7. ENVIRONMENTAL SETTING

This chapter describes components of the environment related to marine resources found in the NWHI. Where possible, trends in the condition of resources, ecosystems, fisheries, and human communities have been identified. This information provides the baseline and historical context needed to evaluate, in Chapter 8, the potential environmental consequences of each of the alternatives considered by the Council.

7.1 Physical Environment

Geographic Setting: In the central North Pacific Ocean, roughly 2,500 miles southwest of North America, lies the Hawaiian Archipelago. This 137-island chain stretches nearly 1,500 miles from Kure Atoll in the northwest to the island of Hawaii in the southwest. The NWHI comprise roughly 1000 miles of the 1,500 mile archipelago, and are composed of volcanic islands, atolls, shoals, and submerged banks. Contrary to statements that the NWHI contain 70% of US coral reefs (Executive Order 13178, 2000), recent evaluations of potential coral ecosystems in the United States have found that the NWHI contain less than 5% of the nation's potential shallow-water tropical and subtropical coral ecosystems when this area is defined as areas within the 10-fathom depth curve, and less than 10% of the nation's total when this area is defined as areas within the 100-fathom depth curve (Rohmann, 2005).

The closest NWHI island to the MHI is Nihoa, which lies nearly 150 miles northwest of Kauai. Nihoa is a volcanic island with two distinct peaks and steep sea cliffs. The next island to the northwest is Necker, which is volcanic island resembling the shape of a fish hook. Continuing west is French Frigate Shoals, an eighteen mile wide crescent shaped atoll. French Frigate Shoals has two exposed volcanic rocks and twelve low sandy islets. Northwest of French Frigate Shoals is Gardner Pinnacles, which consists of two emergent volcanic rocks. Next is Maro Reef, which is mostly a submerged atoll with very little emergent land.

Continuing up the chain is Laysan, the largest island in the NWHI, which is vegetated and even contains an hypersaline (extremely salty) lake. Northwest of Laysan is Lisianski Island, made up of low sand and coral, and located at northern end of a large submerged bank. Pearl and Hermes Reef, northwest of Lisianski, is a large atoll with several small islets that occasionally are submerged during storm activity. Continuing northwest is Midway Atoll, which includes three small islands surrounded by a large barrier reef. Kure Atoll, the northernmost coral atoll in the world, is surrounded by a barrier reef and contains an emergent land area known as Green Island. Between the emergent land areas described above are several submerged banks such as Brooks Bank, Raita Bank, St. Rogatien Bank, etc., which provide habitat for a variety marine resources.

Oceanographic Setting: The archipelago's position in the Pacific Ocean lies within the clockwise rotating North Pacific Subtropical Gyre, extending from the northern portion of the North Equatorial Current into the region south of the Subtropical High, where the water moves eastward in the North Pacific Current. At the pass between the MHI and the NWHI there is often a westward flow from the region of Kauai along the lee side of the lower NWHI. This flow, the North Hawaiian Ridge Current (NHRC), is extremely variable and can also be absent at times. The analysis of 10 years of shipboard acoustic Doppler current profiler data collected by the NOAA Ship Townsend Cromwell shows mean flow through the ridge between Oahu and Nihoa, and extending to 200 m. While the high variability of the NHRC certainly allows for the possibility of direct larval transport toward the MHI, the mean currents indicate that direct larval recruitment is more likely from the MHI to the NWHI (Firing, 2005).

Imbedded in the mean east-to-west flow are an abundance of mesoscale eddies created from a mixture of wind, current, and sea floor interactions. The eddies, which can rotate either clockwise or counter clockwise, have important biological impacts. For example, eddies create vertical fluxes, with regions of divergence (upwelling) where the thermocline shoals and deep nutrients are pumped into surface waters enhancing phytoplankton production, and also regions of convergence (downwelling) where the thermocline deepens.

Sea surface temperatures around the Hawaiian Archipelago experience seasonal variability, but generally vary between 18°-28° C (64°-82° F) with the colder waters occurring more often in the NWHI. The NWHI are unique in that they contain the northernmost coral reef ecosystem (Kure Atoll) on the planet. The water temperatures experienced there are assumed to be the lower limit for corals to thrive and reefs to grow. Grigg (1982) suggests that Kure Atoll lies at the "Darwin Point" for reef development, a geographical limit beyond which corals and coralline algae can no longer deposit enough calcium carbonate to keep up with the subsidence of the area's volcanic base. It is theorized that reefs at latitudes higher than the Darwin Point fail to remain at sea level and sink below the photic zone within which growth can occur (Grigg 1982).

The Hawaiian Archipelago is subject to large storms and high wave energy produced from weather systems generated off the Aluetian Islands and other areas of the North Pacific. Such storms and waves can have major effects on the nearshore environment. For example, a major storm in the NWHI can break off pieces of coral, move underwater boulders, shift large volumes of sand, and erode islands. Such large perturbations in the shallow benthic habitat that result from the action of winter storms and swells are common in the NWHI.

Also due the their position in the North Pacific, the NWHI act as a sink for a multitude of marine debris originating from Pacific-rim countries. Perhaps the most damaging type of this debris is in the form of derelict fishing gear such as nets and rope that are carried by ocean currents from North Pacific trawl fisheries. Other types of debris include materials made from rubber and plastics (e.g. lighters). Marine debris impacts the nearshore environment of the NWHI by choking and breaking coral reefs, entangling marine life, and carrying invasive species. Since 1996, NMFS has led a multi-agency cleanup effort that has removed nearly 450 mt of derelict fishing nets and other debris from the NWHI (Asher, 2005, pers. comm.) In recent years, the effort has removed over 100 tons of marine debris per year. The amount of marine debris accumulating each year in NWHI is unknown, but is thought to be substantial.

A significant source of interannual physical and biological variation are the *El Niño* and *La Niña* events. During an *El Niño,* the normal easterly trade winds weaken, resulting in a weakening of the westward equatorial surface current and a deepening of the thermocline in the central and eastern equatorial Pacific. Water in the central and eastern equatorial Pacific becomes warmer and more vertically stratified with a substantial drop in surface chlorophyll.

Physical and biological oceanographic changes have also been observed on decadal time scales. These low frequency changes, termed regime shifts, can impact the entire ocean ecosystem. Recent regime shifts in the North Pacific have occurred in 1976 and 1989, with both physical and biological (including fishery) impacts (Polovina, 1996; Polovina et al., 1995). In the late 1980's for example, an ecosystem shift from high carrying capacity to low carrying capacity occurred in the NWHI. The shift was associated with the weakening of the Aleutian Low Pressure System (North Pacific) and the Subtropical Counter Current. The ecosystem effects of this shift were observed in lower nutrient and productivity levels and decreased abundance of numerous species including the spiny lobster, the Hawaiian monk seal, various reef fish, the red-footed booby, the red-tailed tropic bird (Polovina and Haight, 1999; Demartini et. al., 2002).

7.2 Biological Environment

The following is a general description of the life history, distribution, habitat characteristics of managed fishery stocks in the NWHI.

7.2A Bottomfish and Seamount Groundfish Stocks

The bottomfish fisheries in Hawaii target an assemblage of species from the taxonomic groups Lutjanidae (Snappers), Serranidae (Groupers), Carangidae (Jacks), and Lethrinidae (Emperors). The seamount groundfish fishery when extant targeted the armorhead *(Pseudopentaceros richardsoni*) and the alfonsin (*Beryx splendens*). The following table represents the MUS listed under the Bottomfish and Seamount Groundfish FMP.

TABLE 7-1: Bottomfish and Seamount Groundfish Management Unit Species

COMMON NAME	LOCAL NAME	SCIENTIFIC NAME
Snappers:		
Silver jaw jobfish	Lehi	*Aphareus rutilans*
Grey jobfish	Uku	*Aprion virescens*
Squirrelfish snapper	Ehu	*Etelis carbunculus*
Longtail snapper	Onaga, ʻulaʻula	*Etelis coruscans*
Blue stripe snapper	Taʻape	*Lutjanus kasmira*

COMMON NAME	LOCAL NAME	SCIENTIFIC NAME
Yellowtail snapper	Palu-i ʻIusama	*Pristipomoides auricilla*
Pink snapper	ʻŌpakapaka	*Pristipomoides filamentosus*
Yelloweye snapper	yelloweye ʻōpakapaka, kalekale	*Pristipomoides flavipinnis*
Snapper	Kalekale	*Pristipomoides sieboldii*
Snapper	Gindai	*Pristipomoides zonatus*
Jacks:		
Giant trevally	White ulua	*Caranx ignoblis*
Black jack	Black ulua	*Caranx lugubris*
Thick lipped trevally	Pig ulua, butaguchi	*Pseudocaranx dentex*
Groupers:		
Blacktip grouper	Fausi	*Epinephelus fasciatus*
Sea bass	Hāpuʻupuʻu	*Epinephelus quernus*
Lunartail grouper	Papa	*Variola louti*
Emperor fishes:		
Ambon emperor	Filoa-gutumumu	*Lethrinus amboinensis*
Redgill emperor	Filoa-paʻloʻomumu mafuti	*Lethrinus rubrioperculatus*
Seamount groundfish:		
Alfonsin		*Beryx splendens*
Ratfish/butterfish		*Hyperoglyphe japonica*
Armorhead		*Pseudopentaceros richardsoni*

7.2A.1 Life History

Relatively little is known about the reproduction and early life history of deepwater bottomfish in the region. Spawning occurs over a protracted period, and peaks from July to September (Haight et al. 1993b). The eggs are released directly into the water column. The eggs hatch in 3 to 4 days, and the planktonic larval phase is thought to last at least 25 days (Leis 1987). For some species this phase may be considerably longer. For example, the pelagic stage for *'ōpakapaka* is thought to be as long as six months (Moffit and Parrish 1996). While preliminary genetic work corroborates the notion of single archipelago-wide stocks of bottomfish, the extent of larval mixing between the NWHI and MHI is unclear. Larval advection simulation research indicates that larval exchange may occur throughout the Hawaiian archipelago, but that bottomfish larval transport most likely occurs from the more northerly Ho'omalu zone to the Mau zone at the southern end of the NWHI, in addition to larval transport from the MHI to the Mau zone (Kobayashi 1998). Kobayashi (1998) found that very little bottomfish larvae are transported into the Ho'omalu or MHI from other areas (most mixing is in the mid-NWHI).

At the pass between the main and the Northwestern Hawaiian Islands there is often a westward flow from the region of Kauai along the lee side of the lower NWHI. This flow, the North Hawaiian Ridge Current (NHRC), is extremely variable and can also be absent at times. While the high variability of the NHRC certainly allows for the possibility of direct larval transport toward the MHI, the mean currents indicate that direct larval recruitment is more likely from the MHI to the NWHI (Firing, 2005).

Little is known of the life history of the juvenile fish after settling out of the plankton, but research on *P. filamentosus* indicates the juveniles utilize nursery grounds well away from the adult habitat (Parrish 1989). Most of the target species have a relatively high age at maturity, long life span, and slow growth rate.

7.2A.2 Habitat and Distribution

Generally, deepwater bottomfish inhabit the deep slopes of island coasts and banks at depths of 100 to 400 m.[1] Throughout their spatial and depth range, deepwater snappers are typically distributed in a clumped pattern, and are often associated with underwater headlands and areas of high relief. Although deepwater snappers are generally thought of as top level carnivores, several snapper species in the Pacific are known to incorporate significant amounts of zooplankton in their diets (Haight et al. 1993a).

7.2A.3 Status of the Stocks

The Bottomfish and Seamount Groundfish FMP established a 20% spawning potential ratio (SPR) as the critical threshold that defines recruitment overfishing. SPR is the ratio of the equilibrium spawning biomass per recruit for a given value of fishing mortality to the equilibrium of spawning biomass per recruit in the absence of fishing. Under the FMP, an SPR value under 20% indicates that a particular stock is likely to be experiencing overfishing and therefore in jeopardy of being overfished. For the species for which values can be calculated

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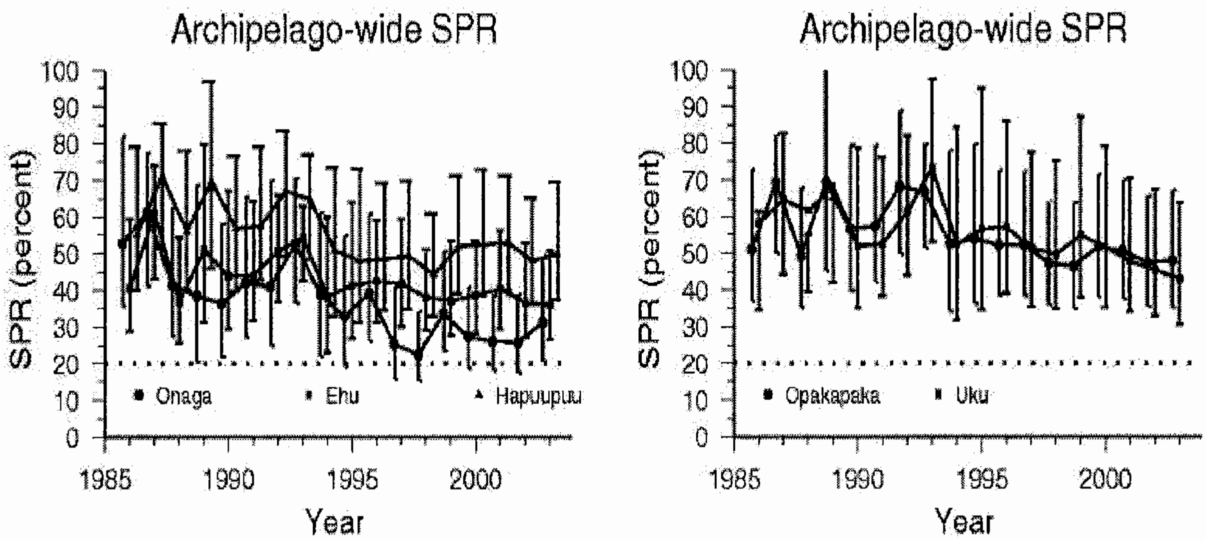
[1] *Uku* is a targeted BMUS, often caught at shallower depths than deepwater snappers using trolling methods rather than bottomfish fishing gear.

(*ehu, onaga, hapu`upu`u, opakapaka, uku*) 2003 SPR values range from a low of 31% for *onaga* to a high of 50% for *hapuupuu* when viewed on an archipelago-wide basis (Figure 7-1).

On a archipelagic basis, targeted bottomfish stocks are generally healthy. However, MHI bottomfish stocks are showing signs of stress and overfishing. In the MHI, targeted bottomfish species are showing a yellow light condition due to a drop in CPUE below 50% of original values. 2003 SPR values for *onaga* and *opakapaka* in the MHI are 9% and 21%, respectively. 2003 SPR values for *Hapuupuu* is 29%, and 26% for both *ehu* and *uku* (WPFMC 2004).

FIGURE 7-1: Archipelago-wide SPR Values for Targeted Bottomfish Species
(Source: WPFMC 2004)

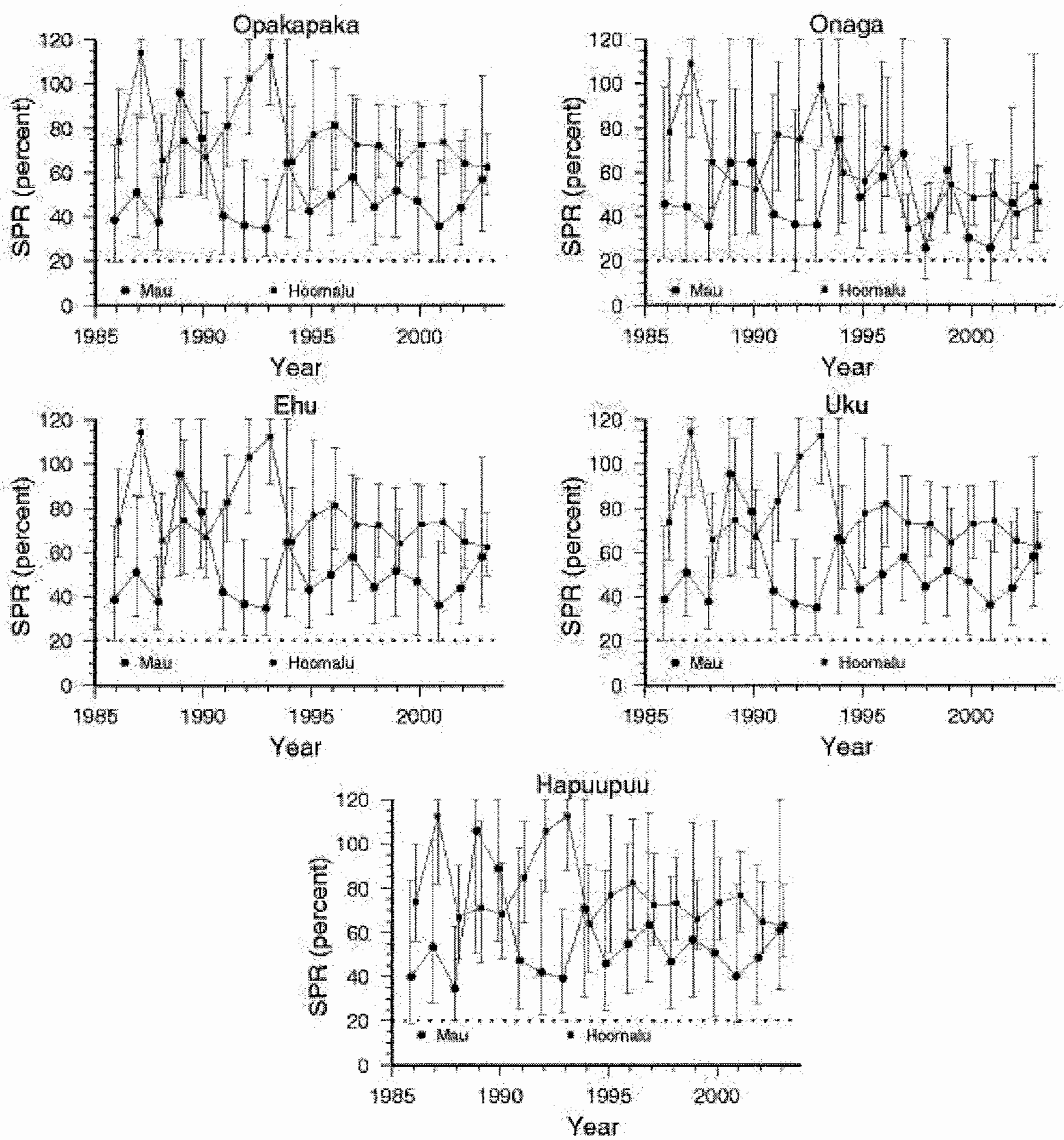


Based on SPR values, bottomfish resources in the NWHI remain relatively healthy (Figure 7-2). 2003 CPUE on a per trip basis increased 46.2% from 2002 in the Mau Zone and dropped 19.9% in the Hoomalu zone . On a per day basis, CPUE values are up 16% in the Mau zone and up 18.9% in the Hoomalu. Analysis of SPR and percent immature in the catch show no localized depletion problems to date for any BMUS species in either zone of the NWHI (WPFMC 2004).

