28	3	–	–	–	–
Molokai	3	129	12	0	51	
Total of 4 islands	**159**	**13**	**210**	**28**	**0**	**51**
State Total	**1,459**	**94**	**705**	**80**	**2,948**	**926**
Percent of state	10.89%	13.83%	29.79%	35%	0	5.51%

[1] As of December 31, 1991. At that time 1,992 vessels were moored (1,365 at catwalks and piers, 627 at other moorage), and valid applications on file numbered 2,801.
[2] As of January 10, 1992. Totals for 20 organizations controlling moorage.
[3] Includes mooring (82), ramps (10), and dry storage (834).

Source: Hawaii Department of Transportation 1993.

The locations of small boat facilities on Kauai, Maui, Molokai, and Lanai are shown in Figure 7.1.

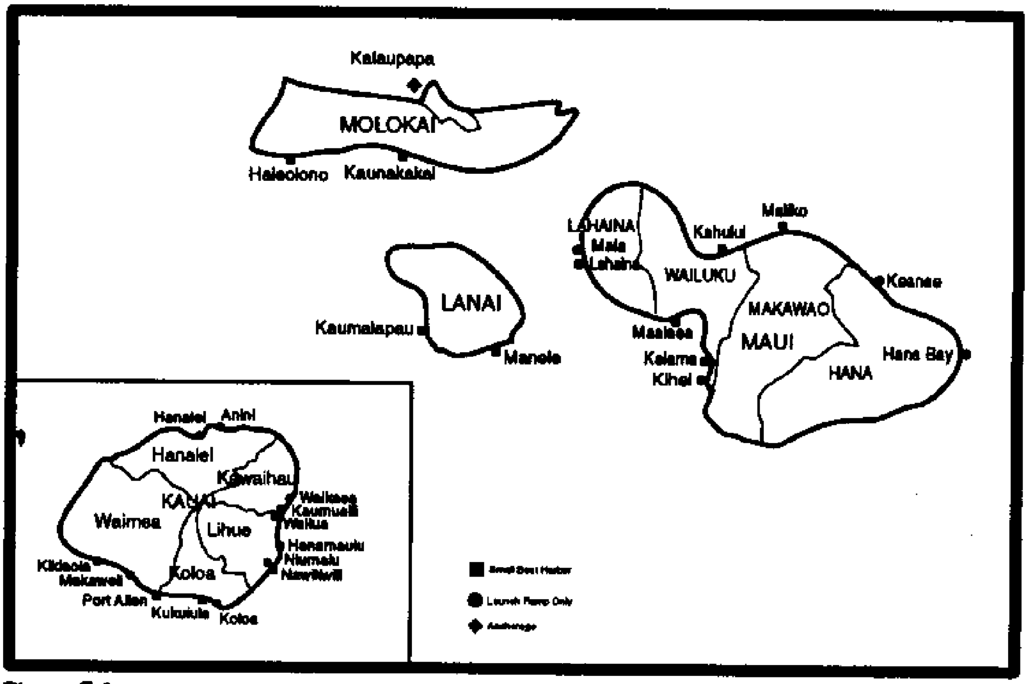

Figure 7.1

Lighthouses and other aids to navigation, such as day beacons, lights, buoys, and surface-floating fish aggregating devices at sea for the area are shown in Table 7.7.

TABLE 7.7. LIGHTHOUSES AND RELATED FACILITIES BY ISLANDS, 1992
(Includes all lights, day beacons, buoys, and similar aids to navigation)

Island	*Number of aids to navigation* *Total*	*By control* *Federal*	*Other* [1]	*Lighthouses*	*Greatest nominal range(nm)*	*Highest above Sea level(ft)*	*Grd.(ft)*
Maui	52	27	25	4	24	170	48
Kauai	39	22	17	6	25	174	80
Molokai	18	10	8	1	25	213	138
Lanai	14	8	6	—	8	91	13
Kahoolawe	1	1	—	—	7	120	20
Molokini	1	1	—	—	7	182	30
Total of 6 islands	125	69	56	11	96	950	329
State total	525	301	224	22	25 [2]	931 [3]	138 [4]
% of state total	23.8%	22.9%	25%	50%	—	—	—

[1] State and private. Includes state-maintained fish aggregating buoys at sea.
[2] Molokai Light, Kaena Point Light, and Kilauea Light.
[3] Kaena Point Light.
[4] Molokai Light.

Source: U.S. Coast Guard 1992.

Boardsailing

On the north shore of Maui, at Hookipa, surfers, boardsailers and fishermen compete for space. There are three professional boardsailing events that take place during the year: the Aloha Classic (with 156 participants, 3,000 spectators), the Marui O'Neil Invitational (64 participants, 3,000 spectators), and the Maui Grand Prix (80 participants, and an unestimated number of spectators) (Markrich, in prep.). Production costs for these three events was $320,000 in 1990 (Markrich in prep.). As many contestants enter several events, Markrich estimated the total expenditures of the out-of-state contestants and dependents to be $774,900 in 1990.

Yachting

Three yacht races occur in the area each year. The routes of the races are: Lahaina to Victoria, Oahu to Maui and back to Oahu, and a triangle race off Lahaina. Expenditures for the Victoria-Maui International Yacht Race in 1990 totaled $688,650 in direct expenditures and $504,051 in indirect expenditures. The expenditures of the two local races total approximately $3,000 each in 1990 (Markrich in prep.).

Kayaking

The major kayak race that occurs in the area of the proposed sanctuary is the Bankoh Kayak Challenge that goes from Lono Harbor on the southwest end of Molokai to Portlock or off Sans Souci Beach, Waikiki, Oahu for a distance of 38 miles. There are also kayak tours on Kauai, Maui, and Hawaii Island. The total race expenditures in 1990 was $95,380 (Markrich in prep.).

Tour Boats

On Maui, the tour boat activity is concentrated at Lahaina and Maalaea small boat harbors. The tour boat business includes activities such as snorkel cruises, scuba diving, raft rides, day trips to Lanai, whale-watching, and excursions on submarines and semi-submersibles. The type, size, and location of the tour boats on Maui, as of 1990 are shown below Table 7.8.

TABLE 7.8. TYPE, SIZE, AND LOCATION OF TOUR BOATS ON MAUI, 1990 (Markrich in prep.)

No. of vessels	*Type*	*Size of vessel*	*Guest capacity*	*Activity*	*Location*
2	Submarines	46'	24	Underwater cruise	Lahaina
10	Inflatable	18-27'	6-22	Adventure Cruise-Molokini/ Whale watch	Maalaea/ Mala Wharf
26	Catamarans	42-65'	20-120	Molokini/Hotel Cruises/ Lanai Cruise/Whale watch	Lahaina/Maalaea Wailea Hotels Kaanapali Hotels
6	Boston Whalers	20-25'	6	Molokini/Snorkel/Whale watch	Keehi Boat ramp/ Trailer Boats
14	Sailboat	30-67'	6-20	Cruise/Whale watch/Molokini Honolua Bay/Kapalua	Lahaina/Maalaea/ Keehi/Offshore Mooring
9	Screw/Propeller	25-100'	30-150	Glass Bottom Boat/ Ferry Whale watch/Molokini/Snorkel	Maalaea/ Lahaina

Source: Markrich in prep.

The Ocean Resources Branch of the Hawaii Department of Business, Economic Development & Tourism contracted a study of the ocean recreation industry in the state (Markrich in prep.). This draft study shows that for the 30 companies active in the Maui tour boat industry in 1990, snorkeling cruises on sail and motor boats provided about 79% of the revenue. Whale watching provided the next highest amount of income, 8%. The remaining revenue was produced by activities such as ferry transportation to Molokai and Lanai, sail charters, glass bottom boat trips, sunset and dinner cruises, inflatable raft riding, and submarine tours (Markrich in prep.). Table 7.9 shows the types of activities, point of origin, employment, and passenger totals for Maui tour boats in 1990.

TABLE 7.9 TYPES OF ACTIVITIES, POINT OF ORIGIN, EMPLOYMENT, AND PASSENGER TOTALS FOR MAUI TOUR BOATS, 1990

Type of Activity	*Point of Origin*	*Total Revenue ($)*	*Passengers*	*Employees*
Raft adventure snorkel	Mala Wharf/Keehi	924,000 (3%)	23,350 (4%)	15 (4%)
Ferry service to Lanai and Molokai	Lahaina	1,645,700 (6%)	32,500 (5%)	11 (3%)
Whale watch	Lahaina/Maalaea	2,240,001 (8%)	90,400 (15%)	[1]
Sail/Motor/snorkel activity/Club Lanai	Maalaea, Lahaina Sugar Beach, Kaanapali	23,791,544 (79%)	405,346 (67%)	386 (90%)
Sail Charter Cruise/ Glass Bottom Boat/ Dinner-Cocktail Sail	Lahaina	1,305,001 (4%)	56,066 (9%)	15[2] (3%)
Total		$29,906,246	607,662	427

[1]The Snorkel vendors often combine their trips with whale watching trips or do snorkel tours during the 120-day whale watch season. Approximately 40-50 people are estimated to participate in the whale watch trade.
[2]This number is considered to be an approximation because many of the employees perform multiple tasks on different boats owned by a single company.
Source: Markrich in prep.

It is noted in a draft report for the Department of Business, Economic Development & Tourism, Ocean Resources Branch (DBEDT/ORB) that,

> ...the rapid development of hotels and tourist packaging on Maui created a strong island market for snorkel trips to Molokini Crater, Olowalu, reef areas along the Maui coast and Lanai. To meet this demand, the tour boat companies built larger and larger catamaran and motor cruisers, some carrying as many as 110 passengers at a time, double the size of the largest vessels working in 1982. (Markrich in prep.)

For Lanai, the draft report states that,

> ...the biggest single vendor in 1990 was Club Lanai, which was a combination activity club and snorkel business. Club Lanai had its own fleet of vessels and sold day trips to a private recreation area on Lanai. This company suspended operations in 1991. However there are indications that it may resume operations in 1992. (Markrich in prep.)

As of this time, Club Lanai remains closed to business.

The draft report describes whale watching as,

> ...a highly seasonal trade lasting only from mid-December through April. Approximately 80% of the business is conducted by four large companies, utilizing eight vessels. Most of the large vessels doing whale watch tours operate out of Lahaina. However, as many as 28 different vessels are involved in the whale watch trade during the season, and it is common for owners of smaller vessels catering to snorkel tours, to offer whale watch excursions when times are slow. (Markrich in prep.)

Whale watching takes place in a wide area offshore Lahaina, Kaanapali, Napili Bay/Honokowai, Molokini Island, Makena Bay/La Perouse Bay, Kihei, Kamaole Beach, and Maalaea Bay.