Seamount Groundfish

Three species of seamount groundfish (amorhead, alfonsin, and rat fish, respectively) are included as BMUS in the FMP. These deepwater species primarily occur at depths of 275 - 500 m at Hancock Seamount, which is located 2,800 km northwest of Honolulu. The seamount species generally occur at higher latitudes, and below the depth range of the snapper-grouper bottomfish species complex. The armorhead and alfonsin spawn free-floating eggs which are dispersed by the North-equatorial and Kuroshio currents. Juvenile fish remain in the pelagic environment for up to a year, and then descend to seamount summits and begin a demersal existence. These species feed on species associated with the deep-scattering layer (euphausids, copepods, shrimps, myctophids, etc.) and make vertical migrations at night to follow their prey.

FIGURE 7-2: Trends in SPR Values for NWHI Bottomfish (Source: WPFMC 2004)

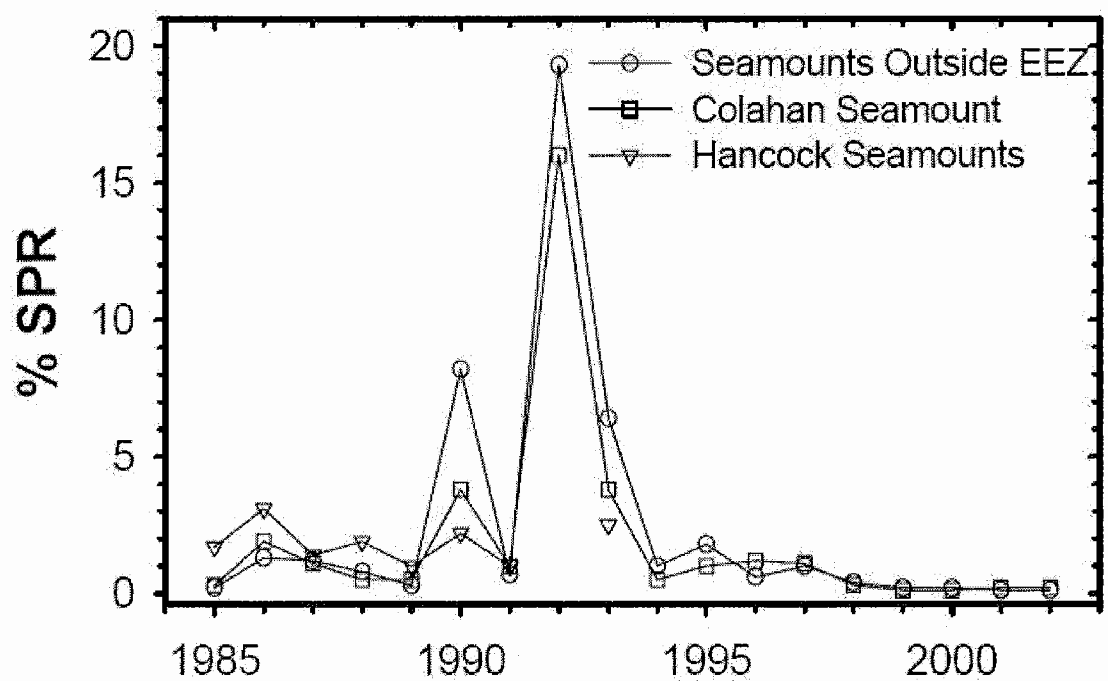


Status of the Groundfish Stocks

Since the seamount-wide crash of the armorhead trawl fishery in 1975, CPUE values have remained depressed and typically far below the 20% SPR overfishing threshold both at the Hancocks and outside the U.S. EEZ (Figure 7-3). Although in 1992 a dramatic increase in armorhead CPUE and %SPR occurred at seamounts outside the U.S. EEZ, these values declined to very low levels by 1994 and remained depressed through 2002. This 1992 event further indicates that any large seamount-wide recruitment peak are likely to be episodic and can originate even at low stock levels (the 1989 parental stock had the lowest SPR values both inside (1.0%) and outside (0.3%) the U.S. EEZ). However, this stock increase was effectively reduced, apparently by increased fishing pressure outside the U.S. EEZ, to the previous low level in a matter of 2 years. The Japan trawl fleet continues to trawl the SE-NHR seamounts outside the U.S. EEZ as these trawlers pass through this area on their way to and from other trawl fisheries in the Pacific. Besides Japan, other Asian nations appear to be fishing the SE-NHR seamounts outside the U.S. EEZ although information remains anecdotal.

The Hancock Seamount groundfish fishery was closed by the Council and NMFS in 1986. As the armorhead stocks near the Hancock Seamounts have yet to recover, the Council and NMFS extended the 6-year fishing moratorium at the Hancock Seamounts until August 31, 2010.

FIGURE 7-3: Trend in SPR Values for Armorhead Stocks at Seamounts Northwest of the NWHI (Source: WPFMC 2004)



7.2B Crustacean Stocks

7.2B.1 Management Unit Species

The following table lists the MUS managed under the Crustaceans FMP.

TABLE 7-2: Crustacean Management Unit Species

COMMON NAME	SCIENTIFIC NAME
Spiny lobster	(*Panulirus marginatus* or *Panulirus penicillatus*)
Slipper lobster	*family Scyllaridae*
Kona crab	*Ranina ranina*

Crustacean fisheries in Hawaii primarily target lobster species of the taxonomic groups Palinuridae (spiny lobster) and Scyllaridae (slipper lobster). Historically, the majority of the lobster catch in the region is taken in the NWHI fishery which targets two species: the endemic Hawaiian spiny lobster, Panulirus marginatus, and the common slipper lobster Scyllarides squammosus. Three other species, the pronghorn spiny lobster (*Panulirus penicillatus*), ridgeback slipper lobster (*S. haanii*) and the Chinese slipper lobster (*Parribacus antarcticus*) are caught incidentally and in low abundance in the NWHI fishery.

7.2B.2 Life History

Reproduction: The spawning period of *P. marginatus* in the NWHI extends over a broad period from early spring to late summer. Ovigerous females are found predominantly in the northern portion of the NWHI during early summer and in the central portion during late summer. But in the MHI around O‘ahu, spawning occurs throughout the year, peaking during May-August (Uchida et al. 1980; McGinnis 1972). The eggs are carried externally and hatch after 30-40 days (MacDonald and Stimson, 1980). Fecundity is positively correlated with body size, and can be expressed as Fecundity = 6.5334(CL)2.3706 (Honda 1980; DeMartini et al. 1993). It is estimated that the largest ovigerous females can carry over 1 million eggs (Honda 1984). After hatching, the larvae (phyllosoma) are planktonic for up to 12 months (Polovina and Moffitt 1995) undergoing metamorphosis through 11 discrete larval stages (Johnson 1968). The temporal distribution of late stage larvae in survey trawls in the NWHI appears to corroborate the 12-month larval cycle (Polovina and Moffitt 1995). Late-stage phyllosoma develop into a free-swimming stage known as a puerulus which actively seeks suitable benthic habitat (Cooke and MacDonald 1982). Puerulus settlement appears to occur in a series of pulses correlated with the lunar cycle, mostly during the new moon or first quarter of the lunar cycle (MacDonald 1986). Field studies in the NWHI and around O‘ahu indicate that puerulus settlement is oppositely seasonal at the north end of the NWHI versus O‘ahu, occurring sporadically throughout the year in the central portion of the NWHI (MacDonald 1986). Peak settlement around O‘ahu occurred during the winter months

(October-April) in contrast to the summer peak at Kure Atoll (May-September); at French Frigate Shoals settlement occurred sporadically throughout the year (MacDonald 1986). After settlement the puerulus molts into a post-puerulus stage and gradually attains adult coloration.

Female lobsters of the genus Scyllarides have never been observed with spermatophora similar to those found in Panulirus, suggesting fertilization may be internal. Of 1,090 slipper lobster females collected during NWHI lobster surveys, none had a spermatophoric mass although 33% were ovigerous (Uchida and Uchiyama 1986). Research at PIFSC on reproduction in NWHI lobsters has focused primarily on spiny lobster; therefore, reproduction parameters for Sycllarides spp. in the NWHI are not well known. Analysis of recent research survey data indicates ovigerous female *S. squammosus* are found during the months of March through September. Peak spawning appears to occur from April to June (Haight unpubl. data).

Growth and Mortality: Several studies encompassing a variety of methods have provided basic life history parameters for spiny lobster in the NWHI. Based on analysis of recaptures of tagged lobsters at O'ahu (McGinnis 1972) and Necker (Uchida and Tagami 1984) the growth parameter k ranges in value from 0.269 for O'ahu males to 0.3857 for O'ahu females, and 0.26 for Necker males. Tagging at Kure Atoll and FFS resulted in k estimates of 0.27 and 0.3 for those locations (MacDonald 1984). Length frequency analysis of spiny lobster at Necker Island resulted in a k estimate of 0.3 for that location (Polovina and Moffitt 1989). The results of MacDonald's (1984) tagging study suggested that the natural mortality rate was higher for female spiny lobsters than for males at both Kure Atoll and FFS. Based on this study, the coefficient of natural mortality for both sexes combined was 0.49. Natural mortality estimates from mathematical modeling of commercial catch and effort data appear to corroborate the rate of natural mortality estimated from tagging research (Haight and Polovina 1992). Asymptotic length ($L\infty$) based on tagging and length frequency analysis ranges from 12.4 cm CL (Uchida and Tagami 1984) to 13.4 cm CL (MacDonald 1984; Polovina and Moffitt 1989). It appears that $L\infty$ may fluctuate with changes in lobster density, having increased at both Maro Reef and Necker Island after the fishery reduced the population density (Polovina 1989). Based on tagging studies at Kure Atoll and FFS, MacDonald (1984) estimated the average individual lifespan of spiny lobster in the NWHI at 7.4 years.

Two different approaches have been used to estimate size at sexual maturity for spiny lobster in the NWHI. Prescott (1984) used changes in allometric growth of the walking legs as an indicator of sexual maturity for lobster at O'ahu and Necker Island. Estimates for the size at maturity were 58.6 mm CL for O'ahu females and 60.07 for Necker females. Polovina (1989) used a hyperbolic tangent function applied to size frequency from annual research trapping to determine the size at which 50% of the female lobsters were ovigerous. Based on this approach, females at Necker island were found to attain sexual maturity at 57.9 mm CL (based on 1985-86 data), a result similar to that from the allometric growth analysis. Analysis of temporal maturity data indicates that size at sexual maturity fluctuates with changes in population density. Polovina (1989) found that the size at sexual maturity from Necker Island and Maro Reef declined from 1977 to 1987. Both of the areas received heavy fishing pressure during this time period which reduced lobster densities. The change in the size at sexual maturity seems to reflect a density-dependent response rather than genetic selection resulting from fishing pressure. Seeb et al. (1990) examined the genetic variability of the NWHI spiny lobster population and found no measurable loss of genetic variability due to fishing pressure. The sex ratio of adult spiny lobster in the NWHI appears to slightly favor males (Uchida and Tagami, 1984). MacDonald's (1984) tagging research indicated that male mortality rates were lower than those for females at the banks examined; therefore, differential mortality might account for the predominance of males in the catch. Genetics may also be a factor in the male to female ratio. Shaklee and Samollow (1980) found that of 2,060 pre-hatch embryos, 52% were male.

Based on the size composition of the unexploited population calculated from carapace length frequency distributions, the smallest lobsters occurred at Necker Island and the largest at Kure Atoll. The same data indicated that males were larger than females in all localities except Lisianski Island where the sample size was too small to provide a statistically valid sample (Uchida and Tagami, 1984).

7.2B.2 Habitat and Distribution

Spiny and slipper lobster occur throughout the tropical oceans of the world (Cobb and Phillips 1980). P. marginatus is endemic to the Hawaiian Islands and Johnston Atoll (Brock 1973) and appears to be closely related to the long-legged spiny lobster, P. longipes, which is widely distributed in the Indo-West-Pacific (Pollock 1992). Genetic studies indicate that a single genetically homogenous population of spiny lobster occurs in the NWHI (Shaklee and Samollow 1980); however, variation in a single gene locus between lobster populations at Necker Island and Maro Reef indicate that it is likely lobster from these two areas are somewhat reproductively isolated (Seeb et al. 1990). Larval research surveys conducted throughout the tropical Pacific during the 1950s and 1960s found late-stage phyllosoma of P. marginatus only in waters near the Hawaiian Archipelago and Johnston Island (Johnson 1968). The distribution of phyllosoma around the Hawaiian Archipelago appears to be relatively homogenous, and the temporal distribution of late stage larvae is indicative of a summer spawning season and a 12-month larval cycle (Polovina and Moffitt 1995).

Adult and juvenile Hawaiian spiny lobster occur throughout the NWHI from Nihoa Island to Kure Atoll (Uchida and Tagami 1984) at depths of 4-174 m (Uchida and Uchiyama 1986). In Hawaii, adult spiny lobster are typically found on rocky substrates in well-protected areas such as crevices and depressions in coral reef habitat. Although the Hawaiian spiny lobster inhabits waters up to 200 m in depth, most of the catch is taken from water depths less than 60 m. In an extensive resource survey conducted by the NMFS during the 1970s, populations of spiny lobster were found at 18 (69%) of the banks in the NWHI extending from Nihoa Island to Kure Atoll. No P. marginatus were found at the banks north of Kure Atoll (Uchida and Tagami 1984). Within the Hawaiian Archipelago, lobster abundance, size, and species ratio varies widely between islands and banks. Variations in abundance and species composition between banks is related to various environmental and biological factors including length of larval cycle, advection of larvae by oceanographic processes, availability of juvenile refuge habitat, and suitability of adult habitat.

Although adult spiny lobster occur as deep as 174 m in the NWHI, it appears that juvenile spiny lobster do not settle onto banks with summits deeper than 30 m and that the amount of habitat with vertical relief of 5-30 cm may limit total distribution and abundance (Parrish and Polovina 1994). At Necker Island, juvenile spiny lobster (<age-3) appear to occupy the same or similar habitat as the adults (Parrish and Polovina 1994), which increases their probability of being caught in the commercial fishery. At Maro Reef, juvenile lobsters appear to utilize shallow reef areas not associated with fishing. In 1993, an area of high juvenile abundance was located during exploratory research trapping in the shallows of Maro Reef (Haight and Polovina 1993). During 1994, the same lagoonal areas were fished, and the area of high juvenile abundance was extensively surveyed. Age-specific catch per unit effort (CPUE- defined as number of lobsters per trap fished) values from inside Maro Reef were significantly higher than the CPUE values from outside the reef. Of the shallow lagoon areas trapped in 1994, only the northwestern reef spur exhibited high juvenile CPUE values. It appears that the juvenile lobster are associated with the northern portion of the reef spur and are more abundant in shallow waters next to the spur (Haight 1998).

Unlike many other species of Panulirid lobster, juveniles of the Hawaiian spiny lobster do not recruit to distinctive "nursery" areas but instead utilize areas within the adult habitat. Adult spiny lobster in Hawaii release eggs into the water column beginning in the early spring of each year, with spawning reaching a peak in the middle of the summer. The planktonic larval phase of P. marginatus may last up to 12 months, during which time oceanic processes act to disperse and/or concentrate the larval pool. The dynamics of this advection process and the oceanographic and physiographic features which result in the retention of lobster larvae within the Hawaiian Archipelago are poorly understood. Recent research suggests that meso-scale oceanographic features such as eddies, gyres and geostrophic currents are critical components in determining if the larvae will be transported to areas suitable for recruitment (Polovina et al. 1999). These oceanographic features vary from year to year and may be influenced by cyclic, large-scale oceanographic processes as well (Polovina and Haight 1999). Because adult lobster are benthic and the islands and banks in the archipelago are separated by water depths of over 1000 m, each individual sub-population of lobster is effectively isolated from the sub-populations at other banks and islands in the Hawaiian Archipelago. The total lobster population in the archipelago therefore exists as a series of isolated spawning populations which all contribute to the total larval pool. The function of each island or bank as a source or sink for population production is important in the understanding of the dynamics of the population as a whole. Unfortunately, these aspects of lobster population biology are not well known.

Scyllarides squammosus is found in localized areas throughout the Indo-West-Pacific region. Resource surveys conducted by the NMFS documented the presence of S. squammosus at 17 (65%) of the NWHI banks from Nihoa Island to Kure Atoll at depths of 13-137 m (Uchida and Uchiyama 1986). During the initial research survey, slipper lobster catch was higher than spiny lobster catch at Brooks Bank, Northampton Seamounts, Lisianski Island, and Salmon Bank. However, slipper lobster comprised only 16% of the resource survey catch for the NWHI as a whole (Uchida and Uchiyama 1986).

7.2B.3 Status of the Stocks

The relative distributional abundance of spiny lobster in the NWHI remained fairly constant from 1976 to 1989. Although lobsters were commercially trapped at up to 15 separate locations in the NWHI, five areas (Necker Island, Gardner Pinnacles, Maro Reef, St. Rogatien Bank, Brooks Bank) produced the majority of the catch throughout the period. After 1990, however, only Necker Island, Maro Reef and Gardner Pinnacles appeared to have lobster abundances suitable for commercial exploitation.

Data on the size structure of the NWHI lobster population since fishery exploitation began were collected by the PIFSC on annual assessment cruises from 1985 to 1995. By using age-specific CPUE values as an indicator of relative abundance, recruitment of spiny lobster to specific banks can be examined. At Maro Reef from 1985 through 1988, CPUE was highest for age-3 spiny lobster. Commercial effort at Maro Reef remained fairly constant during 1985-89 (average effort = 350,000 trap-hauls); the associated high CPUE values of age-3 lobsters at Maro Reef indicates recruitment remained stable during the time period. By 1990 a dramatic decrease in CPUE for all age classes at Maro Reef was apparent. The CPUE values for age-2 and age-3 spiny lobster dropped 90% from 1988 to 1990. In 1991, CPUE values for age-2 and age-3 lobsters declined another 80% and 67%, respectively. The low CPUE values during 1990-91 were not caused by commercial exploitation alone, as commercial effort at Maro Reef dropped 45% from 1988 to 1990 and another 80% in 1991. The dramatic reduction in CPUE of all age classes at Maro Reef in 1990 may be attributed to poor post-larval recruitment of spiny lobster to Maro Reef beginning in 1986, which was compounded by commercial fishing harvest. Further reduction in age-specific CPUE of age-2 and age-3 spiny lobster in 1991, and the associated very low commercial CPUE prior to the 1991 research cruise, indicate poor recruitment of spiny lobster to Maro Reef continued during the years of 1987-88. The depressed CPUE continued from 1991 through 1995. This trend has persisted despite significant reductions in commercial fishing effort at Maro Reef during 1991-92 and 1994, and a fishery closure in 1993.

A similar trend was observed 70 nm to the northwest at Laysan Island (Haight and Polovina 1992), which has been closed to commercial harvest since the beginning of the commercial fishery. In contrast, recruitment of age-2 lobster to Necker Island, 360 nm southeast of Maro Reef, remained fairly constant throughout the time series. Polovina and Mitchum (1992) found recruitment of spiny lobster to Maro Reef to be correlated with the strength of the subtropical countercurrent, suggesting that mesoscale oceanographic features may impact the transport and survival of lobster larvae during their 11- to 12-month pelagic larval cycle. Continued recruitment of spiny lobster to Necker Island suggests that the lower southeastern end of the NWHI is not linked to the same oceanographic or recruitment processes as the northwestern end of the archipelago. The genetic variation in lobster from the two different areas appears to corroborate this hypothesis (Seeb et al. 1990). Because the oceanographic processes which appear to affect recruitment at the northwestern portion of the NWHI occur in approximately decadal cycles (Polovina and Mitchum 1992; Polovina et al. 1995), the spiny lobster stocks may remain at the present level of production for several years.

The Crustaceans FMP also defines overfishing using SPR values and the 20% critical threshold. In 1997, when the last SPR values were calculated for this fishery, the SPR values were 74 %, well above the 0.20 overfished threshold. However, the productivity of lobster stocks appears to have substantially decreased from the level when the fishery began. For example, NMFS research surveys at Necker Island indicate more than 80% drop in mature spiny lobster CPUE, from 4.2 to 0.5 between 1988 and 1999. Changes in environmental conditions compounded by fishery harvest are believed to have contributed to this decline (Polovina and Haight 1999). PIFSC is working on a new stock assessment model which will allow for more accurate lobster population estimates. Currently, slipper lobsters occur in greater abundance in the NWHI than do spiny lobsters (Dinardo, 2005, pers. comm.)

7.2C Precious Coral Stocks

7.2C.1 Management Unit Species

Precious corals MUS include any coral of the genus Corallium and the species listed in the following table.

TABLE 7-3: Precious Coral MUS

Common Name	Scientific Name
Pink coral	*Corallium secundum, Corallium regale,* or *Corallium laauense*
Gold coral	*Narella spp. Gerardia spp.*, or *Calyptrophora spp*
Bamboo coral	*Lepidisis olapa* or *Acanella spp*
Black coral	*Antipathes dichotoma*, *Antipathes grandis*, or *Antipathes ulex*

7.3C.2 Life History

In general, precious corals share several ecological characteristics: they lack symbiotic algae in tissues (they are ahermatypic) and most are found in deep water below the euphotic zone; they are filter feeders; and many are fan shaped to maximize contact surfaces with particles or microplankton in the water column. Because precious corals are filter feeders, most species thrive in areas swept by strong to moderate currents (Grigg 1993). Although precious corals are known to grow on a variety of hard substrate, they are most abundant on substrates of shell sandstone, limestone, or basaltic rock with a limestone veneer.

All precious corals are slow growing and are characterized by low rates of mortality and recruitment. Natural populations are relatively stable, and a wide range of age classes is generally present. This life history pattern (longevity and many year classes) has two important consequences with respect to exploitation. First, the response of the population to exploitation is drawn out over many years. Second, because of the great longevity of individuals and the associated slow rates of turnover in the populations, a long period of reduced fishing effort is required to restore the ability of the stock to produce at the maximum sustainable yield (MSY) if a stock has been over exploited for several years.

Because of the great depths at which they live, precious corals should be insulated from some short-term drastic changes in the physical environment. For the same reason, it is difficult to imagine circumstances in which man-made pollution would affect their environment, except in the unlikely event that large quantities of heavy material, such as waste from manganese nodule refining, were dumped directly on a bed. Nothing is known of the long-term effects of changes in environmental conditions, such as water temperature or current velocity, on the reproduction, growth, or other life activities of the precious corals.

Taxonomy, Biology and Ecology: Precious corals MUS are taxonomically classified as members of the phylum Cnidaria, which includes all of the corals, hydroids, jellyfish and sea anemones. Its members are characterized by the presence of:

1. a sac-like body with only one opening for the gut;
2. only two tissue layers, an outer protective layer of epidermis and an inner digestive layer, the gastrodermis, lining the gut cavity;
3. an intermediate layer called the "mesoglea" or "middle jelly" consisting mostly of protein fibers and generally lacking cells; and
4. explosive, stinging devices called nematocysts used in either prey capture or defense.

Within the *Cnidaria*, precious corals are placed in the class *Anthozoa*, which includes the corals, soft corals and sea anemones, all characterized by having a relatively complicated gut, compared with other cnidarians. Living tissues are composed of polyps, each with a mouth surrounded by tentacles. Some species are composed of a single polyp while others are colonies of many polyps.

Within the *Anthozoa*, precious corals are members of three orders in two subclasses: 1) subclass *Octocorallia* (or *Alcyonaria*), order *Gorgonacea*, and 2) subclass *Hexacorallia* (or *Zoantharia*), orders *Zoanthidae* and *Antipathidae*.

Members of the subclass *Octocorallia* are characterized by their eight tentacles. All octocorals are colonial, with each colony consisting of numerous polyps growing out of, and constituting the body of, the animal. These are all connected by a complicated system of internal tubing running through the colonial mesoglea. Octocoral MUS include the pink corals of the genus *Corallium* and the bamboo corals of the genera *Lepidisis* and *Acanella*.

Other anthozoans have their tentacles in multiples of six and are thus termed the *Hexacorallia*, or hexacorals. Hexacoral MUS include gold corals of the order *Zoanthidea* and black corals of the order *Antipathidae*.

Red, pink and bamboo octocorals of the Order *Gorgonacea* are commonly called fan corals because their growth resembles that of a plant, with a main trunk fastened to the substrate, and lateral branching stems which may be in the same plane, hence the name "fan corals."
Their internal skeleton is decidedly different in structure and composition from the hard skeleton of the stony, reef-building, corals. Gorgonian skeletons contain a much larger proportion of organic material, much of it proteinaceous. This gives them much more flexibility than reef-building corals. They also tend to deposit a significant amount of pigmented material into the skeleton, resulting in some skeletons being highly colored. Brown, red, pink or gold are common colors found in gorgonian skeletons. Precious coral jewelry is made from the cut and polished skeletons of large gorgonians and similar corals.

Gorgonian colonies are all derived from one another and they are all one gender. The age at reproductive maturity is 12-13 years for *Corallium secundum*. Gorgonians of both sexes release gametes into the sea. Fertilization occurs in the sea and a small planula larva develops that chooses a place of settlement. Planula larvae of most corals are not usually dispersed very far from parent colonies. The larva then metamorphoses into a juvenile and the first polyp of the colony is formed. From this point the colony is fastened to the substrate and is immobile. In colonial species, a sexual reproduction also occurs through budding of the primary polyp. The duration of the larval stage is unknown for most species, but Mediterranean studies of *Corallium rubrum* suggest that their larvae remain competent for several weeks.

Corallium species live below the euphotic zone at depths between 100 and 1500 m where temperature varies between 3° and 18° C. These larvae may avoid settling deeper, where lower temperatures may prevent reproduction. As the colony grows, it generally differentiates so the "fan" is perpendicular to the prevalent currents. Growth of many octocorals is slow and they may require over 100 years to reach maximum size.

Little information is available on the ecological associations of the precious corals or their significance to the lives of other organisms. Gorgonians are predatory, suspension-feeding, animals that catch and kill small planktonic animals with their tentacles. Particulate organic matter is also important in the diets of Gorgonians, and like other Anthozoan species, they are associated with numerous kinds of commensal invertebrates.

Gorgonians have few predators. They are, however, the food of some polyp-plucking fish, such as filefish, and of grazing snails, several types of nudibranchs and at least one polychaete annelid. Eucidarid sea urchins are known to prey on precious corals. Gorgonians also provide vertical structure in a habitat where such structure is often lacking. Consequently, they are often settled on by barnacles and other epifauna. Gorgonians, in turn, have developed strong chemicals to deter fouling and predation.

Zoanthidea are a small group of hearty, solitary, sometimes colonial, anemone-like anthozoans that lack a skeleton. There is a large amount of morphological variability in this order, with most species being shallow-water and mat-forming. Some species are encrusting, and may overgrow other octocorals or hexacorals. They are unlike any other anthozoans internally, having a large number of paired and unpaired septa. Zoanthid polyps can occur as single individuals in large groups or they can be joined together by a thin stolon, a thin coenenchyme or a very thick coenenchyme from which only the mouths and tentacles are visible. The coenenchyme is a gelatinous mat of fibrous protein that develops from the mesoglea and supports the polyps.

Gold coral (*Gerardia* sp.) are Zoantharian corals that belong to the family *Parazoanthus*. Many are parasitic species that commonly overgrow other gorgonian corals. *Gerardia* seems to prefer overgrowing the bamboo corals (*Acanella* spp.). In fact, this association may be almost obligate as few colonies of Gerardia have been found without an *Acanella* base within the holdfast of the gold coral colony. In Hawaii, *Gerardia* sp. is found at depths between about 350 and 450 meters and prefers steep drop-offs. Typically it settles at the very top of drop-offs within this depth range where the current appears to be enhanced.

In the NWHI, monk seals have been observed (radio telemetry) to dive in areas where gold coral and arrowtooth eels may occur, suggesting that monk seals forage among precious corals because they provide structural relief for various fish assemblages. In 2000, the National Undersea Research Laboratory conducted a study using manned and unmanned submersibles in known beds of the Western Pacific region. The objective of the study was to test the hypothesis that gold coral provided habitat for deep-water arrowtooth eels. Results of the study found that gold coral did not seem to aggregate arrowtooth eels or any other significant fish assemblage. At the Cross Seamount, the study found arrowtooth eels in areas adjacent to the beds, but without the presence of gold corals (Parrish 2001).

In a study to test the possibility that NWHI precious corals beds aggregate fish assemblages, Parrish (2005, pers. comm.) found that in areas with taller colonies of precious corals (e.g. *Gerardia*) there were twice the fish density of adjacent areas without the corals, but the statistics of the study suggest that this was due to co-occurrence of corals and fish in areas of high relief and high current flow. The Parrish (2005, pers. comm.) study indicates that it is unlikely that fish depend on the corals for habitat, and that monk seal visitation to precious corals beds is thought to be incidental to the seals' targeting high-relief features where fish and precious corals co-occur.

Adult pink, bamboo and gold corals are found in deep water (100-1500 m) on solid substrate where bottom currents are strong. This is in contrast to black corals, discussed below, which also typically occur on solid substrate, but generally at depths between 30 and 110m.

Antipatharia contain the well known precious black or "thorny" coral. These tree-like corals have a thin axial skeleton with distinctive small thorns. A thin veneer of animal tissue, called the cenosarc, secretes the tightly-layered central skeleton of horn-like protein. Depending upon the species, the living tissue may be black, red, orange, brown, green, yellow or white. The gelatinous polyps located in this living "bark" are short and cylindrical, their six, non-retractable tentacles are armed with stinging cells.

More than 150 species of black corals have been described. Some, like the wire corals, grow as a single, spiral coil. Many others have a dendritic growth form, creating a fan shape or elaborate tangle of tree-like branches. At least 14 species of black corals are currently known from Hawaii.