In general, the ocean recreation industry of Maui is undergoing significant changes as the consumer preferences and available recreation technology changes. Tour boat operators out of Maalaea are generally using small vessels and taking passengers out for combined snorkel/whale watch excursions. Glass-bottom boat rides are on the decline; submarine and inflatable raft snorkel tours are popular and growing. The ferry boat business also grew steadily during the 1980s (Markrich in prep). The Maui to Molokai ferries, which are partially subsidized by the state, transport workers and others from Molokai to Maui hotels. The ferry service to Lanai is privately owned.

Destinations and Economic Characteristics of Snorkeling Activities Off Maui

Of the 30 companies active in the Maui tour boat trade in 1990, 29 were involved in snorkel activities. Most of these vendors bring their snorkelers to Molokini Crater, a small mostly submerged crater between Maui and Kahoolawe. In 1990, these boats brought an estimated 167,361 visitors to Molokini during 300 days of the year, averaging over 500 people per day (see Table 7.10). Some vendors even estimated crowds of nearly 1,000 visitors per day during July and August. Twenty five to 30 vessels are reported to visit Molokini regularly, with an estimated 40 vessels working Molokini at some time during the year. With the recent establishment of new hotels in the Wailea area, several more large catamarans have begun operation. Markrich (in prep.) notes that some vendors estimated that approximately 800 to 1,000 tourists visited Molokini each day in 1992.

Molokini Crater is a Marine Life Conservation District (MLCD) located approximately three miles off the coast of Maui. Based on 1990 survey estimates done for the Hawaii Department of Business, Economic Development & Tourism, Ocean Resources Branch, Molokini is the destination for 36% of all visitors who go on a snorkel tour from Maui. Molokini tours generate 30% of all tour boat profits ($9.6 million) and 250 jobs, or nearly 70% of tour boat employment (Markrich in prep.).

Other prime destinations points on Maui for snorkeling include Olowalu, Honolua, and Kapalua. These areas are larger, so activities are spread out over a greater area than those at Molokini.

Visitors to Lanai go primarily to a private beach for shore-based activities and snorkeling. Only two companies have state landing permits and agreements with Dole Corporation, the owners of Lanai Island.

TABLE 7.10. DESTINATIONS AND ECONOMIC CHARACTERISTICS OF SNORKELING ACTIVITIES OFF MAUI, 1990

Destination	*Molokini*	*Lanai*	*Olowalu/Maui Coast*	*Total*
No. of Offerings to snorkel locations	17 (60%)	8 (18%)	6 (22%)	30[1] (100%)
Employees[2]	250 (69%)	60 (16%)	54 (15%)	364 (100%)
Passengers	167,361 (41%)	157,200[3] (39%)	80,785 (20%)	405,346 (100%)
Revenues	$9,552,569 (38%)	$10,250,000[4] (44%)	$3,988,975 (18%)	$23,791,544 (100%)

[1]Four vendors go to both Molokini and Lanai; two vendors go to Lanai and Olowalu. The above number represents the number of offerings to snorkel locations.
[2]In some cases companies go to one or more of the above locations. To gauge the importance of the destination on employment, the question is asked "If you could not go to the locale how many people would be let go from your company?"
[3] 74% of this total was carried by a single vendor. Includes reef areas off Lanai.
[4] 68% of this total was generated by a single vendor.

Source: Markrich in prep.

Thrill Craft: Jet Skis and Parasail Operations

There is one sole operator of thrill craft on Maui who holds three permits and operates six jet skis for each permit and operates off of the south end of Kaanapali Beach. There is one parasail operation in Maui working out of Lahaina. Due to concerns by the state that jet skis and parasail boats harass whales, the state has established rules that no jet skis or parasail operations can take place during the winter season from December

15 through May 15, a period when many tourists are visiting Hawaii. A more detailed description of these management measures is given in Chapter 8. A brief outline of thrill craft operations for the state is shown in Table 7.11.

TABLE 7.11. JET SKI AND PARASAIL OPERATIONS IN HAWAII BY LOCATION, REVENUE, EMPLOYMENT, AND PASSENGER LEVEL, 1990

Activity	*Revenue*	*Employees*	*Passengers*	*Location*
Jet Ski	$4,478,300	93	128,557	Oahu/Maui
Parasail	$3,463,317	70	107,157	Oahu/Maui/BI

Source: Markrich in prep.

The Department of Land and Natural Resources, Division of Boating and Ocean Recreation (DLNR-DOBOR) reports that as of August 1993, there are seven recreational thrill craft and 18 commercial thrill craft registered in Maui (Paul Dolan, Department of Land and Natural Resources, pers. comm. 1993).

Ocean Swims

There are three major ocean swims in this area. The Kihei Classic, the Kaanapali Classic, and the Maui Channel Swim from Maui to Lanai. Data on the number of participants and costs is shown below in Table 7.12.

TABLE 7.12. MAUI OCEAN SWIM EVENTS: COSTS AND NUMBER OF PARTICIPANTS

Event	*Administrative costs*	*Total no. of participants*	*Total no. of participants out of state*
Kihei Classic	$2,000	90	–
Kaanapali Classic	$2,000	90	–
Maui Channel Swim	$10,000	330	228
Total	$14,000	510	228

Source: Markrich in prep.

Canoe Racing

The Molokai Canoe Racing Association consists of three active clubs and about 60 paddlers. The association hosts the Maui-Molokai long distance race each year.

The Maui County Hawaiian Canoe Racing Association consists of nine active clubs and about 1,200 paddlers. Annually, they participate in six regular regattas, three half-day invitational regattas, the Ha regatta, four long-distance races, and five "fun" regattas for fund-raising purposes. Each regular season regatta draws about 1,200 paddlers and about 800 spectators. Four invitational regattas are carried out during the year: the Ben Abiera race, the Kahana Invitational races, the Napili Invitational Double Hull Races, and the special invitational regatta called the Ha Regatta. The first three races mentioned are half-day events with a similar number of paddlers and spectators as the regular season races. The Ha Regatta is held in April over an entire weekend. Approximately 440 adult paddlers and 60 junior paddlers (under 16) participated in the 1990 Ha Regatta. The four long-distance races are the Dutch Kino-Maalaea-Lahaina Long Distance Race, the John Kukahihiko Relays, the Queen Kaahumanu Race, and the Great Kahakuloa Men's Race. Each of these races has an average of 22 participating canoe crews. The five "fun" regattas are the Lahaina Canoe Club Kayak Race, the Hawaiian Canoe Club "FUN in the SUN", the Kihei Paddlers' Open, the Na Kai Ewalu Challenge, and the Lahaina Restaurant Race (Markrich in prep.).

Charter Boat Fishing

The charter boat fishing industry in Maui has been active and thriving for many years. Today, however, charter fleet captains are expressing concern over the diminishing number of billfish in the area because of the increase in longline fishing in Hawaiian territorial waters. Longline fishing for tuna has a significant by-catch of marlin. In addition to the reduced catches of marlin by the charter fleet, the effect of longliners was felt at the fish auction when the longliners began to bring in large numbers of marlin, driving the price of the marlin down. This situation in turn reduced the return to charter boat captains and crew from sales of marlin caught on charters, resulting in significant reductions in revenue that had been traditionally distributed as a bonus to charter boat crews (Markrich in prep.).

The Maui-based charter boat fishing fleet is divided between Lahaina, Maalaea Harbor, and Mala Wharf, with the majority of vessels based at Lahaina (Table 7.13).

TABLE 7.13. MAUI CHARTER FLEET BY LOCATION, NUMBER OF VESSELS, AND NUMBER OF PASSENGERS

Harbor	No. of vessels	Est. no. of passengers
Lahaina	11	6,966
Maalaea	6	4,660
Mala Wharf	?	1,848
Total	?	13,472

Source: Markrich in prep.

The Lahaina harbor-based charter boats travel about 31 miles to the MC fishing buoy as the principal trolling ground for marlin (see Figure 7.2). The Maalaea harbor-based charter boats travel to the JJ and I buoys. These buoys are about 11 miles from the harbor. All of the captains have reported reductions in catches of marlin and ahi in recent years (Markrich in prep.).

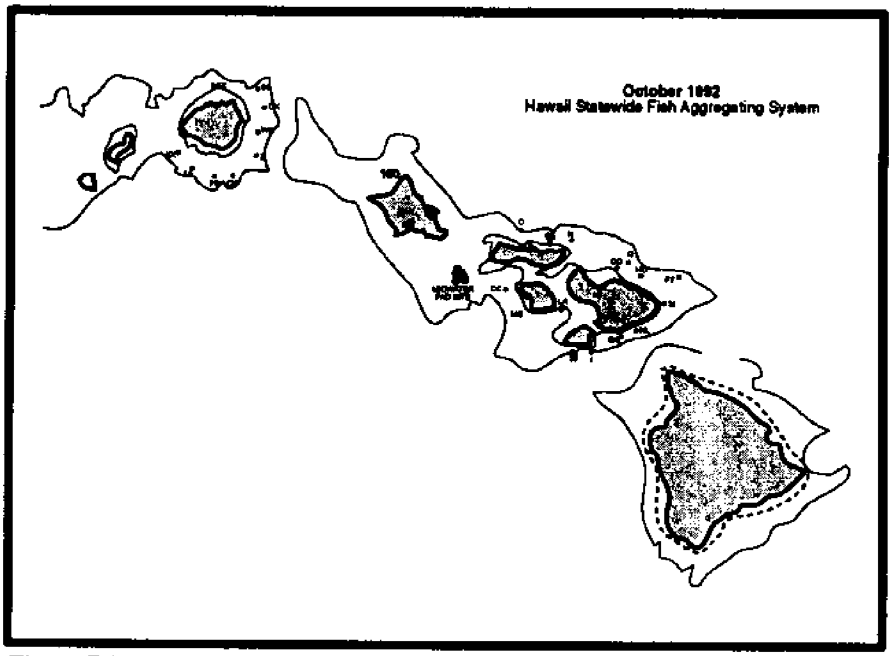

Figure 7.2

Kauai Charter Boat Fishing Fleet

Prior to Hurricane Iniki, the Kauai Charter fleet consisted of eight vessels. Six vessels were moored at Nawiliwili commercial and small boat harbor and two were located at Hanalei River boat ramp. In 1990, Markrich (in prep.) estimated that the fleet grossed $705,560. The Nawiliwili-based vessels traveled to the Anahola buoy, the Nawiliwili buoy, or the CK buoy. The Hanalei-based vessels traveled the Napali Coast while fishing, thereby offering a unique coastal tour of this spectacular location. The only waters around Kauai that are designated as part of the sanctuary are off Kilauea Point. Therefore, only the Hanalei-based charter boats will pass through these waters. The fleet tended to fish using lures and did not necessarily target marlin. Most commonly caught fish included ahi, mahimahi, and ono.