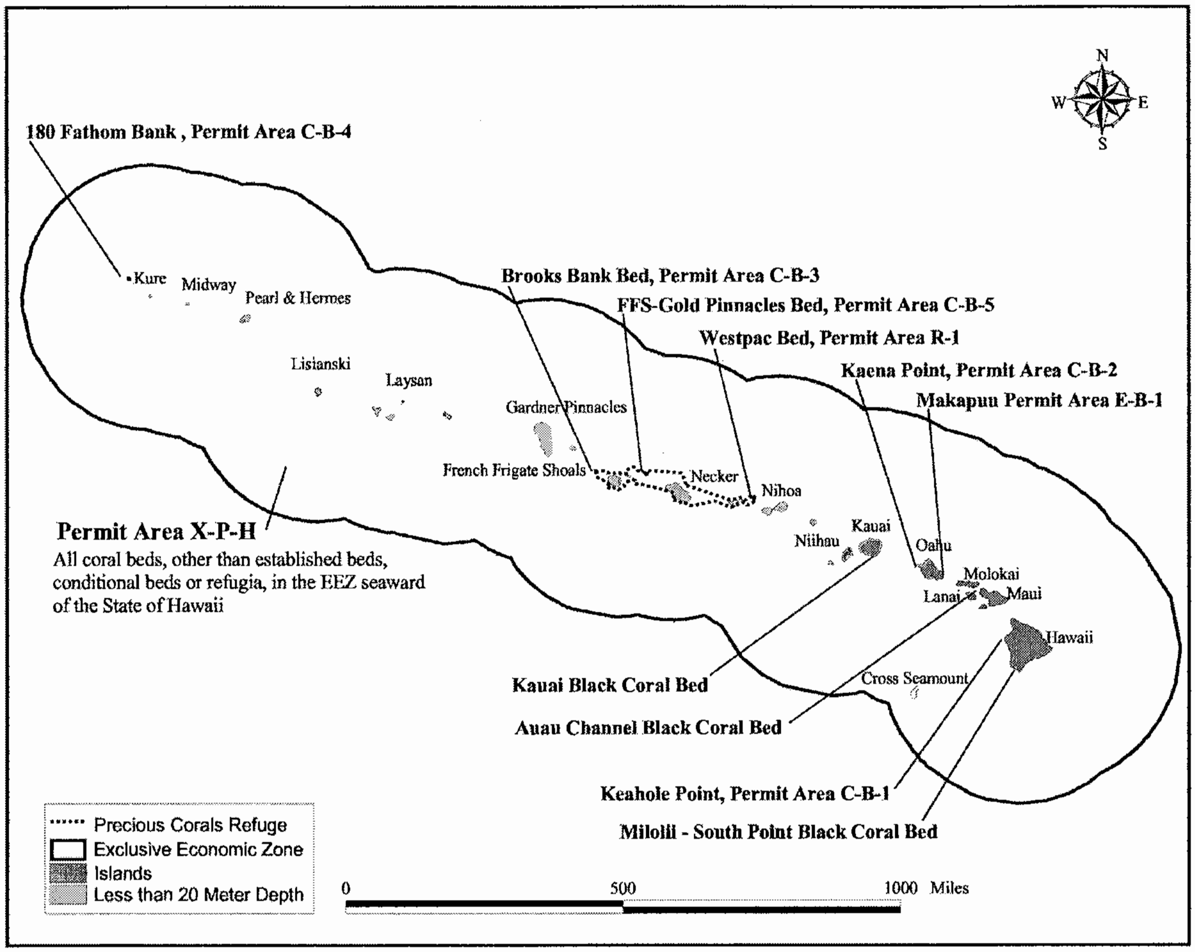
Relatively little is known about the life cycle and reproduction of black corals. Like other cnidarians, black corals have life cycles that include both asexual and sexual reproduction. Asexual reproduction (budding) builds the colony by adding more living tissue that, in turn, secretes more skeleton. Regular growth rings laid down as the skeleton thickens can be used to estimate the age of the colony. Sexual reproduction involves the production of eggs and sperm to create young that can disperse and settle new areas. The larvae of several black coral species are negatively phototactic, and are most abundant in dimly lit areas, such as beneath overhangs and ledges in waters deeper than 30m. All species require firm, hard substrates free of sediment. Polyps are either male or female. The larval stage, called a planula, can drift with currents until a suitable surface is found. Once the larva settles, it metamorphoses into a polyp form and secretes skeletal material that attaches it to the seafloor. Then it begins budding, creating more polyps that will form a young colony. In one Hawaiian species that has been studied (Antipathes dichotoma, a MUS), the colony may grow about 2.5 inches (6.4 cm) per year. The age at reproductive maturity is 12-13 years for Antipathes dichotoma. Reproduction may occur annually. A large six-foot (1.8 m) tall coral tree is estimated to be between 30 and 40 years old. The oldest corals observed in the Maui Auau Channel Bed are thought to be 75 years old, and it is believed that black corals may live even longer (Grigg 1983).

Western Pacific precious coral larvae are more affected by light and temperature than are adults. Larvae of Antipathes species occurring in Hawaii are known to be negatively phototactic, which is why they are not found shallower than 30 m. The lower limit of the A. dichotoma and A. grandis black corals coincides with the top of the thermocline in the high Hawaiian Islands (Grigg 1993).

7.3C.2 Habitat and Distribution

Precious corals are known to exist in the EEZ around Hawaii and very likely exist in the EEZ around American Samoa, Guam, the Northern Mariana Islands and the remote U.S. Pacific Island possessions, but virtually nothing is known of their distribution and abundance in these areas outside of Hawaii. In America Samoa, there are three known areas with pink coral: near Upolu and Falealupo, and at Tupuola Bank (Grigg 1993). In the Northern Mariana Islands, Japanese fishermen have reported pink coral north of Pagen Island and near Rota and Saipan. Since these areas remain unsurveyed, no information is available regarding the abundance of coral present.

FIGURE 7-4: Known Precious Corals Beds in the Hawaiian Archipelago



To date, beds of pink, gold and/or bamboo corals have been found eight locations in the EEZ around Hawaii. This number includes two recently discovered beds, one near French Frigate Shoals in the NWHI, and a second on Cross Seamount, approximately 150 nm south of Oahu (Figure 7-4). The approximate areas of six of these eight beds have been determined. These beds are small; only two of them have an area greater than 1 km², and the largest is 3.6 km² in size. The Keahole Bed off Hawaii's Kona coast, however, is substantially larger than originally thought. Scientists and industry are currently assessing its actual size. Initial calculations appear to increase its size twenty-fold. There are also three known major black coral beds in the Western Pacific Region, in addition to several minor beds (Grigg 1998a). Most of these are located in Hawaii's state waters (0-3 nm). However the largest (the Auau Channel Bed) extends into federal waters of the EEZ.

There are undocumented and unconfirmed reports that precious corals have been observed or exploited in widely scattered locations in the Western Pacific Region: off American Samoa, Guam, the Northern Mariana Islands, and Wake Island, but no details are available. In some cases attempts at scientific surveys in areas referred to in such reports have failed to turn up any evidence of precious corals. Undocumented reports of large past commercial production by Japanese vessels on the Milwaukee Banks, some 500 miles beyond the northwestern extreme of the NWHI, and the large physical area of those banks, lead to conjecture that at some locations precious corals may occur in much larger aggregations than have as yet been demonstrated by scientific surveys. Asian coral fishers, who have roamed the western and central Pacific for decades, undoubtedly have undocumented and unorganized information on precious corals beds which has yet to be revealed to US researchers and or resource managers. In general, the available information on precious corals occurrence and distribution is fragmentary and very incomplete, and there is a high probability that further surveying and prospecting will reveal significant additional precious corals resources in areas under US jurisdiction.

7.2C.3 Status of the Stocks

Precious Corals stocks in the NWHI are believed to be in relatively healthy condition. In 1965, Japanese coral fishermen discovered a large pink coral bed (*Corallium* spp.) on the Milwaukee Banks in the Emperor Seamount Chain near the northwestern end of the NWHI (Grigg 1993). Intermittently over the next two decades, dozens of foreign vessels employed tangle-net dredges to harvest precious corals in the waters around the NWHI. During the 1980's, Japanese and Taiwanese coral vessels frequently fished illegally in the EEZ near the Hancock Seamounts (Grigg 1993). In 1985, Taiwanese vessels reportedly poached about 100 mt of pink coral from north of Gardner Pinnacles and Laysan Island (Grigg 1993). The following are standing stock estimates of known precious coral beds in the NWHI.

Brooks Bank Conditional Bed: The harvest quota listed in the FMP for pink coral at Brooks Bank is 444 kg/yr.[2] This figure was calculated using the a formula provided in the FMP for setting the quota for Conditional Beds for which site specific data are unavailable. According to the Precious Corals FMP, the estimated MSY for pink coral at Makapu'u Bed is 1,000 kg/yr, the estimated area of Makapu'u Bed is 3.6 km^2 and the estimated area of Brooks Bank is 1.6 km^2. This bed was surveyed in September 1998. On this survey, 2.1 km-long transects were conducted at a depth of 350-505 m. Red coral *(C. regale)* was observed to be very abundant, with thousands of colonies present. Colonies occurred in 1-5 m^2 patches, and were located at depths of 430-517 m. These colonies were up to 50 cm in height and averaged 1 cm in diameter.

Extrapolation of these data suggests that a conservative standing crop of 8,000 kg of *C. regale* exists at this bed (Grigg 1998b). If it is assumed that this species of precious coral has the same natural mortality rate as *C. secundum* at the Makapu'u Bed (6.6%), an estimate of the MSY can be derived from the formula provided by Gulland (1970): MSY = 0.4MB, where M is the natural mortality rate and B is the standing crop biomass. Rounding down, it is estimated that 200 kg of *C. regale* could be harvested annually on a sustainable basis, based on these data and assumptions. Pink coral (*C. secundum*) was observed to be moderately abundant on the east side of the bank at

[2] The final rule implementing the Precious Corals FMP published on 20 August 1983 lists the harvest quota for pink coral at Brooks Bank as 17 kg. This is a typographical error.

depths of 363-427 m, but colonies were generally small (less than 20 cm in height). Gold coral was abundant with 250 large colonies found between 392-467 m. It was estimated that there was a standing stock of 2,000 kg of live gold coral, with an equal amount observed dead. Observations of finfish in the area were rare, and there was no evidence of predation by sea urchins at this bed.

Westpac Conditional Bed: This bed was also surveyed in 1998, using 3.2 km-long transects at depths of 360-500 m. No red coral was observed, however, pink coral was abundant, with thousands of colonies in 0.3-1.0 m^2 patches. Gold coral was rare, with only two colonies observed. Finfish (mostly Polymixia) were abundant, and there was high predation by Eucidarid sea urchins, with 50% of colonies showing signs of predation.

***French Frigate Shoals-Gold Pinnacles Exploratory Bed*:** The 1998 survey also located a previously unknown bed near French Frigate Shoals, which has been named the FFS-Gold Pinnacles Bed. No red coral (*C. regale*) was found along 2.9 km-long transects at depths of 360-575 m, and pink coral *(C. secundum.*) abundance was low. Observed pink coral was generally small, averaging less than 12 cm in height (Grigg 1998b). Both live and dead gold coral were found in abundance, and 300 colonies were observed in scattered patches at depths of 365-406 m. Extrapolation of the transect data suggests that the gold coral standing crop at the FFS-Gold Pinnacles Bed is 3,000 kg. If it is assumed that this species of precious coral has the same natural mortality rate as *C. secundum* at the Makapu'u Bed (6.6%), an estimate of the MSY can be derived from the same formula provided by Gulland (1970) and given above. Rounding down, it is estimated that 80 kg of gold coral could be harvested annually on a sustainable basis based on these data and assumptions.

7.2D Coral Reef Ecosystem Associated Stocks

Coral reefs are carbonate rock structures at or near sea level that support populations of scleractinian or reef-building corals. Apart from a few exceptions, coral reefs are confined to the warm tropical and sub-tropical waters lying between 30° N and 30° S. Coral reef ecosystems some of the most diverse and complex ecosystems on earth. The symbiotic relationship between the animal coral polyps and algal cells known as zooxanthellae is a key feature of reef building corals. Incorporated into the coral tissue, these photosynthesizing zooxanthellae provide much of the polyp's nutritional needs, primarily in the form of carbohydrates. Most corals supplement this food source by actively feeding on zooplankton or dissolved organic nitrogen, due to the low nitrogen content of the carbohydrates derived from photosynthesis. The structure and function of all coral reef ecosystems are controlled by the prevailing oceanographic conditions (Maragos and Gulko, 2002).

As coral health and growth rates are dependant on water temperature, the highly variable water temperature of NWHI 18°-28° C (64°-82° F) can affect the coral reef ecosystem. The NWHI are unique in that they contain the northernmost coral reef ecosystem (Kure Atoll) on the planet. The water temperatures experienced there are assumed to be the lower limit for corals to thrive and reefs to grow. Kure Atoll may lie near the "Darwin Point" for reef development, a geographical limit beyond which corals and coralline algae can no longer deposit enough calcium carbonate to keep up with the subsidence of the area's volcanic base. Reefs at latitudes higher than the Darwin Point fail to remain at sea level and sink below the photic zone within which growth can occur Maragos and Gulko 2002).

The distribution of organisms found with coral reef ecosystems (e.g. corals, seagrasses, algae, sponges, and associated animals) are generally influenced by nutrient availability, salinity, light, substrate, wave forces, sediment and temperature (Maragos and Gulko 2002). A coral reef ecosystem generally occurs in water less than 30 m deep, but some coral and algal species that do not depend light to grow can be found in waters of 300 m or more (Grigg and Epp, 1989); Maragos and Jokiel, 1986)

The coral reef ecosystems of the NWHI were once thought to represent nearly 70 percent of the total coral reef area (0-100 fm) under U.S. jurisdiction (Hunter 1995). Recent research, however, estimates that the NWHI represents nearly 5 percent of the total U.S. coral reef area from 0-100 fm (Rohnman et. al., 2005 in review). This large discrepancy is due to Florida's potential coral reef habitat being significantly underestimated in the mid-1990's. It is now thought that the potential coral reef habitat off of Florida composes nearly 80 percent of coral reef habitat in the U.S. (Rohnman et. al., 2005, in review)

The coral reef ecosystems of the NWHI has been found to be pristine condition (Maragos and Gulko, 2002). As opposed to coral reef ecosystems in other regions, the coral reef ecosystem of the NWHI generally has low biodiversity and high endemism. This is due the Hawaii Archipelago's isolation in the Pacific compounded by a general east to west surface current flow and lack of close coral reef ecosystems "upstream" of the Hawaiian Islands (Maragos and Gulko, 2002).

7.2D.1 Management Unit Species

The following table represents the list of MUS contained within the Coral Reef Ecosystems FMP. While the NWHI portions of FMP were unapproved, some alternatives contained in this analysis would provide that the following list apply to the NWHI. Currently, there is no management system in place in the NWHI which categorizes coral reef associated species.

TABLE 7-4: Currently Harvested Coral Reef Taxa

Acanthuridae (Surgeonfishes)	Orange-spot surgeonfish (*Acanthurus olivaceus*) Yellowfin surgeonfish (*Acanthurus xanthopterus*) Convict tang (*Acanthurus triostegus*) Eye-striped surgeonfish (*Acanthurus dussumieri*) Blue-lined surgeon (*Acanthurus nigroris*) Whitebar surgeonfish (*Acanthurus leucopareius*) Blue-banded surgeonfish (*Acanthurus lineatus*) Blackstreak surgeonfish (*Acanthurus nigricauda*) Whitecheek surgeonfish (*Acanthurus nigricans*) White-spotted surgeonfish (*Acanthurus guttatus*) Ringtail surgeonfish (*Acanthurus blochii*) Brown surgeonfish (*Acanthurus nigrofuscus*) Elongate surgeonfish (*Acanthurus mata*) Mimic surgeonfish (*Acanthurus pyroferus)* Yellow-eyed surgeonfish (*Ctenochaetus strigousus*) Striped bristletooth (*Ctenochaetus striatus*) Twospot bristletooth (*Ctenochaetus binotatus*)
	Bluespine unicornfish (*Naso unicornus*) Orangespine unicornfish (*Naso lituratus*) Humpnose unicornfish (*Naso tuberosus*) Black tongue unicornfish (*Naso hexacanthus*) Bignose unicornfish (*Naso vlamingii*) Whitemargin unicornfish (*Naso annulatus*) Spotted unicornfish (*Naso brevirostris*) Humpback unicornfish (*Naso brachycentron*) Barred unincornfish (*Naso thynnoides*) Gray unicornfish (*Naso caesius*)
Balistidae (Triggerfishes)	Titan triggerfish (*Balistoides viridescens*) Clown triggerfish *(B. conspicillum*) Orangstriped trigger*fish* (*Balistapus undulatus*) Pinktail triggerfish (*Melichthys vidua*) Black triggerfish (*M. niger)* Blue Triggerfish (*Pseudobalistesfucus*) Picassofish (*Rhinecanthus aculeatus*) Wedged Picassofish (*B. rectangulus*) Bridled triggerfish (*Sufflamen fraenatus*)
Carangidae (Jacks)	Bigeye scad (*Selar crumenophthalmus*) Mackerel scad (*Decapterus macarellus*)
Carcharhinidae (Sharks)	Grey reef shark (*Carcharhinus amblyrhynchos*) Silvertip shark (Carcharhinus albimarginatus) Galapagos shark (*Carcharhinus galapagenis*) Blacktip reef shark (*Carcharhinus melanopterus*) Whitetip reef shark (*Triaenodon obesus*)

Holocentridae (Soldierfish/Squirrelfish)	Bigscale soldierfish (*Myripristis berndti*) Bronze soldierfish (*Myripristis adusta*) Blotcheye soldierfish (*Myripristis murdjan*) Bricksoldierfish (*Myripristis amaena*) Scarlet soldierfish (*Myripristis pralinia*) Violet soldierfish (*Myripristis violacea*) Whitetip soldierfish (*Myripristis vittata*) Yellowfin soldierfish (*Myripristis chryseres*) Pearly soldierfish (*Myripristis kuntee*) (*Myripristis hexagona*) Tailspot squirrelfish (*Sargocentron caudimaculatum*) Blackspot squirrelfish (*Sargocentron melanospilos*) File-lined squirrelfish (*Sargocentron microstoma*) Pink squirrelfish (*Sargocentron tieroides*) Crown squirrelfish (*Sargocentron diadema*) Peppered squirrelfish (*Sargocentron punctatissimum*) Blue-lined squirrelfish (*Sargocentron tiere*) Ala'ihi (*Sargocentron xantherythrum*) (*Sargocentron furcatum*) (*Sargocentron spiniferum*) Spotfin squirrelfish(*Neoniphon spp.*)
Kuhliidae (Flag-tails)	Hawaiian flag-tail (*Kuhlia sandvicensis*) Barred flag-tail (*Kuhlia mugil*)
Kyphosidae (Rudderfish)	Rudderfish (*Kyphosus biggibus*) (*Kyphosus cinerascens*) (*Kyphosus vaigienses*)
Labridae (Wrasses)	Saddleback hogfish (*Bodianus bilunulatus*) Napoleon wrasse (*Cheilinus undulatus*) Triple-tail wrasse (*Cheilinus trilobatus*) Floral wrasse (*Cheilinus chlorourus*) Harlequin tuskfish (*Cheilinus fasciatus*) Ring-tailed wrasse (*Oxycheilinus unifasciatus*) Bandcheek wrasse (*Oxycheilinus diagrammus*) Arenatus wrasse (*Oxycheilinus arenatus*) Razor wrasse (*Xyricthys pavo*) Whitepatch wrasse (*Xyrichtes aneitensis*) Cigar wrass (*Cheilio inermis*) Blackeye thicklip (*Hemigymnus melapterus*) Barred thicklip (*Hemigymnus fasciatus*) Threespot wrasse (*Halichoeres trimaculatus*) Checkerboard wrasse (*Halichoeres hortulanus*) Weedy surge wrasse (*Halichoeres margaritacous*) (*Halichoeres zeylonicus*) Surge wrasse (*Thalassoma purpureum*) Redribbon wrasse (*Thalassoma quinquevittatum*) Sunset wrasse (*Thalassoma lutescens*) Longface wrasse (*Hologynmosus doliatus*) Rockmover wrasse (*Novaculichthys taeniourus*)

Mullidae (Goatfishes)	Yellow goatfish (*Mulloidichthys spp.*) (*Mulloidichthys Pfleugeri*) (*Mulloidichthys vanicolensis*) (*Mulloidichthys flaviolineatus*) Banded goatfish (*Parupeneus spp.*) (*Parupeneus barberinus*) (*Parupeneus bifasciatus*) (*Parupeneus heptacanthus*) (*Parupeneus ciliatus*) (*Parupeneus ciliatus*) (*Parupeneus cyclostomas*) (*Parupeneus pleurostigma*) (*Parupeneus indicus*) (*Parupeneus multifaciatus*) Bantail goatfish (*Upeneus arge)*
Mugilidae (Mullets)	Stripped mullet (*Mulgil cephalus)* Engel's mullet (*Moolgarda engeli*) False mullet (*Neomyxus leuciscus*) Fringelip mullet (*Crenimugil crenilabis*)
Muraenidae (Moray eels)	Yellowmargin moray (*Gymnothorax flavimarginatus*) Giant moray (*Gymnothorax javanicus*) Undulated moray (*Gymnothorax undulatus*)
Ocotpodidae	Octopus (*Octupus cyanea; O. ornatus*)
Polynemidae	Threadfin (*Polydactylus sexfilis*) -Moi
Pricanthidae (Bigeye)	Glasseye (*Heteropriacanthus cruentatus*) Bigeye (*Priacanthus hamrur*)
Scaridae (Parrotfishes)	Humphead parrotfish (*Bulbometapon muracatum*) Parrotfishes (*Scarus spp.*) Pacific longnose parrotfish (*Hipposcarus longiceps*) Stareye parrotfish (*Catolomus carolinus*)
Scombirdae	Dogtooth tuna (*Gymnosarda unicolor*)*
Siganidae (Rabbitfish)	Forktail rabbitfish (*Siganus aregentus*) Golden rabbitfish (*Siganus guttatus*) Gold-spot rabbitfish (*Siganus punctatissimus*) Randall's rabbitfish (*Siganus randalli*) Scribbled rabbitfish (*Siganus spinus*) Vermiculate rabbitfish (*Signaus vermiculatus*)
Sphyraenidae (Barracuda)	Heller's barracuda (*Sphyraena helleri*) Great Barracuda (*Sphyraena barracuda)*
Turbinidae (turban shells/green snails)	Green snails (*Turbo spp.*)

* *Gymnosarda unicolor* was previously listed as a Pelagic MUS

Aquarium Taxa/Species	Acanthuridae Yellow tang (*Zebrasoma flavescens*) Yellow-eyed surgeon fish (*Ctenochaetus strigosus*) Achilles tang (*Acanthurus achilles*) Muraenidae Dragon eel (*Enchelycore pardalis*) Zanclidae Morrish idol (*Zanclus cornutus*) Pomacanthidae Angelfish (*Centropyge shepardi* and *C. flavissimus*) Cirrhitidae Flame hawkfish (*Neocirrhitus armatus*) Chaetodontidae Butterflyfish (*Chaetodon auriga, C. lunula, C. melannotus* and *C. ephippium*) Pomacentridae Damselfish (*Chromis viridis, Dascyllus aruanus* and *D. trimaculatus*) Sabellidae Featherduster worm (*Sabellidae*)

TABLE 7-5: Potentially Harvested Coral Reef Taxa (Several taxa in the CHCRT list appear below. As noted in the table, all species in these taxa that are not listed as CHCRT or other FMP MUS are by default PHCRT).

Other Labridae spp. (wrasses) ***(Those species not listed on CHCRT list)***	Ephippidae (batfish)
Other Carcharhinidae, Sphyrnidae ***(Those species not listed on CHCRT list)***	Monodactylidae (mono)
Dasyatididae, Myliobatidae, Mobulidae (rays)	Haemulidae (sweetlips)
Other Serranidae spp. (groupers)	Echineididae (remoras)
Carangidae (jacks/trevallies)	Malacanthidae (tilefish)
	Acanthoclinidae (spiny basslets)
Other Holocentridae spp. (soldierfish/squirrelfish) ***(Those species not listed on CHCRT list)***	Pseudochromidae (dottybacks)
Other Mullidae spp. (goatfish) ***(Those species not listed on CHCRT list)***	Plesiopidae (prettyfins)
Other Acanthuridae spp. (surgeonfish/unicornfish) ***(Those species not listed on CHCRT list)***	Tetrarogidae (waspfish)
Other Lethrinidae spp. (emperors)	Caracanthidae (coral crouchers)
Chlopsidae, Congridae, Moringuidae, Ophichthidae (eels) **Other Muraenidae (morays eels)** ***(Those species not listed on CHCRT list)***	Grammistidae (soapfish)
Apogonidae (cardinalfish)	*Aulostomus chinensis* (trumpetfish)
Other Zanclidae spp. (moorish idols)	*Fistularia commersoni* (coronetfish)

Other Chaetodontidae spp. (butterflyfish)	Anomalopidae (flashlightfish)
Other Pomacanthidae spp. (angelfish)	Clupeidae (herrings)
Other Pomacentridae spp. (damselfish)	Engraulidae (anchovies)
Scorpaenidae (scorpionfish)	Gobiidae (gobies)
Blenniidae (blennies)	Lutjanidae
Other Sphyraenidae spp. (barracudas)	Other Ballistidae/Monocanthidae spp. (*Those species not listed on CHCRT list*)
Pinguipedidae (sandperches)	Other Siganidae spp. (*Those species not listed on CHCRT list*)
Gymnosarda unicolor	Other Kyphosidae spp.
Bothidae/Soleidae/Pleurnectidae (flounder/sole)	Caesionidae
Ostraciidae (trunkfish)	Cirrhitidae
Tetradontidae/Diodontidae (puffer/porcupinefish)	Antennariidae (frogfishes)
	Syngnathidae (pipefishes/seahorses)
Stony corals	Echinoderms (e.g., sea cucumbers, sea urchins)
Heliopora (blue)	Mollusca
Tubipora (organpipe)	Sea Snails (gastropods)
Azooxanthellates (non-reefbuilders)	Trochus spp.
Fungiidae (mushroom corals)	Opistobranchs (sea slugs)
Sm/Lg Polyped Corals (endemic spp.)	*Pinctada margaritifera* (black lipped pearl oyster)
Millepora (firecorals)	Tridacnidae
Soft corals and Gorgonians	Other Bivalves
Anemones (non-epifaunal)	Cephalopods
Zooanthids	Crustaceans (Lobsters, Shrimps/Mantis, True Crabs and hermit crabs) (*Those species not managed under the Crustacean FMP*)
Sponges (non-epifaunal)	Stylasteridae (lace corals)
Hydrozoans	Solanderidae (hydroid fans)
Bryozoans	Annelids
	Algae
Tunicates (solitary/colonial)	Live rock
All other coral reef ecosystem associated marine plants, invertebrates and fishes not listed under existing FMPs.	

NWHI Coral Reef Communities: The structure of reef communities is usually defined in terms of the diversity and relative abundances of species characteristic of a habitat type. Commonly, only a few species compose over half the abundance, while hundreds of others are present in low numbers. Coral species richness tends to be higher in the NWHI, where the genus *Acropora*, not found in the MHI, is present. A peak in coral species diversity occurs in the middle of the Hawaiian Archipelago at FFS and Maro Reef (Grigg 1983). Many reefs in the NWHI are comprised of calcareous algae (Green 1997). In general, fish species diversity appears to be lower in the NWHI than in the MHI. Although the inshore fish assemblages of the two regions are similar, fish size, density and biomass are significantly higher in the NWHI. Fish communities in the NWHI are dominated by apex predators (sharks and jacks), whereas those in the MHI are not (Friedlander and DeMartini 2002). Some fish species are common in parts of the NWHI that are rare elsewhere in the archipelago (Green 1997).

7. 3D.2 Life History of Coral Reef Fish

The literature on coral reef fish life histories is voluminous, but convenient entries into the literature are provided by Sale (1991), Polunin and Roberts (1996), and Birkeland (1997). The life of a coral reef fish includes several stages. Typically, spawning occurs in the vicinity of the reef and is characterized by frequent repetition throughout a protracted time of the year, a diverse array of behavioral patterns, and extremely high fecundity. The eggs of many species are fertilized externally and dispersed directly into the pelagic environment as plankton. Other species have demersal eggs, which upon hatching disperse larvae into the pelagic realm. Planktonic mortality is very high and unpredictable. Recruitment is the transition stage from the planktonic larval life to demersal existence on a coral reef. Recruitment is both spatially and temporally highly variable. This is when post-larval juveniles begin their residence on reefs where many remain for life. Highest predation mortality occurs in the first few days or weeks, thus rapid growth out of the juvenile stage is a common strategy.

Terrestrial animal populations are usually dispersed by adults, who deposit eggs or build nests in selected locations. In contrast, the most frequent pattern for coral reef organisms is dispersion of eggs and larvae in water currents, which determine the final location of adults. The adults are often sedentary or territorial. The differences in factors that bring about success in these two life history phases complicate fisheries management (Birkeland 1997a).

Reproduction and Recruitment: The majority of coral reef animals are very fecund, but temporal variations in recruitment success have been recorded for some species and locations. Many of the large, commercially-targeted coral reef animals are long-lived and reproduce for a number of years. This is in contrast to the majority of commercially-targeted species in the tropical pelagic ecosystem. Long-lived species adapted to coral reef systems are often characterized by complex reproductive patterns like sequential hermaphroditism, sexual maturity delayed by social hierarchy, multi-species mass spawnings, and spawning aggregations in predictable locations (Birkeland 1997a).

Growth and Mortality Rates: Recruitment of coral reef species is limited by high mortality of eggs and larvae, and also by competition for space to settle out on coral reefs. Predation intensity is due to a disproportionate number of predators, which limits juvenile survival (Birkeland 1997a). In response some fishes—such as scarids (parrotfish) and labrids (wrasses)—grow rapidly compared with most coral reef fishes. But they still grow relatively slowly compared to pelagic species. In addition, scarids and labrids may have complex haremic territorial social structures that contribute to the overall effect of harvesting these resources. It appears that many tropical reef fishes grow rapidly to near-adult size, and then often grow relatively little over a protracted adult life span; they are thus relatively long-lived. In some groups of fishes, such as damselfish, individuals of the species are capable of rapid growth to adult size, but sexual maturity is still delayed by social pressure. This complex relationship between size and maturity makes resource management more difficult (Birkeland 1997a).

Population Dynamics: Studies on coral reef fisheries are relatively recent, commencing with the major study by Munro and his co-workers during the late 1960s in the Caribbean (Munro 1983). Even today, only a relatively few examples are available of in-depth studies on reef fisheries. It was initially thought that the maximum sustainable yields for coral reef fisheries were in the range of 0.5-5 $t/km^{-2}yr^{-1}$, based on limited data (Marten and Polovina 1982; Stevenson and Marshall 1974). Much higher yields of around 20 $t/km^{-2}yr^{-1}$, for reefs in the Philippines (Alcala 1981; Alcala and Luchavez 1981) and American Samoa (Wass 1982), were thought to be unrepresentative (Marshall 1980), but high yields of this order have now been independently estimated for a number of sites in the South Pacific and Southeast Asia (Dalzell and Adams 1997; Dalzell *et al.* 1996). These higher estimates are closer to the maximum levels of fish production predicted by trophic and other models of ecosystems (Polunin and Roberts 1996). Dalzell and Adams (1997) suggest that the average MSY for Pacific reefs is in the region of 16 $t/km^{-2}yr^{-1}$ based on 43 yield estimates where the proxy for fishing effort was population density.

However, Birkeland (1997) has expressed some scepticism about the sustainability of the high yields reported for Pacific and south east Asian reefs. Among other examples, he notes that the high values for American Samoa reported by Wass (1982) during the early 1970's were followed by a 70% drop in coral reef fishery catch rates between 1979 and 1994. Saucerman (1995) ascribed much of this decline to a series of catastrophic events over the same period. This began with a crown of thorns infestation in 1978, followed by hurricanes in 1990 and 1991, which reduced the reefs to rubble, and a coral bleaching event in 1994, probably associated with the El Niño phenomenon. These various factors reduced live coral cover in American Samoa from a mean of 60% in 1979, to between 3-13% in 1993.

Further, problems still remain in rigorously quantifying the effects of factors on yield estimates, such as primary productivity, depth, sampling area, or coral cover. Polunin et al. (1996) noted that there was an inverse correlation between estimated reef fishery yield and the size of the reef area surveyed, based on a number of studies reported by Dalzell (1996). Arias-Gonzales et al. (1994) have also examined this feature of reef fisheries yield estimates and noted that this was a problem when comparing reef fishery yields. The study noted that estimated yields are based on the investigator's perception of the maximum depth at which true reef fishes occur. Small pelagic fishes, such as scads and fusiliers, may make up large fractions of the inshore catch from a particular reef and lagoon system, and if included in the total catch can greatly inflate the yield estimate. The great variation in reef yield summarized by authors such as Arias-Gonzales et al. (1994), Dalzell (1996) and Dalzell and Adams (1997) may also be due in part to the different size and trophic levels included in catches.

Another important aspect of the yield question is the resilience of reefs to fishing and recovery potential when overfishing or high levels of fishing effort have been conducted on coral reefs. Evidence from a Pacific atoll where reefs are regularly fished by community fishing methods, such as leaf sweeps and spearfishing, indicated that depleted biomass levels may recover to pre-exploitation levels within one to two years. In the Philippines, abundances of several reef fishes have increased in small reserves within a few years of their establishment (Russ and Alcala 1994), although recovery in numbers of fish is much faster than recovery of biomass, especially in larger species such as groupers. Other studies in the Caribbean and South East Asia (Polunin et al. 1996) indicate that reef fish populations in relatively small areas have the potential to recover rapidly from depletion in the absence of further fishing. Conversely, Birkeland (1997) cites the example of a pinnacle reef off Guam fished down over a period of six months in 1967, that has still not recovered thirty years later.

Estimating the recovery from, and reversibility of, fishing effects over large reef areas appears more difficult to determine. Where growth overfishing predominates, recovery following effort reduction may be rapid if the fish in question are fast growing, as in the case of goatfish (Garcia and Demetropolous 1986). However, recovery may be slower if biomass reduction was due to recruitment overfishing because it takes time to rebuild adult spawning biomasses and high fecundities (Polunin and Morton 1992). Further, many coral reef species have limited distributions; they may be confined to a single island or a cluster of proximate islands.

Individual sub-populations of larger stocks of reef species may increase, decrease, or cease to exist locally without adversely affecting the overall population. The condition of the overall populations of particular species is linked to the variability among sub-populations: the ratio of sources and sinks; their degrees of recruitment connection; and, the proportion of the sub-populations with high variability in reproductive capacity. Recruitment to populations of coral reef organisms depends largely on the pathways of larval dispersal and "downstream" links.

Perhaps the most important factor in the population dynamics of many coral reef species in the NWHI and the ecosystem as a whole are cyclical oceanographic events which affect productivity over large areas and may account for large fluctuations in population abundance. In a study of climatic and oceanographic events and their effect on productivity in the NWHI, Polovina et al. (1994) found declines of 30 to 50% in a wide variety of species from various trophic levels, from the early 1980s to the present, could be explained by a shift in oceanographic conditions. Prior to this time period, oceanographic conditions that lasted from the late 1970s until the early 1980s moved nutrient-rich deep ocean water into the euphotic zone, resulting in higher densities of reef fish, crustaceans, Hawaiian monk seals and seabirds.

7.2D.3 Habitat and Distribution of Coral Reef Fish

Species diversity declines eastwards across the Pacific from the locus of maximum species richness in Southeast Asia (especially in the Philippines and Indonesia), and is related in part to the position of land masses in relation to the Pacific Plate, the earth's largest lithospheric plate (Springer 1982). In general, species richness is greatest along the plate margin and declines markedly on the plate itself. As a result, islands in the Central Pacific generally have a lower reef organism diversity, but also a high degree of endemism. For example, Guam has about 269 species of zooxanthellate Scleractinian corals, about 40 Alcyonacea and just under a thousand species of fishes; Hawaii has far fewer in comparison. The proportion of endemic species increases in the opposite direction. For example, the Hawaiian Islands have about 18% endemic zooxanthellate corals, 60% endemic Alcyonacea and 25% endemic reef fishes, compared to the islands in the southwest part of the Western Pacific Region. The proportion of alien species in Hawaiian waters is also greater, and it is increasing (Birkeland 1997a).