Concerns of the Kauai fleet are similar to those of Maui, that is, the detrimental impact of the long-line fleet on the stocks of targeted fish in Kauai waters. In addition, the conflict among Hanalei-based tour boats has been reported to create a bad atmosphere in which to attract customers to the charterboat fishing in that area. Now, in the aftermath of Hurricane Iniki, the industry is beginning to get back on its feet (Athline Clark, Department of Business, Economic Development & Tourism, pers. comm. 1993).

Other Fishing and Gathering

Recreational fishing is a significant, yet unquantified fishery in sanctuary waters. Smith (in press) reports that 19% to 35% of Hawaii residents fish, recreational fishers outnumber commercial fishers 50 to 1, and nearly 75% of small boat owners engage in fishing as their primary activity. Estimates of recreational fishing catch vary widely. Smith (in press) states that it is "impossible at present to interpret overall trends in landings and catch rates for species taken jointly by the recreational and commercial sectors. An independent estimate of recreational landings is needed". Evans (1992a) estimates that recreational fisheries "may account for as much as 50% of the small boat fleet catch in Hawaii". Fishing takes place from boats that target a variety of bottomfish and pelagic fish. Along various points of the shoreline of Maui, Molokai, and Lanai, people fish primarily for recreational and possibly subsistence purposes. Because there is no licensing program or requirements to report catch from recreational fishing, data are limited to a limited number of creel surveys of shore fishermen and women. Surveys of this type were conducted on Oahu, Kauai, and Hawaii and may provide the basis in the future for estimates of recreational fish catch (Smith in press). Traditional fishing techniques, such as throw net for reef fish and lift net for opelu, are used in some areas of the sanctuary. For a more detailed discussion on traditional uses of sanctuary waters, see Chapter 6.

Shipping

The shipping of goods and basic fuels is essential for the islands' economies. For many people it provides a lifeline to centers of production either on the mainland or overseas. The two major harbors in the designated area are Kahului on Maui and Nawiliwili on Kauai. Kaunakakai and Kalaupapa on Molokai, and Port Allen on Kauai also have some shipping business. The shipping routes for the harbors on Maui and Molokai transit the sanctuary waters through the interisland channels of the Maui County islands. Harbor depths and vessel arrivals, by draft, for 1989 are shown for these harbors in Table 7.14. Table 7.15 shows the freight and passenger traffic for Kahului and Nawiliwili Harbors from 1985 to 1989. Specific breakdown of overseas and interisland cargo for Kahului and Kaunakakai in 1992 are shown in Table 7.16.

TABLE 7.14. HARBOR DEPTHS AND VESSEL ARRIVALS BY DRAFT FOR 1989
(excludes domestic fishing craft)

	Controlling depth (ft.)			*Inbound vessels by draft*	
Harbor	*Entrance channel*	*Basin*	*Total*	*18 ft. and less*	*19 ft. and more*
Kahului	—	34	1,766	1,630	136
Kaunakakai	—	—	738	738	—
Kalaupapa	—	—	8	8	—
Nawiliwili	41	34	1,079	966	113
Port Allen	—	—	100	NA*	NA*

* NA: Not Available

Source: U.S. Department of the Army, Corps of Engineers 1991.

TABLE 7.15. FREIGHT AND PASSENGER TRAFFIC FOR KAHULUI AND NAWILIWILI HARBORS: 1985–89

Harbor	*1985*	*1986*	*1987*	*1988*	*1989*
Freight[1] (short tons)					
Kahului	1,516,509	1,626,650	2,035,247	2,156,631	2,278,516
Nawiliwili	933,477	745,396	916,422	875,753	1,038,452
Passengers[2]					
Kahului	–	–	–	–	9,083
Nawiliwili	–	–	–	–	9,082

[1] Excludes cargo carried by Army and Navy vessels and cargo in transit.
[2] Total arrivals and departures for transpacific, interisland, and local travel.
Source: U.S. Department of the Army, Corps of Engineers 1991.

TABLE 7.16. CARGO STATISTICS FOR KAHULUI AND KAUNAKAKAI HARBORS FOR 1992 (TONNAGE IN SHORT TONS)

	Kahului	*Kaunakakai*
Overseas		
In	188,552	0
Out	271,067	0
Total	459,619	0
Interisland		
In	1,284,276	81,022
Out	562,897	98,771
Total	1,847,173	179,793
Overseas and Interisland		
In	1,472,828	81,022
Out	833,964	98,771
Total	2,306,792	179,793
Number of vessels	1,423	422

Source: Department of Transportation, Harbors Division 1993b.

RESEARCH

A significant amount of research on humpback whales is being conducted. The research includes, whale identification (fluke photographs), audio mapping and behavioral studies (effects of boats and other human water craft on whale behavior). Research teams include the University of Hawaii, Pacific Whale Foundation, Center for Whale Studies, Albright College, Moss Landing Marine Laboratories, and Southern Illinois University (Eugene Nitta, National Marine Fisheries Service, pers. comm. 1993). Some of this work is supported by the National Marine Fisheries Service; however, most is supported by private non-profit organizations through public contributions.

Evans (1992b) compiled a list of research projects initiated and funded by the National Marine Fisheries Service, specifically designed to address agency concerns. Much of this work was done in Alaska, although the results have direct relevance to the Hawaiian Islands Humpback Whale National Marine Sanctuary. These studies focused on a variety of topics including: (1) impacts of vessel traffic on humpback whale behavior, (2) resource assessments, (3) surveys of humpback whale populations, (4) surveys of humpback whale forage, (5) effects of oil on the marine environment, including humpback whales, and (6) periodic workshops and conferences to compile and compare information on humpback whales, marine mammal researchers, and the review and reevaluation of whale watching programs and management needs. This research is discussed in more detail in Chapter 4, and research on human interactions with whales is discussed in Chapter 8.

There is a limited amount of research being conducted on other cetaceans in the area. The most extensive marine mammal survey performed to date was conducted from February to March 1993 to evaluate the effect of the ATOC (Acoustic Thermometry of Ocean and Climate) transmission on marine mammals. This is a very low frequency acoustic transmission designed to measure oceanic thermal characteristics. Four aerial surveys were conducted and are described in Chapter 4.

The sanctuary area has also been the site of research on coral reefs (see Chapter 3). Other marine research is focused on the marine resources around Kahoolawe, which includes studies on sea turtles, water quality, fish, and corals. A significant research and monitoring project has begun in west Maui, which focuses on determining the factors relating to the macroalgae blooms in the nearshore waters of west Maui. The different types of research focus on monitoring and research into the dynamics of potential impacts of different land use on nearshore water quality. Special attention is placed on nutrient loading which may cause nuisance algal blooms (June Harrigan, Hawaii Department of Health, pers. comm. 1993). A list of research projects under this program is presented below. This issue is discussed further in Chapter 8 under nonpoint source pollution. In addition, there are several coastal water quality and marine life monitoring programs that are on-going in sanctuary waters around the Maui County islands, including Lanai, Kaanapali (Maui), and Kahului (Maui). These programs are mostly related to construction projects and are discussed in Chapter 3.

State and federally funded projects that are planned or underway in the Lahaina district as of October 1993 include: (June Harrigan, Hawaii Department of Health, pers. comm. 1993).

State Funding ($100,000)

1. Macroalgal mapping survey (Oceanit Laboratories, Inc, Honolulu; Principal Investigator, Robert Bourke). Content: Four consecutive quarterly field surveys designed to discover where macroalgal species comprising the "blooms" are growing attached to the bottom. Expected completion date: summer 1994.

2. Physiological responses of the nuisance species of *Cladophora* and *Hypnea* and investigations of marine communities in which these seaweeds are found on Maui. (University of Hawaii at West Oahu; Principal Investigator, Lynn Hodgson, Ph.D.) Content: This project includes both field and laboratory work designed to determine what marine species are feeding on macroalgae that are "blooming," and to measure nutrient uptake rates and growth characteristics of the macroalgal species in the "bloom." Expected completion date: summer 1994.

Federal funding (Environmental Protection Agency (EPA) $500,000+)

1. Preliminary assessment of possible anthropogenic nutrient sources in the Lahaina District of Maui (Tetra Tech, Inc., California). Content: A screening-level study of historical estimates of nutrient loadings in the Lahaina District. Completion date: June 1993.

2. West Maui Watershed Management Coordinator (Wendy Wiltse, Ph.D.; two-year appointment). Content: Dr. Wiltse's primary responsibility is to guide the development of a written nutrient/sediment management plan for selected watersheds in the Lahaina District. Components of the plan will be primarily voluntary; some regulatory components will be included where authorized by Federal, State, and County permit programs. Expected dates: September 1993 to September 1995.

3. Tracer Test — Lahaina Wastewater Reclamation Facility (LWRF). (Tetra Tech, Inc., California). Content: Nearshore coastal waters survey designed to detect, if present, a flourescent dye introduced into the LWRF injection wells. Expected completion date: end of October 1993.

4. Water Quality Monitoring Project (presently in design phase). Content: This project will be complementary to the monitoring project funded by the National Oceanic and Atmospheric Administration (NOAA) (see description below), and will focus on nutrient outputs from the upper forested watershed or on estimating a Total Maximum Daily Load (TMDL) for sediment discharges into nearshore coastal waters along the West Maui coastline.

5. Land application of Best Management Practices to reduce nutrient loading to coastal waters off West Maui. (U.S. Soil Conservation Service & Maui Land and Pineapple Company). Content: Construct two sediment retention basins on West Maui, one within the Pohaku-Kaanapali subwatershed (near Mahinahina Point), and the other in an unnamed gulch adjacent to Kaopala Gulch. The SCS will fund construction of the first basin and ML&P will construct the second, with technical assistance from the SCS. Expected completion date: This project is in the design phase; construction will begin in spring 1994, after the required permits have been obtained, with completion scheduled for fall 1994.

6. Evaluation of applicability of existing nutrient-stripping technologies to operations at the Lahaina Wastewater Reclamation Facility (LWRF). (Initiation of this project depends on results from the tracer tests at the LWRF).

Federal Funding (National Oceanic and Atmospheric Administration (NOAA): $450,000)

1. Algal blooms off West Maui: Assessing the causal linkages between land and the coastal ocean. (University of Hawaii at Manoa: Principal Investigators: Steven Dollar, Ph.D. and Frank Peterson, Ph.D.). Content: Construct a Geographic Information System (GIS) database of nutrient inputs, conduct a water quality sampling program, collect data on physical variables that may affect biotic responses, conduct a sampling program for the nuisance algal species, and build a predictive model to be used for land and water quality management purposes. Expected completion date: September 1995.