As noted above, among the diverse array of species in each taxa on coral reefs, there are usually only a few that are consistently abundant, with the relative abundance of species within a taxa possibly approximating a log-normal distribution. The majority of species are relatively uncommon or only episodically abundant, following unusually successful recruitment (Birkeland 1997a).

Community Variability: High temporal and spatial variability is characteristic of reef communities. At large spatial scales, variation in species assemblages may be due to major differences in habitat types or biotopes. For example, sea grass beds, reef flats, lagoonal patch reefs, reef crests, and seaward reef slopes may occur in relatively close proximity, for example, but represent notably different habitats.

Reef fish communities from the geographically isolated Hawaiian Islands are characterized by low species richness, high endemism, and exposure to large semiannual current gyres, which may help retain planktonic larvae. The NWHI is further characterized by: (1) high latitude coral atolls; (2) a mild temperate to subtropical climate, where inshore water temperatures can reach below 18° C in late winter; (3) species that are common on shallow reefs and attain large sizes, which to the southeast occur only rarely or in deep water; and, (4) inshore shallow reefs that are largely free of fishing pressure.

Coral Reef Habitat: Even within a thriving coral reef habitat, not all space is occupied by corals or coralline algae. Reefs are typically patchworks of hard and sediment bottoms. A reef provides a variety of environmental niches, or combination of resources. The wide variety of survival strategies employed by coral reef organisms allows different species to exploit some combination of resources better than their competitors. The ecosystem is dynamic, however. If conditions change, a very specialized species may not be able to survive the rigors of the new environment or may be forced out by another species more adept at using the available resources, including space, food, light, water motion, and temperature.

Long-term Ecosystem Variability: Climate and ecosystem shifts may occur over decadal scale cycles or longer, meaning that resources management decisions need to consider changes in target level productivity over the long-term as well as short-term inter-annual variation. For example, the climatic shift that occurred in the central North Pacific in the late 1980s produced an ecosystem shift in the NWHI to a lower carrying capacity, with a 30-50% decline in productivity (Polovina *et al.* 1994). This in turn reduced recruitment and survival of monk seals, reef fish, albatross, and lobsters. Under the lower carrying capacity regime, excess fishing may alter the age-structure of the population and may also lead to stock depletion.

At Laysan Island, where lobster fishing is prohibited, the spawning biomass of lobsters was also depleted by natural mortality. This suggests that marine reserves may not guarantee the protection that is typically assumed (Polovina and Haight 1999). In response to this natural variability, the Council adjusted its management measures (e.g., limited entry, annual quota) to reduce catch and effort to about 25% of its 1980s level.

Coral bleaching occurs when corals lose or expel their zooxanthellae in large numbers, usually due to some trauma such as high or low temperatures or lower than usual salinities (Brown 1997). The corals that lose zooxanthellae also lose their color, becoming white and hence the term 'bleaching.' Although first described in the 1900s, interest in this phenomenon was heightened in the 1980s and 1990s after a series of major bleaching events in the Atlantic and Pacific Oceans. Some of these episodes were linked to the El-Niño Southern Oscillation or ENSO events (Gulko 1998). In 2002, several areas of the NWHI (Kure, Midway, Pearl and Hermes) were found to have experienced some coral bleaching (Kenyon, 2004, pers. comm).

When bleaching occurs, some corals are able to regain zooxanthellae by slowly re-infecting themselves with the algae, or through the reproduction of remaining zooxanthellae within the colony. Frequently, the loss of large amounts of symbiotic algae results in the colony becoming energy deficient; it expends more energy than it is consuming. If this occurs over the long term the colony dies (Brown 1997). Coral bleaching events require only a 1-2° C increase in water temperature. Thus, due to global warming, bleaching may become more common. According to Goreau *et al.* (1997), similar events in the Atlantic and the Indian Oceans suggest that worldwide corals are acclimated close to their upper temperature limits. As a result, they are unable to adapt rapidly to an anomalous warming (Goreau *et al.* 1997). Consequently, global warming represents a very serious threat to the survival of coral reefs.

Other physical phenomena that may bring long-term change to coral reef systems include the impact of hurricanes and tectonic uplift. Bayliss-Smith (1988) describes the changes in reef islands at Ontong-Java Atoll over a 20-year period following a severe hurricane. Most atoll islands are on reef flats in what are frequently high wave-energy locations near to seaward reef margins. Unless composed of coarse shingle and rubble, these islands are unstable. Hurricanes will destroy such small cays and scour *motu* beaches, and strip small or narrow islands of fine sediment during over-wash periods. Bayliss Smith (1988) notes that while hurricanes tend to erode islands, they also produce the material for their reconstruction. More frequent, lower magnitude storms contribute to the process by transporting the rubble ramparts thrown up by hurricanes. This reconstructs scoured beaches and eroded shorelines. Clearly, such destruction and reconstruction activity on reef flats will have an effect on reef organisms, including fish and invertebrates, particularly where large areas of reef are smothered by sand and silt following a hurricane.

7.2D.4 Status of the Stocks

NWHI coral reef associated fish stocks are believed to be in healthy condition as compared to the MHI. For example, the overall standing stock of the Spectacled Parrotfish (*Chlorurus perspicillatus*) is 1160 percent greater in NWHI than in the MHI (Maragos and Gulko, 2002). Average fish biomass is three times higher in the NWHI than in the MHI. This is due to 54 percent of biomass is comprised of top-level predators, whereas top-level predators in the MHI comprise only 3 percent of the fish biomass (Friedlander and DeMartini 2002). While the abundance of herbivores in the NWHI is similar to MHI coral reefs, the size and weight of these fish are higher in the NWHI than in the MHI (Maragos and Gulko, 2002). Studies conducted at French Frigate Shoals and Midway found that reef fishes declined by about one-third from the early eighties to early nineties. Such declines are thought to be associated with interdecadel regime shifts in productivity (Demartini et. al, 2002). As with many marine organisms, relative abundance of reef fish species are linked to fluctuations in environmental conditions that result in changes to productivity levels, larval transport, and recruitment.

7.2E Pelagic Stocks

Fishing for pelagic species within the proposed NWHI sancutary is done primarily by bottomfish permit holders trolling to and from bottomfish grounds, in addition to small-scale handline fisheries near the southern end of the NWHI. Regulations promulgated under the Pelagics FMP prohibit Hawaii-based longline vessels from fishing within 50 nm of the NWHI. The extent of recreational or subsistence pelagic fishing is unknown, but is thought to be minimal.

7.2E.1 Management Unit Species

The following table lists the MUS contained in the Pelagics FMP.

TABLE 7-6: Species complexes for pelagic management unit species (PMUS)

Marketable	
Temperate species complex:	Striped Marlin (*Tetrapturus audax*)
	Bluefin Tuna (*Thunnus thynnus*)
	Swordfish (*Xiphias gladius*)
	Albacore tuna (*Thunnus alalunga*)
	Mackerel (*Scomber* spp)
	Bigeye tuna (*Thunnus obesus*)
	Pomfret (family Bramidae)

Marketable	
Tropical species complex:	Yellowfin tuna (*Thunnus albacares*)
	Kawakawa (*Euthynnus affinis*)
	Skipjack tuna (*Katsuwonus pelamis*)
	Frigate and bullet tunas (*Auxis thazard, A. rochei*)
	Blue marlin (*Makaira mazara*)
	Slender tunas (*Allothunnus fallai*)
	Black marlin (*Makaira indica*)
	Dogtooth tuna (*Gymnosarda unicolor*)
	Spearfish (*Tetrapturus* spp.)
	Sailfish (*Istiophorus platypterus*)
	Mahimahi (*Coryphaena hippurus, C. equiselas*)
	Wahoo (*Acanthocybium solandri*)
	Opah (*Lampris guttatus*)
Non-Marketable	
	Snake mackerels or oilfish (family Gempylidae)
	Crocodile sharks (*Pseudocarcharias kamoharai*)
	Requiem sharks (family Carcharhinidae)
	Mackerel sharks (family Lamnidae)
	Hammerhead sharks (family Sphyrnidae)

7.2D.2 Life History

Pelagic species are closely associated with their physical and chemical environment. Suitable physical environment for these species depends on gradients in temperature, oxygen or salinity, all of which are influenced by oceanic conditions on various scales. In the pelagic environment, physical conditions such as isotherm and isohaline boundaries often determine whether or not the surrounding water mass is suitable for pelagic fish, and many of the species are associated with specific isothermic regions. Additionally, areas of high trophic transfer as found in fronts and eddies are an important habitat for foraging, migration, and reproduction for many species (Bakun, 1996).

Oceanic pelagic fish such as skipjack and yellowfin tuna, and blue marlin prefer warm surface layers, where the water is well mixed by surface winds and is relatively uniform in temperature and salinity. Other fish such as albacore, bigeye tuna, striped marlin and swordfish, prefer cooler, more temperate waters, often meaning higher latitudes or greater depths. Preferred water temperature often varies with the size and maturity of pelagic fish, and adults usually have a wider temperature tolerance than sub-adults. Thus, during spawning, adults of many pelagic species usually move to warmer waters, the preferred habitat of their larval and juvenile stages. Large-scale oceanographic events (such as *El Niño*) change the characteristics of water temperature and productivity across the Pacific, and these events have a significant effect on the habitat rànge and movements of pelagic species. Tunas are commonly most concentrated near islands and seamounts that create divergences and convergences which concentrate forage species, also near upwelling zones along ocean current boundaries, and along gradients in temperature, oxygen and salinity. Swordfish and numerous other pelagic species tend to concentrate along food-rich temperature fronts between cold, upwelled water and warmer oceanic water masses.

These fronts represent sharp boundaries in a variety of physical parameters including temperature, salinity, chlorophyll, and sea surface height (geostrophic flow) (Niiler and Reynolds, 1984; Roden, 1980; Seki *et al.*, in press). Biologically, these convergent fronts appear to represent zones of enhanced trophic transfer (Bakun, 1996; Olsen *et al.*, 1994). The dense cooler phytoplankton-rich water sinks below the warmer water creating a convergence of phytoplankton (Roden, 1980). Buoyant organisms, such as jellyfish as well as vertically swimming zooplankton, can maintain their vertical position in the weak down-welling, and aggregate in the front to graze on the down-welled phytoplankton (Bakun, 1996). The increased level of biological productivity in these zones attracts higher trophic-level predators such as swordfish, tunas, seabirds, and sea turtles, and ultimately a complete pelagic food web is assembled.

7.2E.3 Habitat and Distribution

Near Hawaii, there are two prominent frontal zones. These frontal zones are associated with two isotherm (17° C and 20° C), and they are climatologically located at latitudes 32°-34° N. (the Subtropical Front or STF) and latitudes 28°-30° N. (the South Subtropical Front or SSTF) (Seki *et al.*, 2002). Both the STF and SSTF represent important habitats for swordfish, tunas, seabirds and sea turtles. Variations in their position play a key role in catch rates of swordfish and albacore tuna, and distribution patterns of Pacific pomfret, flying squid, loggerhead turtles (Seki *et al.*, in press), and seabirds. Hawaii-based longline vessels targeting swordfish set their lines where the fish are believed to be moving south through the fronts following squid, the primary prey of swordfish (Seki *et al.*,). Squid is also the primary prey item for albatross (Harrison *et al.*, 1983), hence the albatross and longline vessels targeting swordfish are often present at the same time in the same area of biological productivity.

These frontal zones have also been found to be likely migratory pathways across the Pacific for loggerhead turtles (Polovina *et al.*, 2000). Loggerhead turtles are opportunistic omnivores that feed on floating prey such as the pelagic cnidarian *Velella velella* ("by the wind sailor"), and the pelagic gastropod *Janthina sp.*, both of which are likely to be concentrated by the weak downwelling associated with frontal zones (Polovina *et al.*, 2000). Data from on-board observers in the Hawaii-based longline fishery indicate that incidental catch of loggerheads occurs along the 17° C front (STF) during the first quarter of the year and along the 20° C front (SSTF) in the second quarter of the year. The interaction rate, however, is substantially greater along the 17° C front (Polovina *et al.*, 2000).

Species of oceanic pelagic fish live in tropical and temperate waters throughout the world's oceans. They are capable of long migrations that reflect complex relationships to oceanic environmental conditions. These relationships are different for larval, juvenile and adult stages of life. The larvae and juveniles of most species are more abundant in tropical waters, whereas the adults are more widely distributed. Geographic distribution varies with seasonal changes in ocean temperature. In both the Northern and Southern Hemispheres, there is seasonal movement of tunas and related species toward the pole in the warmer seasons and a return toward the equator in the colder seasons. In the western Pacific, pelagic adult fish range from as far north as Japan to as far south as New Zealand. Albacore, striped marlin and swordfish can be found in even cooler waters at latitudes as far north as latitude 50° N. and as far south as latitude 50° S. As a result, fishing for these species is conducted year-round in tropical waters and seasonally in temperate waters.

Migration patterns of pelagic fish stocks in the Pacific Ocean are not easily understood or categorized, despite extensive tag-and-release projects for many of the species. This is particularly evident for the more tropical tuna species (e.g., yellowfin, skipjack, bigeye) which appear to roam extensively within a broad expanse of the Pacific centered on the equator. Although tagging and genetic studies have shown that some interchange does occur, it appears that short life spans and rapid growth rates restrict large-scale interchange and genetic mixing of eastern, central and far-western Pacific stocks of yellowfin and skipjack tuna. Morphometric studies of yellowfin tuna also support the hypothesis that populations from the eastern and western Pacific derive from relatively distinct sub-stocks in the Pacific. The stock structure of bigeye in the Pacific is poorly understood, but a single, Pacific-wide population is assumed. The movement of the cooler-water tuna (e.g., bluefin, albacore) is more predictable and defined, with tagging studies documenting regular and well-defined seasonal movement patterns relating to specific feeding and spawning grounds. The oceanic migrations of billfish are poorly understood, but the results of limited tagging work conclude that most billfish species are capable of transoceanic movement, and some seasonal regularity has been noted.

In the ocean, light and temperature diminish rapidly with increasing depth, especially in the region of the thermocline. Many pelagic fish make vertical migrations through the water column. They tend to inhabit surface waters at night and deeper waters during the day, but several species make extensive vertical migrations between surface and deeper waters throughout the day. Certain species, such as swordfish and bigeye tuna, are more vulnerable to fishing when they are concentrated near the surface at night. Bigeye tuna may visit the surface during the night, but generally, longline catches of this fish are highest when hooks are set in deeper, cooler waters just above the thermocline (275-550 meters or 150-300 fathoms). Surface concentrations of juvenile albacore are largely concentrated where the warm mixed layer of the ocean is shallow (above 90 m or 50 fm), but adults are caught mostly in deeper water (90-275 m or 50-150 fm). Swordfish are usually caught near the ocean surface, but are known to venture into deeper waters. Swordfish demonstrate an affinity for thermal oceanic frontal systems which may act to aggregate their prey (Seki *et al.*, 2002) and enhance migration by providing an energetic gain by moving the fish along with favorable currents (Olsen *et al.*, 1994).

7.2D.4 Status of the Stocks

Pacific-wide stock assessments are conducted annually for the major commercial tuna species (bigeye, yellowfin, skipjack and albacore). Bigeye is experiencing high levels of fishing mortality (e.g. longline, purse seine fisheries) from overfishing, however the population has yet to be determined as overfished. The future stock depends on the future fishing mortality and future recruitment (SCTB 2004)

Yellowfin stocks are experiencing nearly full levels of exploitation. However, based on fishing mortality rates and recruitment levels, overfishing of yellowfin stocks is not thought to be occurring. The yellowfin stock assessment estimates that the tropical stocks (Indonesia) are being fully exploited, whereas the temperate region (Hawaii) stocks are likely being lightly exploited (SCTB 2004).

Although skipjack stocks experience high levels of fishing mortality, the stocks appear to be in healthy condition due higher levels of recruitment. Currently, there is not an stock assessment of the North Pacific albacore stock, however it is believed to healthy. South Pacific albacore stocks are believed to be healthy and at 60 percent of unfished levels (SCTB 2004).

Stock assessments of other important pelagic fish such as mahi mahi and ono are not available. Both of these populations, however, are thought to be in healthy condition. Most studies suggest that Pacific billfish stocks are healthy but there is considerable uncertainty because of the quality of data and differences in the methods used to evaluate the trends. Blue marlin stocks, however, may currently be fully exploited and facing high fishing mortality from various fisheries in the Central and Western Pacific.

7.2F Essential Fish Habitat

For each FMP and list of MUS, the Council has declared Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC). The Council and NMFS must ensure that any activities conducting in such areas do not adversely affect, to the extent possible, EFH of HAPC for any MUS. The following table represents the EFH and HAPC for all Western Pacific MUS.