2. A retrospective analysis of satellite sea surface temperature data collected near the Hawaiian Islands (NOAA staff).

3. Development of a conceptual computer model for descriptive purposes and database organization (NOAA staff).

4. Funding of an additional transect within Oceanit's macroalgal mapping survey (see State-funded projects).

Waste Disposal

There is one National Pollution Discharge Elimination System (NPDES) permit for direct point-source discharge of wastes into the waters of the sanctuary. This is located at the Lahaina Sewage Treatment Plant, however, treated sewage effluent is usually discharged into injection wells. In addition, there is one dredge spoil disposal site in the vicinity of the sanctuary area. It is located over five miles from the northern part of Maui, outside the sanctuary waters (U.S. Department of the Army Corps of Engineers, 1989).

Of greater concern than direct discharges of waste into the sanctuary waters is nonpoint source pollution. Nonpoint source pollution includes runoff from agricultural and urban lands, including construction projects and other earth moving, which bring sediments into nearshore waters, storm drain runoff, and leaching of cesspools and injection wells. Hawaii Department of Health reports that the most critical marine water quality problem facing the state is sedimentation (Hawaii Department of Health 1989). Areas of coral reef adjacent to large urban areas and coastal developments show signs of disturbance (James Maragos, East-West Center, pers. comm. 1993), which can be from nonpoint source pollution as well as increased fisheries use.

Ocean Thermal Energy Conversion

Ocean Thermal Energy Conversion (OTEC) is an electricity generating technology that has been pioneered at Keahole Point on the Big Island at the Natural Energy Laboratory of Hawaii. In simple terms, the technology generates power from the temperature differential between cold seawater drawn from over 2,000 feet below sea level and warm surface seawater. The major expense in an OTEC system is the deep water pipeline, so it is economically necessary to have the OTEC plant located close to very deep water. Keahole Point is a prime location because the slope of the sea floor is steep, resulting in very deep water close to shore. The water surrounding the four-islands group in Maui County is not as favorable because of the shallow shelf surrounding the islands. The potential for OTEC development in the sanctuary is very low, so it is not a management concern.

High Voltage Underwater Cable

In the late 1980s, a proposal was made to link the Big Island geothermal power plant in Puna with the main area of electricity demand in the state, Honolulu. To do this, a high voltage underwater cable was to run from north Kohala on Hawaii Island to Kipahulu or Huakini on Maui. From this eastern site on Maui, the possible route for the cable would take it over land to Ahihi, back into the water through the Auau channel between Maui and Lanai, then on to Oahu. At this time, the likelihood of this cable coming to reality is very low. State officials note that even though the technology has been proven feasible, the economics is very unfavorable. The state Energy Division is no longer proposing such a development. Nonetheless, the environmental assessment process continues due to a court order (John Tatlinger, Hawaii Department of Business Economic Development & Tourism, pers. comm. 1993).

Seabed Mining

There is no seabed mining proposed for this area. The area surrounding the main Hawaiian Islands was excluded for environmental reasons (Hawaii Department of Planning and Economic Development and Department of Interior 1987). Several areas were considered for siting of the processing plant for seabed minerals, however, none of these are in the coastal area adjacent to the sanctuary waters.

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APPENDIX 7.1

Personal communications and interviews on issues relating to management of ocean use and activities in the sanctuary waters.

Reginald Kokubun (Department of Land and Natural Resources, Division of Aquatic Resources)

Paul Dolan (Department of Land and Natural Resources, Division of Boating and Ocean Recreation)

Craig MacDonald and Athline Clark (Department of Business, Economic Development & Tourism, Ocean Resources Branch)

John Tatlinger (Department of Business, Economic Development & Tourism, Energy Division)

June Harrigan (Department of Health)

Robert Schroeder (Western Pacific Regional Fishery Management Council)

Eugene Nitta and John Naughton (National Marine Fisheries Service)

CHAPTER 8
MANAGEMENT ISSUES RELATED TO ACTIVITIES AND USES IN SANCTUARY WATERS

DATA SOURCES

Information has been gathered from peer-reviewed articles, government reports, plans, and laws, and discussions with government resource managers, scientists, and ocean recreation company representatives. A list is presented in Appendix 8.1.

This chapter examines how human activities in the ocean may affect humpback whales and their habitat, and how present management regimes address conflicts of use in waters of the proposed sanctuary and issues related to resource management.

HUMPBACK WHALE HABITAT

The Oceans Act of 1992 designated the Hawaiian Islands Humpback Whale National Marine Sanctuary with its primary purposes, inter alia, to "protect humpback whales and their habitat", and "to manage such human uses of the sanctuary consistent with this subtitle and title III of the Marine Protection Research and Sanctuaries Act". An important first step in developing sanctuary management measures for resources and activities related to humpback whales is to identify the humpback whale "habitat." A review of the scientific literature is useful for this purpose.

Important humpback whale habitat includes the shallow-water areas and interisland channels of the four-islands region (Maui, Lanai, Molokai, and Kahoolawe), the shallow northwestern part of Penguin Bank, the area off the northwestern coast of Hawaii, and the waters around Niihau and Kauai (Tinney 1988). Penguin Bank, a shallow shoal area with a depth of 25 to 100 fathoms, lies about 25 nm southwest of Molokai.

The NOAA draft Environmental Impact Statement for the proposed Hawaiian Islands Humpback Whale National Marine Sanctuary suggested that humpback whales prefer areas of warm, calm waters within the 100-fathom contour of continental shelves and outlying banks of large islands for breeding and calving (NOAA/OCRM 1983). The coastal waters around the main Hawaiian Islands satisfy several other reported preferences: remote, isolated regions devoid of dense human habitation; prevailing calm, clear weather conditions characteristic of leeward coasts; warm tropical waters averaging 22°C (77°F); wide, shallow banks, and water quality unhampered by excessive turbidity or thermal burdens (Herman and Antinoja 1977; Winn 1977). The requirement of calm wind conditions is not always satisfied, as Penguin Bank is subject to heavy, gusty trade winds; however, it is still preferred by humpback whales.

Wolman and Jurasz (1977) reported that most whales are found within the 100 m isobath. Forestell (Pacific Whale Foundation, pers. comm. 1993) states that whales tend to favor water depths of 46 m or less. Other researchers, however, have noted that cow-calf pairs favor waters, at or less than, 18 m in depth (Glockner and Venus 1983). Smultea (1989) found that significantly more cow-calf pairs were found in waters less than 55 m. Similar findings were reported by Brown and others (1980). A more detailed discussion on humpback whale habitat is found in Chapter 4.

Human Activities That Affect Whale Behavior and the Quality of Whale Habitat

Human activities in sanctuary waters are discussed in Chapter 7 and include commercial fishing, recreational boating, boardsailing, yachting, kayaking, tour-boating, snorkeling, whale-watching, jet skiing, parasailing, canoeing, charter boat fishing, shipping, research, and waste disposal. Potential activities that were examined and found to be unlikely to occur in these sanctuary waters include ocean thermal energy conversion, seabed mining, and the installation of the high voltage underwater cable.

Human activities can affect the behavior of humpback whales directly through physical disturbance and indirectly through habitat modification by reducing the water quality. Scientists generally agree that human activities, in water depths of 60 m to 100 m, can be disruptive to whale behavior (Tinney 1988). The extent of the disturbance depends on the location, type, and frequency of the activity. The scientific community is not in full agreement on the extent of these impacts because there is limited empirical data.

The Humpback Whale Final Recovery Plan (NOAA 1991) notes that the known and potential impacts of human activities on whales in the Pacific include subsistence hunting, incidental entrapment or entanglement in fishing gear, collision with ships, and disturbance or displacement caused by noise and other factors associated with shipping, recreational boating, high-speed thrill craft, whale watching, or air traffic. The report also states that "introduction and/or persistence of pollutants and pathogens from waste disposal; disturbance and/or pollution from oil, gas or other mineral exploration and production; habitat degradation or loss associated with coastal development; and competition with fisheries for prey species..." have negative impacts on whales as well (NOAA/NMFS 1991).

Impacts of fishing, in terms of competition for prey species, may only be a concern in areas where humpback whales feed, such as Alaska. Entanglement is a more likely conflict in areas where whales do not feed such as Hawaii. In Hawaiian waters deeper than 20 m, fishermen do not regularly use large nets. There is no trawling in Hawaiian waters and driftnets are prohibited in U.S. waters. As a result, there have been few reported cases in Hawaii of entanglement in fishing nets. In early 1993, a humpback whale was found entangled in a net off Hilo and was freed by fishermen and local wildlife officials. Later that same year, a whale was reportedly entangled in a marker buoy line on a short longline off the Kona coast. By the time officials arrived on the scene, the whale had apparently freed itself. The frequency of these and similar events is rare.

Noise has been identified as a potential disturbance to whales (Tinney 1988; Bauer and Herman 1986; Atkins and Swartz 1988). The impact of noise depends on three factors: loudness, frequency (tonal pitch), and continuity (noise changes in frequency or direction). Studies in Alaska show that erratic noises are particularly disturbing to whales (Tinney 1988).

Some scientists have noted that whales tend to avoid low-flying aircraft and surface vessels and areas near dense human habitation or disturbance (Herman et al. 1980). Tinney (1988) states that whales avoid areas where there is an increase in human activities in those waters, such as jet skis, ultralight aircraft, and parasailing boats in nearshore waters. The author states that commercial whale-watching, jet skiing, diving, aircraft operations, military activities, and scientific research can all impact whale behavior (Tinney 1988).

Concern over the impacts of boating activities on whales has been growing since a 1977 report by Wolman and Jurasz. Another study (Herman et al. 1980) indicates that human activities may influence distribution of whales in Hawaii. Concerns over vessel and whale interaction centers on two questions: (1) What is the immediate response by whales to an approaching boat?, and (2) What are the long term changes to distribution and abundance patterns of the entire whale population from boating activities?

The effects of vessel traffic on whale behavior have been shown directly using shorestation observation of whales at varying distances from vessels (Bauer 1986; Baker et al. 1982; Baker et al. 1983) as well as indirectly through demonstrations of negative distributional effects with vessels based on aerial survey results. Bauer (1986), observing whales in the waters off Maui, examined a variety of behavioral variables and found changes in respiration rates, dive times, and general activity levels with increasing proximity of vessels. Baker and others (1982, 1983; Baker and Herman 1989) noted similar responses in southeastern Alaskan waters and showed patterns of "horizontal avoidance" (i.e., faster swimming with fewer dives) when vessels were 2,000 m to 4,000 m away, and "vertical avoidance" (i.e., longer dive times) when vessels were from 0 m to 2000 m away. These studies did not indicate how long these behavioral changes persisted.

Forestell and others (1990) state, "there are reliable data which indicate that unpredictable, high-speed movement of any motorized vessel within 0.4 km of whales may cause short-term changes in behavior, such as respiration rate or movement direction". The same study confirms that humpback whales avoid the Lahaina area of Maui, "in all likelihood because of the density of human activity" (Forestell et al. 1990). Glockner-Ferrari and Ferrari (1987) note that the number of physical injuries to calves, juveniles, and adult humpback whales as a result of collisions with boats has increased in Hawaiian waters.

There is no indication that any one type of boat has a greater effect on whales, except possibly large vessels such as cruise ships (Baker et al. 1983) or large military or seismographic vessels (Tyack 1989). In addition to these large ships, some scientists are concerned that barges with long tow lines may have detrimental impacts on whales (Townsend 1991; Tinney 1988).

Scientific studies have indicated some general tendencies of whales to avoid areas of dense human habitation, such as Oahu, the area of Maui around Lahaina, and the area around Kahoolawe (Herman et al. 1980). In 1980, the military was actively bombing Kahoolawe but this has since stopped. The surveys of Herman, Forestell, and Antinoja (1980) also showed sudden decreases in whale density for the waters off Lahaina Roadstead, an area of heavy vessel utilization. Forestell (1989) noted the same negative distributional trend for the Lahaina area as well as the waters adjoining the Keawakapu boat ramp on the Kihei coast of Maui during the 1985 breeding season.

Comparisons between earlier aerial surveys (1977–80) with those of 1990 offered mixed evidence regarding vessel effects (Mobley and Bauer 1991). Sighting rates (no. of whales/hour of survey) increased in the majority of subregions examined across the 10- to 13-year period, including those areas previously described as showing negative distributional effects (waters off Lahaina and Kaanapali); however, those regions showing the greatest increases from the 1977–80 to the 1990 surveys (Figure 4.5) were all characterized as leeward areas with low levels of vessel traffic (Mobley and Bauer 1991). Mobley and Bauer hypothesized a "spill over" effect into these less utilized coastal regions, suggesting that densities of whales in the four-islands and Penguin Bank regions had reached some threshold level and whales were moving into other waters with less traffic. It should be emphasized that factors other than vessels may account for these recent distributional changes. There is no recent evidence that whales are abandoning areas heavily traveled by vessels.

Aerial survey data from Forestell and others (1985) and Forestell (1989) indicated that "human impact on distribution patterns appeared to be highly localized, dynamic, and reversible." Forestell and others (1990) suggest that all boats operating regularly between Maui and Lanai are essentially the same from a whale's perspective. There is no evidence that the whales differentiate between a whalewatch boat, a charter fishing boat, a privately owned recreational boat, or a parasail boat. Any of these types of boats can bother a whale, and any of them may be ignored by a whale. What the boat is doing, and how many of them there are, is probably more important than what kind of boat it is (Bauer and Herman 1986). On the basis of the information we currently have, it seems wise to institute regulations to control all vessels to the same degree, since it has not been possible to show that a given vessel has a greater or lesser impact than another vessel type.

The authors also suggest that because whales move throughout the nearshore waters of the main Hawaiian Islands and humans engage in such a wide variety of activities in these same waters, there is a "complex and dynamic set of interactions [that] requires a comprehensive, state-wide monitoring and management plan" (Forestell et al. 1990).

In addition to the Whale Recovery Plan, other researchers agree that pollution from ships or shore can be a problem for whales (Tinney 1988). Additional concerns include pollution from cruise ships, military activities, use of driftnets, development of geothermal energy, sand mining activities, and development of harbors and resort facilities (Forestell et al. 1990).

In summary, scientific opinion and evidence suggest that the human activities that could affect humpback whale behavior and whale habitat include entanglement in fishing nets and longlines, shipping, disturbance from recreational boating, tour-boating, jet skiing, parasailing, and degradation to the water quality from waste disposal and nonpoint source pollution from coastal development.

IDENTIFICATION OF MANAGEMENT ISSUES RELATING TO HUMAN USE AND ACTIVITIES IN SANCTUARY WATERS

Evaluation of management issues relevant to humpback whale interactions with human uses and activities in sanctuary waters will be discussed. These activities include fishing, shipping, boating, other ocean recreation activities, and waste disposal and nonpoint source pollution.

Commercial and Recreational Fishing

Because fishermen spend a great deal of time on the open ocean, they interact frequently with humpback whales. It is not apparent that these interactions are detrimental to whales. Although there is a potential for whales to become entangled in nets or longlines, few fishermen use nets in the deep waters of the sanctuary, and such entanglement is not reported to be a common event. Nets generally are used close to shore in embayments, along reef faces, and on the open coast in flat, open areas (Smith in press). Entanglement in longlines is not reported to be a frequent occurrence either. Therefore, conflicts of entanglement and interference between current fishery practices and humpback whales do not appear to be major management issues.

In Hawaii, there is a special regulation that prohibits vessels from approaching within 100 yds of a humpback whale and within 300 yds in designated cow-calf areas. Fishermen have expressed concern over the effectiveness and fairness of the distance regulations, although they are in agreement that whales need protection. Many fishermen, however, stated that keeping the requisite distance between the fishing vessel and the whale isn't easy. Altering course with many fishing lines trailing can cause tangling of lines and potential interference with other vessels (Michael Trask, fisherman, pers. comm. 1993). The effectiveness of these distance requirements and their fairness to fishermen has been identified as a management concern of fishermen (Department of Land and Natural Resources, Aquatic Life and Wildlife Advisory Committee 1993).

Shipping

As noted previously, the movement of large ships, such as cruise ships, cargo ships, and barges, may affect whale behavior either through noise or collision. The extent of this disruption is unknown. Because the shipping lanes to and from the ports on Maui and Molokai are already established, and the ships move at a regular pace, their passage is a predictable event. This lack of erratic pace or motion reduces the potential for a negative impact on whale behavior. As a result of such characteristics, there have been no reported collisions between large cruise ships or cargo vessels and humpback whales in Hawaii (Dean Owren, National Marine Fisheries Service, pers. comm. 1993). Shipping impacts on the humpback whale and its habitat do not appear to be a significant management issue. The effects of low-frequency noise on whales is a concern, though little is known about the specific impacts. Therefore, the issue of noise is best addressed as an important research topic.

Boating and Other Ocean Recreation Activities

Boating and other ocean recreation activities in sanctuary waters may have impacts on humpback whales because of proximity to whales, density of users, speed, noise, and erratic directional patterns of vessels.

The Hawaii state government has made a major effort in recent years to identify and manage conflicts of use in boating and ocean recreation. In 1987, the Hawaii State Legislature passed a resolution to formulate an Ocean Recreation Motorcraft Management Plan aimed at reducing conflicts among motorized watercraft and other ocean recreation users. In response, the Hawaii Department of Transportation commissioned Aotani and Associates to write the Statewide Ocean Recreation Management Plan Final Report (Aotani and Associates 1988). The plan focused on ocean recreation areas extending from the high-water mark out to 1,000 yds offshore and was based on a survey of the general public and not of resource managers. Therefore, the technical issues raised here may not necessarily be based on scientific analysis of data, rather it may be based on experience and anecdotal information.

Because whales are not found in shallow nearshore waters, human activities taking place there may not necessarily affect whale behavior. These nearshore activities include surfing, body boarding, body surfing, beachgoing, shoreline fishing and gathering, reef walking, and swimming. Therefore, the major management concern is with boating and other ocean recreation activities occurring in deeper waters. The discussion will focus only on the part of the plan dealing with these activities.

Waters Offshore Kilauea Point, Kauai

Over 300,000 people a year visit Kilauea National Wildlife Refuge. No specific conflicts of ocean recreation use have been identified in the waters off the Refuge, which are the only waters around Kauai that are designated as sanctuary waters; however, just west of the refuge along the Napali (North) coast, hundreds of thousands of visitors come by foot, helicopter, cruise ships, inflatable boats, kayaks, and surfboards. The increasing density of users and activities in this general area may cause an increased frequency of disturbance to whales.

Maui County Waters

In Maui, the areas that were identified as having significant conflicts include west Maui from Olowalu to Napili Bay; Kihei/Makena side of Maui, from Maalaea to La Perouse Bay; and north Maui. These areas were surveyed as to their level and type of recreational use and existing or potential conflicts from these uses.

The Ocean Recreation Plan Final Report listed the top five ranking management concerns in Maui:

1) Lack of enforcement of rules and regulations;
2) Lack of a comprehensive Ocean Recreation Management Plan;
3) Inadequate protection of aquatic life;
4) Lack of environmental concerns and shoreline protection; and
5) Water safety.

Conflicts of use have been identified primarily in the West Maui area, in Lahaina and Kaanapali, Kihei, Molokini Island, Maalaea Bay, and Hoookipa Beach area. Commercial whale-watching reportedly takes place in the following areas: Lahaina, Kaanapali, Napili Bay/Honokowai, Molokini Island, Makena Bay/La Perouse Bay, Kihei, Kamaole Beach, and Maalaea Bay. Specific concerns relating to these areas as determined by Aotani and Associates (1988) are:

Lahaina: Noise and odor of motorized craft, including jet skis, which scare whales and people; water pollution from gas runoff and spillages; and unrestricted commercial use of waters, such as by parasails, jetskis, and ultralight aircraft.

Kaanapali: Noise pollution from large and small vessels; jetskiing and parasailing in conflict with whales in the area.

Napili Bay/Honokowai: Water pollution from the sewage treatment plant, and runoff causing siltation of waters.

Molokini Island and Makena/La Perouse Bay: High density of use in the area with snorkel boats and dive boats competing for space, as well as lack of enforcement of conservation laws. Such high density could displace whales in the area, and lack of enforcement could be problematic.

Kihei/Kamaole Beach: Water pollution in certain areas from sewage, debris, and trash; and parasailors' use of an area heavily populated by whales, particularly mothers and calves.

Maalaea Bay: Noise pollution from jet skis and outboard motors.

To address these areas of conflict, specific rules were adopted and are described below. In addition to these conflicts, a management issue, identified by the boating and ocean recreation industry, is the effectiveness and fairness of the distance regulations for vessels and whales. For many operators, it is difficult not to have at least one unintentional encounter per day with a humpback whale inside the 100- or 300-yd limit (Jim Coon, Maui County Boat Owners Association, pers. comm. 1993). There is concern that this regulation may not be working well.

Waste Disposal and Nonpoint Source Pollution

There are no direct discharges of waste that are permitted in the waters currently designated as the sanctuary. The primary problem contributing to degradation of coastal waters in this area is nonpoint source pollution, primarily sedimentation from eroding topsoil (Hawaii DOH 1989). Conditions that contribute to soil erosion include overgrazing of pasture land, inadequate soil conservation measures while cultivating land, and grubbing and grading large tracts of land for construction of coastal developments.