TABLE 7-7: EFH and HAPC for all Western Pacific MUS

FMP	EFH (Juveniles and Adults)	EFH (Eggs and Larvae)	HAPC
Pelagics	Water column down to 1,000 m	Water column down to 200 m	Water column above seamounts and banks down to 1,000 m
Bottomfish and Seamount Groundfish	Bottomfish: Water column and bottom habitat down to 400 m Seamount Groundfish: (adults only) water column and bottom from 80 to 600 m, bounded by 29°-35°N and 171°E-179°W	Bottomfish: Water column down to 400 m Seamount Groundfish: (including juveniles) epipelagic zone (0-200m) bounded by 29°-35°N and 171°E-179°W	Bottomfish: All escarpments and slopes between 40-280 m, and three known areas of juvenile *ʻōpakapaka* habitat Seamount Groundfish: not identified
Precious Corals	Keāhole Point, Makapuʻu, Kaʻena Point, Westpac, Brooks Bank, 180 Fathom Bank deep water precious corals (gold and red) beds and Miloliʻi, Auʻau Channel and S. Kauaʻi black coral beds	Not applicable	Makapuʻu,Westpac, and Brooks Bank deep water precious corals beds and the Auʻau Channel black coral bed
Crustaceans	Bottom habitat from shoreline to a depth of 100 m	Water column down to 150 m	All banks within the NWHI with summits less than 30 m
Coral Reef Ecosystem	Water column and benthic substrate to a depth of 100 m	Water column and benthic substrate to a depth of 100 m	All MPAs identified in FMP, all PRIAs, many specific areas of coral reef habitat

Note: All areas are bounded by the shoreline and the outer boundary of the EEZ, unless otherwise indicated.

As the above table shows, Western Pacific EFH and HAPC fall into two categories: either the water column above the ocean bottom, or the ocean bottom itself. Water column EFH and HAPC have been designated for pelagic, bottomfish, precious corals, crustacean and coral reef ecosystem MUS.

Areas of ocean bottom have been designated EFH and HAPC for precious corals, crustaceans, bottomfish and coral reef ecosystem MUS. The use of explosives, poisons, trawl nets, and other destructive gears which may adversely affect any EFH or HAPC in th Western Pacific Region is prohibited. No fishery under Council jurisdiction has been found to adversely affect the EFH or HAPC of any Western Pacific Region MUS. Kelley and Moffitt (2004) found that bottomfishing does not affect habitat or other marine resources on Raita and West St. Rogatien Banks of the NWHI.

7.3 Protected Species

Protected species include those species listed as endangered or threatened under the ESA, all marine mammals, listed or not, as they are protected under the MMPA, and seabirds, listed or not, as they are protected under the MBTA. Appropriate information on the species' life history, habitat and distribution, and other factors necessary to its survival, is included to provide background for analyses in other sections of this document.

In March 2002, NMFS completed a formal consultation under ESA Section 7 and released its Biological Opinion (BiOp) for the Bottomfish FMP. The BiOp concluded that the bottomfish fisheries of the Western Pacific Region are not likely to jeopardize the continued existence of any threatened or endangered species under NMFS' jurisdiction or destroy or adversely modify critical habitat that has been designated for them.

7. 3A Marine Mammals

Protected marine mammals fall into two categories: species listed under the ESA and those species which are not listed, but otherwise protected under the MMPA. Cetaceans and pinnipeds are discussed separately in the sections below.

7.3A.1 Listed Cetaceans

The six species of cetaceans listed under the ESA that occur within the Hawaiian Archipelago are found in the following table. Although these whales may be found within the proposed sanctuary boundaries, there are no reported or observed interactions with the fisheries which may operate within the NWHI sanctuary.

TABLE 7-8: ESA listed Cetacea of the Hawaiian Archipelago

Common Name	Scientific Name
Blue whale	*Balaenoptera musculus*
Fin whale	*Balaenoptera physalus*
Humpback whale	*Megaptera novaeangliae*
Sei whale	*Balaenoptera borealis*
Sperm whale	*Physeter macrocephalus*
Right whale	*Eubalaena glacialis*

7.3A.2 Other Cetaceans

Species of whales that are not listed under the ESA but are protected under the MMPA and occur around the Hawaiian Archipelago are listed in the following table.

TABLE 7-9: Non-ESA listed Ceatacea of the Hawaiian Archipelago

Common Name	Scientific Name
Blainsville beaked whale	*(Mesoplodon densirostris)*
Bottlenose dolphin	*(Tursiops truncatus)*
Bryde's whale	*(Balaenoptera edeni)*
Cuvier's beaked whale	*Ziphius cavirostris*
Dwarf sperm whale	*Kogia simus*
False killer whale	*Pseudorca crassidens*
Killer whale	*Orcinus orca*
Melon-headed whale	*Peponocephala electra*
Pygmy killer whale	*Feresa attenuata*
Pygmy sperm whale	*Kogia breviceps*
Risso's dolphin	*Grampus griseus*
Rough-toothed dolphin	*Steno bredanensis*
Short-finned pilot whale	*Globicephala macrorhynchus*
Spinner dolphin	*Stenella longirostris*
Spotted dolphin	*Stenella attenuata*
Striped dolphin	*Stenella coeruleoalba*
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*
Minke whale	*Balaenoptera acutorostrata*
Dall's porpoise	*Phocoenoides dalli*
Fraser's dolphin	*Lagenodelphis hosei*
Longman's beaked whale	*Indopacetus pacificus*

From the list above, only the bottlenose dolphin (*Tursiops truncatus*) has been documented to interact with a NWHI fishery (Bottomfish). Bottlenose dolphins have been observed stealing hooked fish off of bottomfish lines, the extent of such interactions are not known and are believed to be low. Bottlenose dolphins are widely distributed throughout the world in tropical and warm-temperate waters (Reeves et al. 1999). Average size at birth is 0.9 to 1.2 m and 8 - 9 kg. Maximum size reported is 3.9 m and 275 kg. Males are sexually mature at 10 - 12 years of age, females between 5 and 12 years. Once reproductively active, females bear a single calf every second or third year. Gestation is about 12 months. Calves are nursed for a year or more. Maximum age appears to be 46 - 48 years, based on tooth growth analysis of both wild and captive dolphins.

The bottlenose dolphin is primarily coastal, but populations also occur in offshore waters. The species is common throughout the Hawaiian archipelago, usually within five miles of emergent land or shallow banks (Shallenberger 1981). School sizes range from single animals and small groups (3-10 individuals) to aggregations of more than 100 individuals. A combined aerial and vessel survey indicated at least 430 individuals in the shallow waters around the MHI (Nitta and Henderson 1993). Data suggest that the bottlenose dolphins in Hawai'i belong to a separate stock from those in the eastern tropical Pacific (Scott and Chivers 1990). The status of bottlenose dolphins in Hawaiian waters relative to their optimum sustainable population (OSP) is unknown, and there are insufficient data to evaluate trends in abundance or carrying capacity of the region (Forney et al. 2000). The relative impact of the bottomfish fishery on the behavior or foraging success of bottlenose dolphins is unknown, but thought to be minimal.

Although the other species listed above may be found within the action area and could interact with NWHI fisheries, no reported or observed interactions have ever been reported or observed.

7.3A.3 Listed Pinniped: The Hawaiian Monk Seal

In 1976, the Hawaiian monk seal was listed as endangered under the ESA following a 50% decline in beach counts from the late 1950s to the mid-1970s (41 FR 33922). It was also designated a depleted species in 1976 under the MMPA, and its population is considered to be below sustainable levels. The Hawaiian monk seal is the most endangered pinniped in U.S. waters and is second only to the northern right whale as the nation's most endangered marine mammal (Marine Mammal Commission 1999). The Hawaiian monk seal is also the only endangered marine mammal that exists wholly within the jurisdiction of the U.S.

The Hawaiian Monk Seal Recovery Team (HMSRT), appointed pursuant to the ESA in 1980, is a forum, supported by NMFS, in which issues involving recovery planning and implementation are discussed and recommendations for actions forwarded to NMFS. In 1982, the HMSRT completed the Hawaiian Monk Seal Recovery Plan. The highest priority activities identified by that report are those that support the following recovery-related objectives: 1) Determine the ultimate and proximate factors influencing population dynamics at each of the six major breeding locations; 2) Enhance survival of female Hawaiian monk seals and their pups to maximize reproductive potential and population growth; 3) Facilitate recovery of the depleted populations; and 4) Mitigate human impacts (HMSRT 1999).

Under the ESA, critical habitat may be designated to afford protection or special management consideration to physical or biological features essential to the conservation of a listed species. In May 1988, NMFS designated critical habitat for the Hawaiian monk seal out from shore to 20 fathoms in 10 areas of the Northwestern Hawaiian Islands. Critical habitat for this species includes "all beach areas, sand spits and islets, including all beach crest vegetation to its deepest extent inland, lagoon waters, inner reef waters, and ocean waters out to a depth of 20 fathoms around the following: Pearl and Hermes Reef, Kure Atoll, Midway Islands, except Sand Island and its harbor, Lisianski Island, Laysan Island, Maro Reef, Gardner Pinnacles, French Frigate Shoals, Necker Island, and Nihoa Island" (53 FR 18990, May 26, 1988, 50 CFR § 226.201).
Critical habitat was designated in order to enhance the protection of habitat used by Hawaiian monk seals for pupping and nursing, areas where pups learn to swim and forage, and major haul-out areas where population growth occurs.

7.3A.3.1 Biology and Distribution

Monk seals are phocids, and are one of the most primitive genera of seals. They are brown to silver in color, depending upon age and molt status, and can weigh up to 270 kg. Adult females are slightly larger than adult males. Monk seals are solitary, and it is thought they can live up to 30 years. Females reach breeding age at about 5 to 10 years of age, depending on their condition, and can give birth about once every year. An estimated 40-80% of adult females give birth in a given year (NMFS unpub. data. 2001). After birth, pups nurse for 5-6 weeks, during which time the mother rarely, if at all, leaves the pup to feed. At weaning, the mother leaves and the pup must subsequently forage independently. Newly weaned pups tend to stay in the reef shallows, entering into more diverse and deeper waters to forage as they gain experience. Monk seals may stay on land up to about two weeks during their annual molt. Hawaiian monk seals are nonmigratory, but recent studies show their home ranges may be extensive (Abernathy and Siniff 1998). Counts of individuals on shore compared with enumerated subpopulations at some of the NWHI indicate that Hawaiian monk seals spend about one-third of their time on land and about two thirds in the water (Forney et al. 2000).

The Hawaiian monk seal breeds only in the Hawaiian Archipelago, with most monk seals inhabiting the remote, largely uninhabited atolls and surrounding waters of the NWHI.
More than 90 percent of all known pups are born at six NWHI breeding colonies which include French Frigate Shoals, Laysan Island, Pearl and Hermes Reef, Lisianski Island, Kure Atoll and Midway Atoll. A few births also occur annually at Necker, Nihoa, and Niʻihau Islands and in the main Hawaiian Islands. NMFS researchers have also observed Hawaiian monk seals at Gardner Pinnacles and Maro Reef. Although Hawaiian monk seals occasionally move between islands, females generally return to their natal colony to pup. Since 1990, there has been an apparent increase in the number of Hawaiian monk seal sightings and births in the main Hawaiian Islands (HMSRT 1999; Johanos 2000). A 2001 aerial survey determined a minimum abundance of 52

seals in the MHI (Baker and Johanos, 2003). Table 7-10 shows that monk seal births in recent years are increasing.

TABLE 7-10: Known Hawaiian Monk Seal Births in the MHI

Year	Niihau	Kauai	Oahu	Molokai	Maui	Kahoolawe	Hawaii	Total
1962	?	1	0	0	0	0	0	1
1988	?	1	0	0	0	0	0	1
1991	1	1	1	0	0	0	0	3
1992	?	1	0	0	0	0	0	1
1996	?	0	1	1	0	0	0	2
1997	?	0	1	1	1	0	0	3
1998	?	0	2	1	1	0	0	4
1999	?	1	0	1	1	0	0	3
2000	2	4	0	1	0	0	0	7
2001	5	3	0	2	0	1	1	12
2002	?	1	0	2	0	0	1	4
2003	?	2	1	4	0	1	2	10

(Source: PIFSC 2003)

Hawaiian monk seals feed on a wide variety of teleosts, cephalopods and crustaceans, indicating that they are highly opportunistic feeders (Rice 1964; MacDonald 1982; Goodman-Lowe 1998). Research to identify prey species is currently underway using several methods: collection of potential prey items and blubber samples for fatty acid analysis; Crittercam[3] recording of foraging behavior; correlation of dive/depth/location profiles with potential prey species habitat; and analysis of Hawaiian monk seal scat and spew samples for identifiable hard parts of prey. Table 7-11 identifies adult male Hawaiian monk seal prey families as indicated by Crittercam studies at French Frigate Shoals.

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[3]A Crittercam is a self-contained video camera that has been mounted on a Hawaiian monk seal to record its foraging behavior.

TABLE 7-11: Crittercam Study- Prey Items Eaten by Free Swimming Adult Male Hawaiian Monk Seals at French Frigate Shoals

FAMILY	NUMBER SEEN
Anthiinae	2
Balistidae	1
Bothidae	1
Cheilinninae	2
Congridae	1
Pentacerotidae (groundfish)	1
Pomacentridae	1
Tetradontidae	1
Unidentified Eels	2
Unidentified fish	8
Octopus	2

(Source: Parrish et al. 2000; WPRFMC 2000a)

In a study at five of the principle breeding sites for the Hawaiian monk seal (FFS, Laysan Island, Lisianski Island, Pearl and Hermes Reef, and Kure Atoll) focused on identifying items eaten by Hawaiian monk seals, Goodman-Lowe (1998) analyzed scat and spew samples to identify prey, and to obtain size estimates of the more common cephalopod prey species.[4] This study also examined the temporal differences in diet among years. The frequency of occurrence (FO) was calculated as the number of samples in which an identified prey type was found. The percent frequency of occurrence (percent FO) was calculated as the FO divided by the total number of scat and spew samples analyzed (n=940)(Table 7-12).

[4]Scat and spew analysis is known to be biased due to differential digestion of various prey types. However, scat and spew analysis is, at this time, the best available scientific information for investigating Hawaiian monk seal diets.

TABLE 7-12 : Goodman-Lowe Results of Prey found in Scat and Spew samples Referenced to Bottomfish MUS and Bycatch Families

FAMILY	FO/%FO n=940
Labridae	194/20.6
Balistidae	123/13.1
Scaridae	99/10.5
Acanthuridae	71/7.6
Pomacentridae	44/4.7
Tetradontidae	41/4.4
Kyphosidae	32/3.4
Monacanthidae	29/3.1
Synodontidae	25/2.7
Pomocanthidae	17/1.7
Kuhliidae	14/1.5
Cirrhitidae	12/1.3
Chaetodontidae	10/1.1
Diodontidae	10/1.1
Bothidae	9/0.9
Cheilodactylidae	6/0.6
Scorpaenidae	5/0.5
Ostraciidae	1/0.1
Unidentified Eels	207/22.0
Holocentridae	135/14.4
Muraenidae	53/5.6
Congridae	52/5.5
Priacanthidae	40/4.3
Apogonidae	9/0.9

FAMILY	FO/%FO n=940
Opichthidae	6/0.6
Mullidae	58/6.2
Lutjanidae	24/2.6
Carangidae	11/1.1
Polymixiidae	9/1.0
Serranidae	5/0.5
Belonidae	1/0.1
Unidentified remains	330

Source: Goodman-Lowe 1998

The results indicated that Hawaiian monk seals are opportunistic predators that feed on a wide variety of available prey as compared to the case of other seals in which the bulk of the diet is made up of only a few species (Goodman-Lowe 1998). The analysis revealed that teleosts (bony fish) were the most represented prey (78.6%) followed by cephalopods (15.7%) and crustaceans (5.7%). The most common teleost families found were eels (22.0%), Labridae (20.6%), Holocentridae (14.4%), Balistidae (13.1%) and Scaridae (10.5%). All teleost families found include common, shallow-water reef fishes, except for the beardfish family, Polymixiidae (1.0%), which is recognized to consist of deep-water benthic fish. The deep-water Polymixiidae are not caught in the bottomfish fishery either as target or bycatch species. Evidence of target species such as snapper and grouper appeared infrequently in fecal and regurgitate samples.

An ongoing study contracted by NMFS is using quantitative fatty acid signature analysis to identify which prey items are most important to the various age and sex components of the several island populations of Hawaiian monk seals. The first report detailing the collection and fatty acid analyses of prey specimens is expected in FY05. A final report should be completed in early FY06. Preliminary findings of the fatty acid study suggest that there are variations in diets among individual Hawaiian monk seals as well as diet variation among demographic groups and groups in different locations (Antonelis, 2005 pers. comm.)

Information about the foraging activities of Hawaiian monk seals is available through the dive/depth/location profiles and the correlation with the habitat of potential prey families.
The foraging and dive patterns of Hawaiian monk seals and the availability of prey items to Hawaiian monk seals are important to understand when determining the potential impact of fisheries in terms of areas fished, potential for gear interactions, and prey competition. The foraging range of the Hawaiian monk seal extends to areas managed under the all FMPs. Various studies have been undertaken to determine the habitat use patterns of Hawaiian monk seals (Schlexer 1984; DeLong et al. 1984; Abernathy and Siniff 1998; Stewart 1998; Parrish et al. 2000).