There has been a recurring problem with large-scale algal blooms occurring in west Maui. Preliminary studies indicate that sources of nutrients may include injection wells used by a sewage treatment plant, agricultural runoff, and storm water runoff (Tetra Tech, Inc. 1993). There is no required nearshore water quality monitoring of the potential leaching of nutrients from injection wells at this time, so the extent of this problem is not known. Extensive research and management programs were begun in 1993 to better understand and identify solutions to the problem. Increased turbidity of nearshore waters due to sedimentation could affect humpback whales by degrading the water quality of its nearshore habitat.

Other pollutants, such as petrochemical and agrichemical contaminants, may also enter the nearshore waters with suspended sediments and through storm drain runoff. These pollutants may affect the health of humpback whales if they are in high concentrations. Considering the level of nonpoint source pollution that is entering the coastal waters of the sanctuary, water quality is potentially a significant management concern for humpback whales.

Other Impacts of Coastal Development

Coastal developments, such as resorts and residential areas, contribute to nonpoint source pollution through soil runoff and storm drain runoff as described above. Increased population density along coastal areas potentially increases the use of coastal waters, thereby indirectly affecting the whales. Other coastal development, such as marinas and dredging operations, could also cause high turbidity in coastal waters. In addition, use of explosives during these construction activities can cause significant disturbance to the whales. This concern has been well addressed in permit conditions by the National Marine Fisheries Service that prohibit the use of explosives during the winter season when whales are in Hawaiian waters. Thus, besides nonpoint source pollution and increased use of coastal waters, direct impacts of coastal development do not appear to be a major management concern.

PRESENT MANAGEMENT REGIME

Because the sanctuary, as designated in the Oceans Act of 1992, lies primarily in state waters, it is important to understand the state's role in managing the marine resources and activities in these waters. This section discusses the Hawaii Ocean Resources Management Plan policies and objectives relating to marine protected areas and shows how they relate to the national marine sanctuary purposes and objectives. This section also discusses management measures that were established to address conflicts resulting from different uses of these waters and the reduction of detrimental environmental impacts relating to use of these sanctuary waters.

Hawaii Ocean Resources Management Plan

In order to understand how the national marine sanctuary will be coordinated with the existing management regime in Hawaii, it is instructive to examine the state's policy on marine ecosystem protection as articulated in the *Hawaii Ocean Resources Management Plan* (HORMP) developed by the Hawaii Ocean and Marine Resources Council (HOMRC). The HORMP has an entire section on marine ecosystem protection in which the main objectives and policies are presented.

The main objective is to:

> *Provide for protection of marine and coastal ecosystems, and establish a comprehensive system of marine and coastal protected areas within an integrated program which protects, preserves, and enhances marine species and areas of exceptional resource value on each main island, representing each of the natural ecosystems and resources found in the marine and coastal environment of the State (HOMRC 1991:27).*

The four main policies are:

Policy A: Expand protection of species, natural habitats, and other resources of exceptional value, thereby minimizing environmental degradation from marine and coastal activities and uses (HOMRC 1991:27).

Implementing actions direct the Hawaii Department of Land and Natural Resources (DLNR) and the Hawaii Office of State Planning (OSP) to prepare "a comprehensive and cohesive statewide master plan for marine and coastal protected areas..."; "identify areas of exceptional resource value which should be considered for protected area status"; and "establish a system of marine and coastal protected areas throughout the State to protect the best examples of these natural ecosystems and resources on each island" (HOMRC 1991:27). The establishment of the sanctuary in Hawaii can complement this effort because the Oceans Act of 1992 states the purposes of the sanctuary are to, inter alia, "...protect humpback whales and their habitat;" "manage such human uses of the Sanctuary consistent with this subtitle and title III and the Marine Protection Research and Sanctuaries Act;" and "...provide for the identification of marine resources and ecosystems of national significance for possible inclusion in the sanctuary."

Policy B: Facilitate coordinated and comprehensive inter-agency management where jurisdiction overlaps exist between federal, state, and county governments in marine and coastal protected areas (HOMRC 1991, 28).

Implementing actions direct DLNR and OSP, in conjunction with appropriate federal, state, and county agencies, to "facilitate and coordinate federal, state, and private-cooperative research and monitoring efforts at developing baseline information regarding the locations of critical habitats of endangered and threatened species;" "Encourage the designation of these critical habitats as protected areas; and "Encourage joint efforts of federal, state, county, private, and community involvement in marine life and water quality monitoring programs" (HOMRC 1991:28). The establishment of the sanctuary could also complement these efforts. According to the Oceans Act of 1992, the Sanctuary Management Plan is to "ensure coordination and cooperation between Sanctuary managers and other federal, state, and local authorities with jurisdiction within or adjacent to the Sanctuary."

Policy C: Improve enforcement of regulations protecting marine and coastal protected areas and species (HOMRC 1991:29).

Implementing actions include establishing several memoranda of understanding between federal and state agencies to enable personnel from these agencies to enforce both state and federal regulations" (HOMRC 1991:29). The Oceans Act of 1992 states that the Sanctuary Management Plan shall "...set forth the allocation of Federal and State enforcement responsibilities, as jointly agreed by the Secretary [of Commerce] and the State of Hawaii". This builds on efforts already underway such as the cross-deputization of state enforcement agency personnel to enforce federal laws and regulations. The

Department of Land and Natural Resources, Division of Conservation and Resource Enforcement and the Department of Public Safety Marine Patrol have been deputized to enforce the U.S. National Marine Fisheries Service rules regarding harassment of marine mammals. There have been other efforts to coordinate enforcement activities such as a UH Sea Grant supported project called REACH (Resource Enforcement And Conservation Hawaii) that sponsored a series of workshops for federal, state, and county enforcement agencies to improve coordination and public participation.

Policy D: Enhance local community awareness, appreciation, and participation in marine conservation and preservation efforts (HOMRC 1991. 29).

Various implementing actions include public participation programs, focusing on natural, cultural, and historical values; facilitating public participation in ocean resources management plan development; and supporting the development of interpretive centers (HOMRC 1991). Education efforts regarding humpback whales and marine resources in Hawaii are discussed below. The Oceans Act of 1992 also supports a similar policy as it states that a purpose of the sanctuary is to "educate and interpret for the public the relationship of humpback whales to the Hawaiian Islands marine environment. Also, the Act states that the Sanctuary Management Plan will "promote education, among users of the Sanctuary and the general public, about conservation of humpback whales, their habitat, and other marine resources". The legal requirements of the development of a draft Environmental Impact Statement and Management Plan direct the National Oceanic and Atmospheric Administration to include public participation in the planning process.

As shown in this analysis, the purposes for which the sanctuary has been established can be complementary to the state's policies and objectives regarding marine ecosystem protection as set forth in the Hawaii Ocean Resources Management Plan.

Management of Ocean Activities

Interactions in Hawaiian waters between boating and shipping activities and humpback whales, whether in sanctuary waters or not, are regulated by federal law. Humpback whales are protected under numerous existing federal and international laws including the Marine Mammal Protection Act (MMPA) of 1972; the Endangered Species Act (ESA) of 1973; the Fishery Conservation and Management Act of 1976; and the International Whaling Convention and the Convention on International Trade in Endangered Species.

The MMPA and ESA provide the primary protection for humpback whales in the U.S. The MMPA prohibits the "taking" of marine mammals and marine mammal products. The Act defines "to take" as "to harass, hunt, capture, or kill" any marine mammal." Harassment of marine mammals has been shown to be the most broadly applied of these definitions and has been enforced by the U.S. National Marine Fisheries Service to mean a variety of unintentional acts that adversely affect whales. The designation of certain Hawaiian waters as a National Marine Sanctuary provides the opportunity to provide additional regulatory protection or additional enforcement of existing rules protecting these whales.

Management of Fishing Activities

Federal and state laws prohibit possession and use of gillnets, discarding or disposing of any fishing net or gear, and taking of marine life with explosives, poisons, or electrical shocking devices. In addition, federal laws prohibit the use of trawl nets and bottom set gillnets in Hawaiian waters. There are also several state rules regarding minimum size of different species, as well as seasonal restrictions on kona crab and lobster.

State law prohibits longline fishing in state waters. In addition, federal law prohibits longline fishing within 50 nm around the four-islands region of Maui County and Hawaii Island, and within 75 nm around Oahu and the islands of Kauai County. Longline fishing is defined as using gear consisting of at least one main line, over 1 nm in length, to which a number of branchlines with baited hooks are attached. The main line is suspended below the surface by floatlines attached to surface floats.

Management of Boating and Ocean Recreation

The primary management measure to deal with interactions between boats and humpback whales is the distance regulation regarding the approach of vessels and swimmers to whales. For some specific activities, such as jet skiing and parasailing, there are restrictions as to the area and seasons when they can operate to prevent interference between such activities and the humpback whales. There are also state laws that regulate the density of activities in areas used by whales within 3,000 ft of shore. These regulations are based on the work done in the Ocean Recreation Management Plan (Aotani and Associates 1988) and are contained in Section 19, Chapter 86 of the *Hawaii Administrative Rules* (HAR).

Kauai

Although there are no specific rules governing the waters off Kilauea Point, ocean recreation activities for adjacent parts of the north shore of Kauai are regulated. The north shore of Kauai, from Makaha Point along the Napali coast, and extending 3,000 ft seaward of the territorial sea baseline, are included in the North Kauai Ocean Recreation Management Area. The general rules cover permits and fees and prohibit parasailing and jet skiing in the area. There are specific additional rules for Anini Beach, Hanalei Bay, Haena ocean waters, and the Napali coast regarding delineation of "swimming only" zones and ingress and egress channels for boats.

Maui County waters

For West Maui, Ocean Recreation Management Area rules are also contained in Section 19, Chapter 86 of the Hawaii Administrative Rules. The West Maui Ocean Recreation Management Area includes all ocean waters and navigable streams from the northeast boundary of Honolua Bay to McGregor Point and extending 3,000 ft seaward of the territorial sea baseline.

The restricted areas are: (1) Napili Bay with swimming and surfing only and no mooring or operating of vessels; (2) Lahaina-Kaanapali offshore where there is a parasailing area with no more than five commercial operator permits allowed. No parasailing is allowed between December 15 and May 15; (3) Kaanapali Commercial Thrill Craft Area in which no more than six commercial thrill craft are allowed at any one time, and thrill craft are prohibited from December 15 to May 15; (4) Kaanapali commercial water-sledding zone in which only two permits are allowed and is closed from December 15 to May 15; (5) Olowalu Beach Restricted Area where only swimming, snorkeling, scuba diving, and shoreline fishing are allowed; and (6) the Maui Humpback Whale protected area in which no thrillcraft, parasailing, watersledding, or commercial high-speed boating are allowed in the area from December 15 to May 15.

Rules in South and North Maui Ocean Recreation Management Areas are not directly relevant to management of humpback whales.

State Marine Protected Areas: Marine Life Conservation Districts and fishery Management Areas

The State of Hawaii uses marine protected area designations as a management tool to address concerns over resource depletion as well as conserving important recreational resources from detrimental impacts of consumptive activities. There are three Marine Life Conservation Districts in the sanctuary area: the Honolua-Mokuleia Bay Marine Life Conservation District, the Molokini Shoal Marine Life Conservation District, and the Manele-Hulopoe Marine Life Conservation District.

There are also fishing rules and regulations for Kahului Harbor on Maui, Kaunakakai Harbor on Molokai, and Manele Harbor on Lanai. Other protected or managed marine areas in the four-islands region include the nearshore marine area that is a part of Ahihi-Kinau Natural Area Reserve (Maui).

Although these Marine Life Conservation Districts (MLCDs) overlap with some humpback whale habitat, the rules are not designed specifically to minimize interference between vessels and humpback whales. Nonetheless, the management of MLCDs are relevant to the discussion here because these plans and regulations are primary examples of the state's approach to marine protected area management. A description of MLCDs in the designated national marine sanctuary area are as follows.

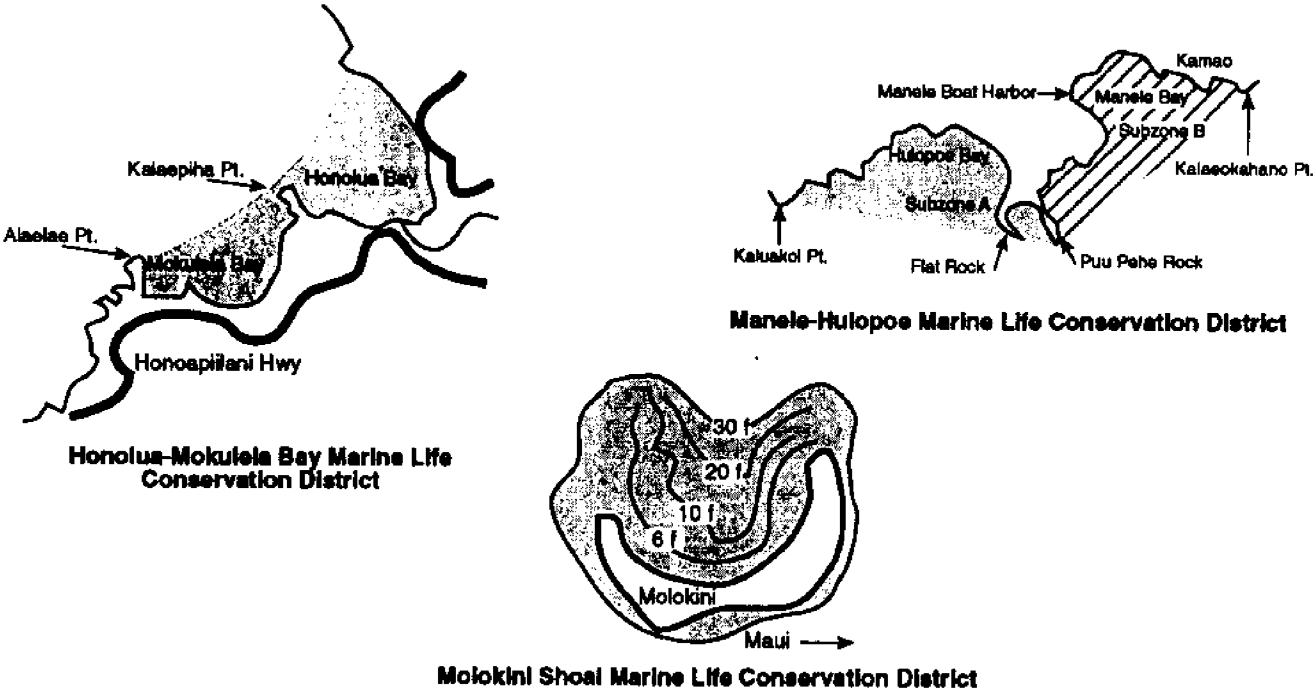

Figure 8.1 Marine Life Conservation Districts in the Sanctuary

1) Honolua-Mokuleia Bay MLCD is located along the northwestern coast of Maui and bounded by Alaeloa and Kalaepiha Points, and the northwestern point of Honolua Bay as shown in Figure 8.1.

Permitted:

- To possess aboard any boat or watercraft any legal fishing gear and fish or other aquatic life taken outside of the District.
- To possess in the water any knife, shark billy, bang stick, powerhead, or carbon dioxide injector.
- With a permit, to bag and remove *akule* netted outside of the District provided the net is moved only over the sandy bottom areas of the District, and to engage in activities otherwise prohibited by law for scientific, propagation, or other purposes.

Prohibited:

- To fish for, take, or injure any marine life (including eggs), or possess in the water any device that may be used for the taking of marine life, except as indicated in permitted activities above.
- To take or alter any sand, coral, or other geological feature or specimen, or possess in the water any device that may be used for the taking or altering of a geological feature or specimen.

2) Molokini Shoal MLCD is located offshore of Molokini Shoal, from the highwater mark seaward to a depth of 30 fathoms (180 ft.) as shown in Figure 8.1.

Permitted:

- To fish for, take, or possess any finfish by trolling with artificial lures.

- To possess in the water any knife, shark billy, bang stick, powerhead, or carbon dioxide injector.
- With a permit to engage in activities otherwise prohibited by law for scientific, propagation, or other purposes.

Prohibited:

- To fish for, take, or injure any marine life (including eggs), or possess in the water any device that may be used for the taking of marine life, except as indicated in permitted activities above.
- To take or alter any sand, coral, or other geological feature or specimen, or possess in the water any device that may be used for the taking or altering of a geological feature or specimen.

3) Manele-Hulopoe MLCD is located in the waters offshore of Palawai and Kamao on the southwestern coast of Lanai as shown in Figure 8.1. Subzone A refers to the area bounded seaward by a line from Kaluakoi Point to Flat rock, then to Puu Pehe Rock. Subzone B refers to the area bounded seaward by Puu Pehe Rock and Kalaeokahano Point. The Department of Transportation has established rules relating to boating, anchoring, and mooring within the Manele-Hulopoe MLCD.

Permitted:

- To fish for, take, or possess any finfish or crustacean by hook-and-line from the shoreline within Subzone A, and by any legal fishing method except spear, trap, and net other than thrownet within Subzone B.
- To possess in the water any knife, shark billy, bang stick, powerhead, or carbon dioxide injector.
- With a permit to engage in activities otherwise prohibited by law for scientific, propagation, or other purposes.

Prohibited:

- To fish for, take, or injure any marine life (including eggs), except as indicated in permitted activities above.
- To take or alter any sand coral or other geological feature or specimen.

Management of Nonpoint Source Pollution

Measures to control nonpoint source pollution are being identified and coordinated through the state's Nonpoint Source Pollution Control Program through the Hawaii Coastal Zone Management Program and the Department of Health in conjunction with county governments. In Maui, specific efforts to reduce sedimentation into nearshore waters are being conducted in the Honolua Watershed Hydrologic Unit, which is directly upslope from the Honolua Bay MLCD, a state marine protected area. The Honolua Watershed Hydrologic Unit Area project is administered by the U.S. Soil Conservation District in cooperation with the West Maui Soil and Water Conservation District and Hawaii Department of Land and Natural Resources, Division of Forestry and Wildlife. The objective is to reduce soil erosion from cultivated lands and exposed areas. A similar project has been initiated on Molokai at the Manawainui watershed.

Management and control of nonpoint source pollution is being initiated in Hawaii and in sanctuary waters. The federal government requires the state to promulgate regulations to control and minimize this pollution. The process to develop regulations is a cooperative effort with the state, county, and land users.

Current Educational Efforts to Address Management Concerns

Various public and private groups are involved in educational efforts relating to humpback whales. A detailed list of such programs is given in Appendix 8.1 based on the *Environmental Education Resource Guide* by the

Hawaii Environmental Education Association (HEEA) and further discussions with various environmental education organizations.

The Bishop Museum Education Program offers elementary schools guided tours through the Bishop Museum's whaling exhibits. Earthtrust, a non-profit organization offers field trips aboard whale-watch boats that include natural history interpretation for passengers. Earthtrust has also produced a whale-watching guide and brochure. Kilauea Point National Wildlife Refuge on Kauai operates a public information center at the refuge and produces publications on conservation issues available to schools and the general public, including a publication available on whales (HEEA 1993).

The Pacific Whale Foundation (PWF) is probably the largest non-profit research, education, and conservation organization in the state whose purpose is to educate the public, from a scientific perspective, about marine animals and the ocean environment. They have numerous public programs including monthly presentations each winter by an expert in marine environmental issues. The PWF also sponsors an Annual Whale Day/Earth Day celebration, which provides an opportunity for environmental groups to meet with the public. They coordinate an island-wide network of volunteers to conduct a monitoring program to determine locations and numbers of humpback whales observed within the nearshore waters of Maui. The PWF has an Adopt-a-Whale program in which participants "adopt" an endangered Pacific humpback whale and receive a certificate, photograph, and newsletters. The PWF also has a mobile educational program called the Ocean Van that visits schools and community events throughout Maui to help make information about whales more accessible. They also have educational programs that introduce participants to endangered marine life, including whales and dolphins, using interactive games, displays, and media demonstrations. Finally, PWF sponsors two-hour guided whale-watch tours from January to March each year for school and community groups. In addition, these whale-watch tours are available for a fee to visitors. The PWF has numerous publications including a very popular whale-watching guide (HEEA 1993).

Evans (1992) developed a survey of environmental education programs focusing on whales in Hawaii. He identified the major participants as the National Marine Fisheries Service (NMFS), the State of Hawaii, University of Hawaii Sea Grant College Program, Earthtrust, Pacific Whale Foundation, and others.

The National Marine Fisheries Service educational efforts are through public meetings and public hearings related to changes in the marine mammal regulations; two information brochures, outreach programs, and two brochures — one on humpback whales and the other on federal regulations on approaching humpback whales (Evans 1992).

The State of Hawaii has designated the humpback whale as its state marine mammal. No educational campaign, focusing specifically on humpback whales, has been initiated by any state agency; however, administrative rules relating to management of human activities potentially affecting whales have been promulgated, as described below.

University of Hawaii Sea Grant has conducted several workshops, and developed reports and brochures to help educate the public about humpback whales. These include a guide for the amateur whale watcher (UHSG 1985), a catalog of individual identification photographs (Perry et al. 1988), and numerous articles in its newsletter, *Makai*.

There are numerous other private and non-profit groups conducting educational efforts that include humpback whales. These include the Bishop Museum, Center for Marine Conservation, Greenpeace, Hale Kohola (House of the Whale), Hawaii Maritime Museum, Moanalua Gardens Foundation, Sea Life Park, Waikiki Aquarium, and West Coast Whale Research Foundation (Evans 1992). In addition, there are several programs to develop curriculum material for local elementary schools that include a focus on humpback whales in Hawaii, including work supported by the Malama Kai Foundation, Friends for the Future, and other Hawaii-based groups.

SUMMARY AND RECOMMENDATIONS FOR MANAGEMENT OR FURTHER RESEARCH

The primary management issues facing the national marine sanctuary are (1) reducing the density of ocean activities in the humpback whale habitat to prevent detrimental interference with the whales, (2) working with the existing program to control nonpoint source pollution affecting the quality of the coastal waters of the sanctuary in which the humpback whales live, and (3) addressing the concern of the effectiveness and fairness of the distance regulations in dealing with intentional interference of vessels with humpback whales. If the scope of the sanctuary expands to include other marine resources, then management issues related to coral reef conservation will need to be addressed. Education, research, monitoring, and enforcement all need to be improved. Therefore, the most effective management approach to address these issues in the sanctuary would be a cooperative approach of working with the user groups and government agencies through a combination of education, research, monitoring, and coordinated enforcement of fair and effective rules.

It must be emphasized that all the management and research recommendations included here must be done in close cooperation between the federal and state government, and in many cases, with university researchers, private industry, and local government. Most importantly, the partnership between the state and federal government is essential for success of this sanctuary, in terms of management, research, and education.

1. Conduct additional research and monitoring on whale distribution. Although there is some excellent work being done on whale fluke identification, whale movement tracking, acoustical studies and others, there is a need for a more comprehensive monitoring of whale distribution to assess whale population, stock characteristics, and geographical distribution. Additional aerial survey work is necessary as well.
2. Conduct additional research and monitoring to identify important humpback whale habitat. Scientists and others are only beginning to understand the importance of habitat for resting, singing, group behavior, courting, mating, birthing, and nursing of humpback whales.
3. Conduct additional research on impacts of human activities on whale behavior. Understanding the effects of human activities on whale behavior is essential to effective management of these activities. The monitoring of whale behavior in the presence of humans, boats, and other watercraft would provide useful data for management purposes and would help in identifying acceptable levels of use of different types of vessels. The effects of noise on whales are not well understood and need to be studied.
4. Conduct research on interactions between cetaceans and humans. An area of research that needs to be explored is the identification and understanding of why humans are drawn to whales and dolphins, and whether the opportunities to view them in their natural environment can increase awareness of the marine ecosystems. Such information will help design and manage whale-watching programs so they can be a useful educational and management tool for marine ecosystem protection.
5. Evaluate the effectiveness and fairness of the distance regulations in managing interactions between vessels and humpback whales. The National Marine Fisheries Service management and enforcement personnel, scientific researchers, fishermen, and ocean recreation boaters, would work cooperatively to evaluate the effectiveness of these distance regulations in minimizing intentional harassment and interference with the humpback whales, and their fairness to fishermen and ocean recreation activities.
6. Update and revise the ocean recreation management plan. The system of ocean recreation management areas is a useful and effective tool with which to control the density of uses in humpback whale habitat. It needs, however, to be constantly updated to adapt to changing use patterns in the coastal waters. Clearly this is a state management issue, although federal assistance may be useful.
7. Conduct additional research and management efforts on reducing the impacts of nonpoint source pollution on whale habitat. Understanding the effects of environmental change on humpback whales requires further research. These environmental changes include increased turbidity from soil erosion, nuisance

algal blooms, and nutrient loading. It will be important to work with existing efforts to reduce nonpoint source pollution of humpback whale habitat.

8. Establish a comprehensive environmental monitoring program. To identify those areas where environmental changes are taking place, an environmental monitoring program is needed in coastal areas to assess water quality and marine life quality on an on-going basis. This is of benefit to the public resources, as well as to the private tourism industry. Consequently, the cost for such monitoring in the coastal waters can reasonably be shared between the public and private sector. This effort will need to examine the effects of land use on the nearshore coastal marine environment, as is currently being done in West Maui. The West Hawaii Coastal Monitoring Protocol (West Hawaii Coastal Monitoring Task Force 1992) is a useful model for such a monitoring program.
9. Identify other marine resources that would benefit from protection and management through a national marine sanctuary. The Hawaii Ocean Resources Management Plan identifies one of its implementing actions as the establishment of a state-wide system of marine protected areas. The national marine sanctuary program could be beneficial in complementing this effort through cooperative efforts to protect those areas that are identified as specially important areas for the humpback whales, as well as those containing specially significant natural resources.
10. Establish a state-wide system of day-use mooring buoys. The Hawaiian coral reefs may be identified as another marine resource that is nationally significant and in need of sanctuary management. If this occurs, the establishment of a state-wide system of day-use mooring buoys in frequently used coral reef areas of the sanctuary waters would serve many purposes: protection of coral reefs from anchor damage, a management tool to limit use of an area, and as an enforcement tool delineating specially managed areas.
11. Develop additional education programs. The most fundamental and effective tool for protecting sanctuary resources will be an educational program developed and implemented in a partnership of federal and state governments, local schools, non-profit institutions, and the community. A primary tool is a simple pamphlet describing whales and their habitat; the ways in which humans affect them both; and the ways humans can work to protect the whales and the marine environment. Such brochures have already been developed by groups such as the Pacific Whale Foundation. Establishing a co-sponsorship program where the costs of reproduction can be shared by numerous public and private organizations is an effective way of sharing resources.

Besides pamphlets and brochures, additional outreach programs are needed. Some can be developed on existing programs by non-profit organizations and university programs. Incorporating well-informed and accurate interpretive programs into all whale-watching cruises is very important. An interpretive training program for whale-watch cruise crews is another valuable method of ensuring that the educational opportunities afforded by whale-watch cruises are fully utilized, and the passenger receives a consistent and accurate message about conservation of whales and the marine environment.

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APPENDIX 8.1

Personal communications and interviews on issues relating to management of ocean use and activities in the sanctuary waters.

State government representatives:

Reggie Kokubun (Department of Land and Natural Resources, Division of Aquatic Resources)

June Harrigan (Department of Health)

M. Carolyn Stewart (Hawaii Coastal Zone Management Program)

Federal government representatives:

Robert Shroeder (Western Pacific Regional Fishery Management Council)

Eugene Nitta (National Marine Fisheries Service)

John Naughton (National Marine Fisheries Service)

Dean Owren (National Marine Fisheries Service)

University scientists:

Paul Forestell (Pacific Whale Foundation)

Dan McSweeney (private whale researcher)

James Maragos (East-West Center)

Richard Grigg (University of Hawaii Institute for Marine Biology)

Richard Brock (University of Hawaii Sea Grant Extension Service)

Ocean recreation industry representatives:

Kim Roberts (Lahaina Divers)

Teri Leicher (Jack's Diving Locker)

Jim Coon (Maui County Boat Owners Association)

Jim Housch (Maui-based ocean recreation consultant)

Fishermen:

Michael Trask and Leonard Tanaka

The cruise ship representative was Richard Haugh (American Hawaii Cruise Lines)

APPENDIX 8.2

Whale Education Programs in Hawaii

Bishop Museum Education Program

1525 Bernice Street
P.O. Box 19000A
Honolulu, HI 96817

Activities: **There She Blows**
Guided tours through the Bishop Museum's whaling exhibits offered to elementary schools.

Earthtrust

Kihei, Maui, HI 96753
Earthtrust is a naturalist program that educates people about whales.

Activities: **Whale-watch Program**
Naturalist program that educates people about whales through field trips aboard whale-watch boats.

Save the Whales
Whale-watch tour conducted by a naturalist aboard a boat who gives a presentation on whales, whaling, and whale issues.

Hawaii Institute of Marine Biology, University of Hawaii

P.O. Box 1346
Kaneohe, HI 96744

The Hawaii Institute of Marine Biology (HIMB) is a research institute of the University of Hawaii that fosters research and education in marine biological sciences. HIMB maintains a collection of books, reports, theses, and dissertations.

Kilauea Point National Wildlife Refuge

P.O. Box 87
Kilauea, Kauai, HI 96754

The Kilauea Point National Wildlife Refuge staff, in cooperation with Kilauea Point National History Association, operates a public information center at the refuge and makes publications on conservation issues available to schools and the general public. Publications: Kilauea Point Natural History Association.

Whale — What is a Whale? (Hawaii Nature Focus — Nature Studies for Children — No 1.)

Pacific Whale Foundation

101 N. Kihei Rd.
Kihei, Maui, HI 96753

The Pacific Whale Foundation is a non-profit research, education, and conservation organization whose purpose is to educate the public, from a scientific perspective, about marine animals and the ocean environment.

Public Programs: **Whales and Friends Lecture Series**

Monthly presentations each winter by an expert in marine environmental issues is offered. The programs highlight the efforts of leaders in the marine science and environmental protection.

Whale Day/Earth Day
Annual Whale Day/Earth Day celebration provides an opportunity for environmental groups to meet with the public.

The Great Whale Count
Island-wide network of volunteers conducts a monitoring program to determine locations and numbers of humpback whales observed within the near-shore waters of Maui.

Adopt-a-Whale
Participants "adopt" an endangered Pacific humpback whale and receive a certificate, photograph, and newsletter.

The Ocean Van
Pacific Whale Foundation's Ocean Van visits schools and community events throughout Maui to help bring learning to life.

Endangered Marine Life
This program introduces participants to some of Hawaii's unique and endangered species: the humpback whale, the Hawaiian monk seal, and the green sea turtle.

Whales and Dolphins
This program reviews the many species of whales and dolphins with interactive games, displays, and media demonstrations.

Whalewatch (Maalea, Bay, Maui)
Guided two-hour whalewatch from January-March each year for school groups, and others.

Publications: Kaufman, G.D., and P. Forestell. *Hawaii's Humpback Whales: A Complete Whalewatcher's Guide.*

Fin and fluke report. J. Pa. Whale Found.

Soundings. Adopt-a-whale program newsletter.

Kaufman, G.D., and P. Forestell. *Pacific Whale Foundation Whalewatching Guide.*

1992 Catalog. Listings of environmentally related written materials and articles available.

Sea Grant Extension Service

1000 Pope Road, MSB 226
Honolulu, HI 96822

The University of Hawaii Sea Grant Extension Service is the public outreach and information/technology program that supports research, education, and extension efforts that encourage sound management of the ocean's resources.

Sea Life Park Hawaii/ SLP Marine Research and Education

Makapuu Point
Waimanalo, HI96795

Humpback Whale Awareness Month
Annual conservation program celebrating the humpback whale's annual return to Hawaii with lectures, marine artist youth competition and exhibit, and daily mini-lectures.

Source: Hawaii Environmental Education Association. 1993. *Environmental Education Resource Guide.* Honolulu, Hawaii Environmental Education Association.