These studies used various technologies, including radio tags, dive depth recorders, Crittercams, and satellite telemetry, to study the foraging behavior of Hawaiian monk seals. The results of these studies vary by location.

DeLong et al. (1984) instrumented seven Hawaiian monk seals at Lisianski Island with radio transmitters and multiple depth of diving recorders and recorded movements for an aggregate of 94 days in which 4,817 dives were recorded. Most dives (59 percent) were in the 10-40 m depth range, and the remainder of dives were to deeper depths. Thirteen dives were recorded to depths of at least 121 m. The outer edge of the reef around Lisianski Island is generally delineated by the 40 m isobath. The study concluded that during breeding season at Lisianski Island males depend entirely upon the food resources on the coral reefs, sandy beach flats and deeper reef slopes around that island.

Schlexer (1984) also recorded diving patterns of Hawaiian monk seals at Lisianski Island. In that study, eight Hawaiian monk seals (five adult males, one juvenile male, one subadult female, and one juvenile female), tracked with radio transmitters and multiple depth of diving recorders, were recorded diving within the 0 - 70 m range. One subadult female and one juvenile female dove in the shallow range of 10 - 40 m, with some dives recorded from 150 - 180 m. None of the adult males instrumented dove to depths greater than 70 m.

Stewart (1998) investigated diving patterns of 24 Hawaiian monk seals at Pearl and Hermes Reef using satellite-linked radio transmitters to record dive depth and duration. That study concluded that the Hawaiian monk seals at Pearl and Hermes Reef foraged in relatively shallow waters, and that foraging activity was different for males and females and among age classes. At Pearl and Hermes Reef, juveniles foraged almost exclusively within the fringing reef, adult males foraged mostly on the inside and outer edge of the fringing reef, and adult females foraged mostly within the center of the atoll and near the atoll's southwestern opening (Stewart 1998). Adult males generally dove within the 8 - 40 m range, with a secondary mode at 100 - 120 m. Male juveniles generally dove within the 8 - 40 m range. Adult females rarely dove deeper than 40 m, although one female made a number of dives to 60 - 140 m.

Abernathy and Siniff (1998) instrumented adult seals at FFS with satellite-linked time depth recorders. Data showed that instrumented adult male Hawaiian monk seals appeared to utilize the banks to the northwest, with a daytime diving range between 50 - 80 m and a nighttime range between 110 - 190 m. The study also suggested that seals that did not leave the vicinity of FFS rarely dove deeper than 80 m during the day, but made more dives closer to 80 m at night. The study also identified a few seals that were extremely deep divers. These seals' daytime dives reached depths > 300 m on a ridge to the east of the atoll. The researchers modeled the home range of individuals and concluded that the average home range was 6,467 km^2 (n=28, SE=3,055 km^2). For example, individuals were documented traveling between FFS and Gardner Pinnacles, St. Rogatien Bank, Brooks Bank, and Necker Island. The conclusion was that Hawaiian monk seals forage on benthic (bottom) and epibenthic (near bottom) species, in addition on other prey items in the fringing reef complex.

Parrish et al. (2000) provided further information that Hawaiian monk seal foraging behavior and range are extensive. Twenty-four Hawaiian monk seals were outfitted with Crittercams. The Crittercam recorded the habitat depth and bottom type at locations where Hawaiian monk seals were identified as successful in the capture of prey items. It was found that the diurnal pattern of foraging by male adults occurred mainly at the 60 m isobath. A few seals foraged at depths >300 m. Some of these areas were outside the critical habitat area and overlapped with areas fished by both lobster and bottomfish fisheries.

Since 1995, the abundance of shallow water (<20 m) reef fish has been surveyed at FFS and Midway. The data are checked as a potential indicator of changes in the abundance of Hawaiian monk seal prey. The surveys are conducted annually by NMFS and are designed to detect changes of 50 percent or greater in fish densities (Laurs 2000). The surveys have not indicated any statistically significant changes in prey abundance at either site (DeMartini and Parrish, 1996; DeMartini et al. 1999; DeMartini et al. 2002).

Recent information suggests Hawaiian monk seals may forage in beds of precious corals, some of which are habitat for known Hawaiian monk seal prey items such as arrowtooth eels (Parrish et al. 2002). In 2000, the National Undersea Research Laboratory conducted a study using manned and unmanned submersibles in known beds of the Western Pacific region. The objective of the study was to test the hypothesis that gold coral provided habitat for deep-water arrowtooth eels. Results of the study found that gold coral did not seem to aggregate arrowtooth eels or any other significant fish assemblage. At the Cross Seamount, the study found arrowtooth eels in areas adjacent to the beds, but without the presence of gold corals (Parrish 2001). A recent study using a submersible was conducted in the NWHI and MHI to evaluate the possibility that precious coral beds aggregate fish. The study found that it is unlikely that fish aggregations at such depths are dependant up precious corals for habitat and relief, but that precious corals and fish share habitat that has high relief and high nutrient flow, i.e. co-occurrence and not a dependancy of fish on corals (Parrish, 2005 pers. comm).

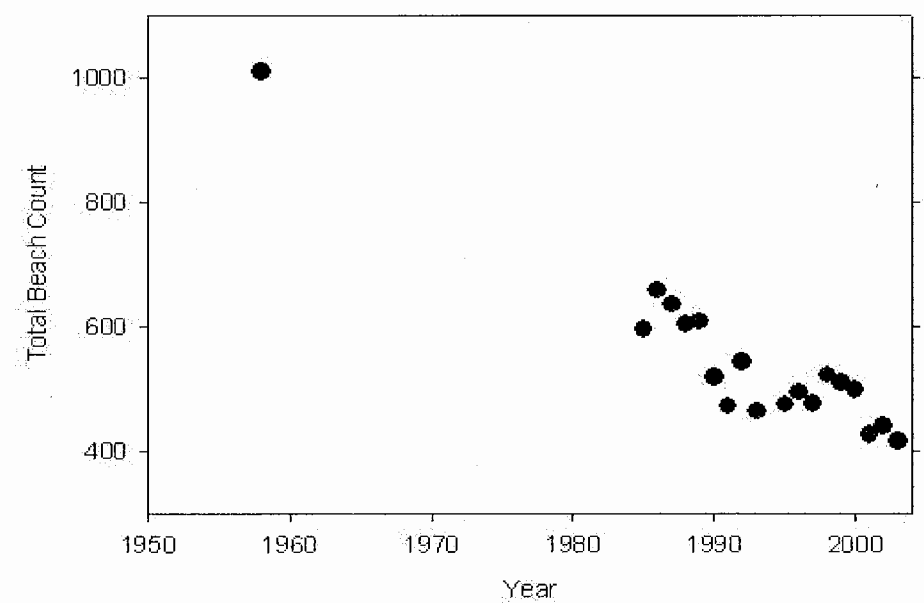
Overall, the science of the Hawaiian monk seal diet and foraging preferences indicate the monk seals eat a variety of prey species and forage at varying depths. There is not one single prey item that has been determined to be essential in the success of monk seals. Hawaiian monk seals are a high level predatory mostly foraging within coral reef ecosystems that support a variety of prey species.

7.3A.3.2 Population Status and Trends

Little is known about Hawaiian monk seals or their population status before the 1950s. As a result of natural constraints, the species was probably never very abundant, presumably numbering, at most, in the thousands (as opposed to hundreds of thousands) (Ragen and Lavine 1999). The arrival of humans in the Hawaiian Islands may have reduced the range of the Hawaiian monk seal largely to the NWHI and contributed to its current endangered status. In historic times, human-related mortality appears to have caused two major declines of the Hawaiian monk seal (NMFS 1997; Marine Mammal Commission 2000). It generally is acknowledged that the species was heavily exploited in the 1800s during a short-lived sealing venture. Several island populations may have been completely eliminated during that period. The second major decline occurred after the late 1950s and appears to have been determined by the pattern of human disturbance from military activities at Kure Atoll, Midway Atoll and FFS. Such disturbance caused pregnant females to abandon prime pupping habitat and nursing females to abandon their pups. The result was a decrease in pup survival, which led to poor reproductive recruitment, low productivity and population decline (NMFS 1997; Marine Mammal Commission 2000).

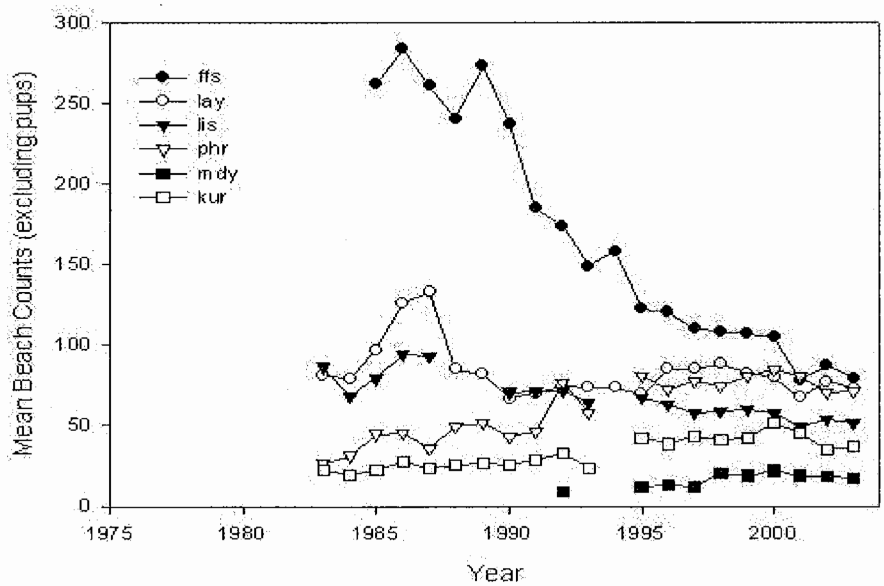
When monk seal population measurements were taken in the 1950s, the population was already considered to be in a state of decline. The minimum population estimate (N_{MIN}) for monk seals is 1378 individuals (based on a 2001 enumeration of individuals of all age classes at each of the subpopulations in the NWHI, derived estimates based on beach counts for Nihoa and Necker, and estimates for the MHI) (Draft 2003 Stock Assessment Report). The PIFSC estimates the population to be 1300 to 1400 individuals (PIFSC 2003). Figure 7-5 illustrates the long-term trend in total non-pup population size.

FIGURE 7-5: Historical Trend in Beach Counts (non-pups) of the Six Main Reproductive Subpopulations of Hawaiian Monk Seals (Source: PIFSC 2003)



Various surveys of the islands and atolls in the NWHI that support the main monk seal breeding subpopulations indicate that the NWHI non-pup population (juveniles, sub-adults and adults) declined 60% between the years 1958 and 1999. Trends in subpopulations are measured by beach counts for each of these subpopulations. Trends vary within the NWHI. For example, from 1990 to 1998, the subpopulation at Lisianski Island decreased slightly, and the Laysan Island subpopulation increased slightly. The subpopulation at Kure Atoll increased at about 5% per year from1983 to 1998. The subpopulation at Pearl and Hermes Reef experienced the highest increase of 7% per year between 1983 and 1998. Researchers have been able to establish the minimum count of individuals in the main breeding subpopulations, and in 2001 the count of monk seals was 182 at Lisianski Island, 300 at Laysan Island, 122 at Kure Atoll, 322 at FFS, 259 at Pearl and Hermes Reef and 64 at Midway Atoll (NMFS, unpub. data). Figure 7-6 illustrates trends in beach counts (a relative measure of population size) of Hawaiian monk seals for each of the principle Hawaiian monk seal breeding areas in the NWHI.

FIGURE 7-6: Trends in Beach Counts (non-pups) of Hawaiian Monk Seals at the Major NWHI Breeding Areas (Source: PIFSC 2003)



The overall population decline is primarily attributable to low reproductive recruitment and high juvenile mortality at the largest of the subpopulations at FFS. At this site, the average beach count of animals older than pups is now less than half the count in 1989. In the late 1990's, poor survival of pups resulted in a relative paucity of young seals, so that further decline is expected for this subpopulation as adults die and there are few immature seals to replace them. The recent trend in mean beach counts for births can be found in Figure 7-7.

FIGURE 7-7: Mean beach counts of pups born at the major NWHI breeding areas (Source: PIFSC 2003)

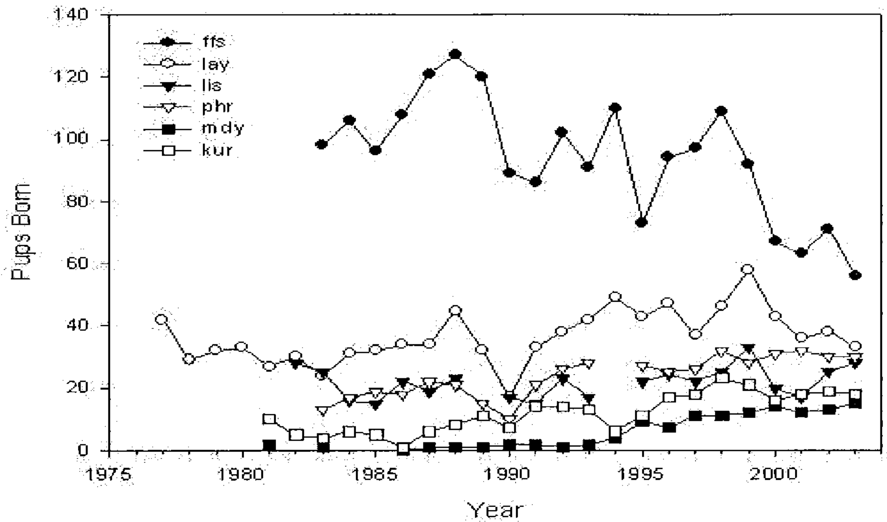
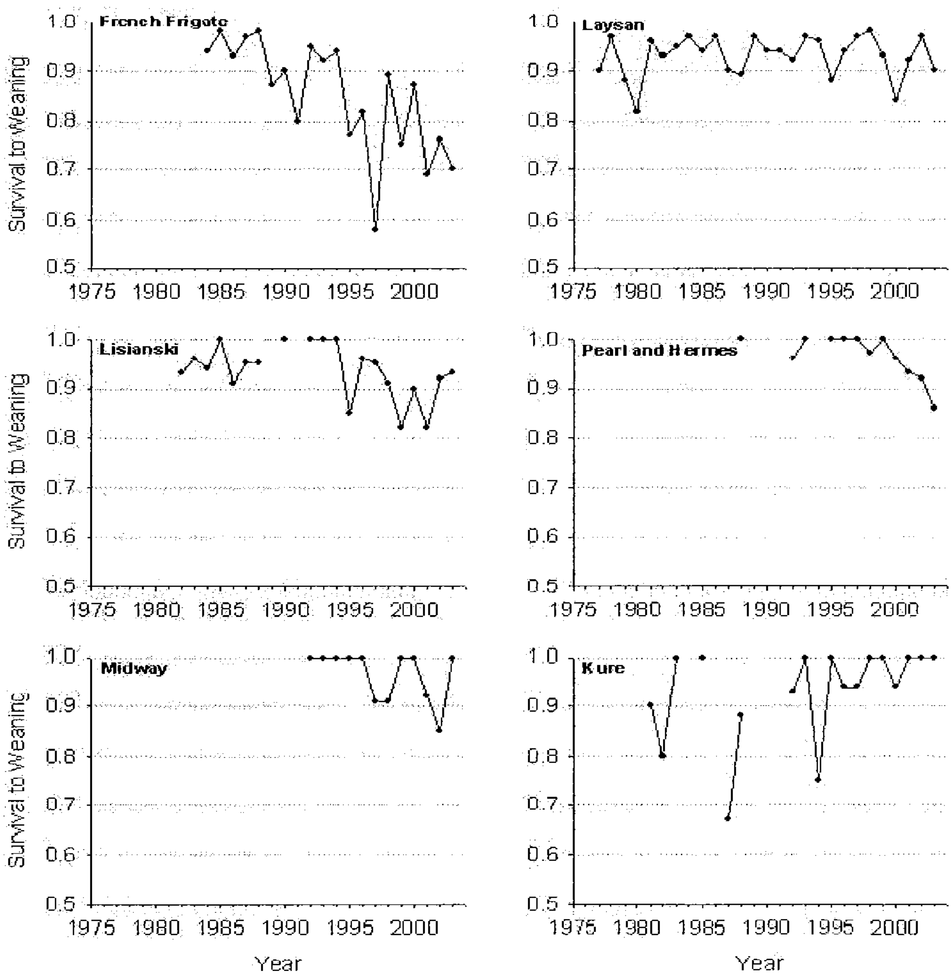


FIGURE 7-8: Survival of Hawaiian monk seals from birth to weaning the major NWHI breeding areas (Source: PIFSC 2003)



However, pup survival may be improving at FFS and at the other major subpopulations as Figure 7-8 and Figure 7-9 indicate. In addition, Figure 7-10 shows that the age structure of monk seals at the major subpopulations may also be improving, with relatively more younger seals in the populations than older ones.

FIGURE 7-9: Survival of Hawaiian monk seals from weaning to age 1 and 2 yr at the major NWHI breeding areas (Source: PIFSC 2003)

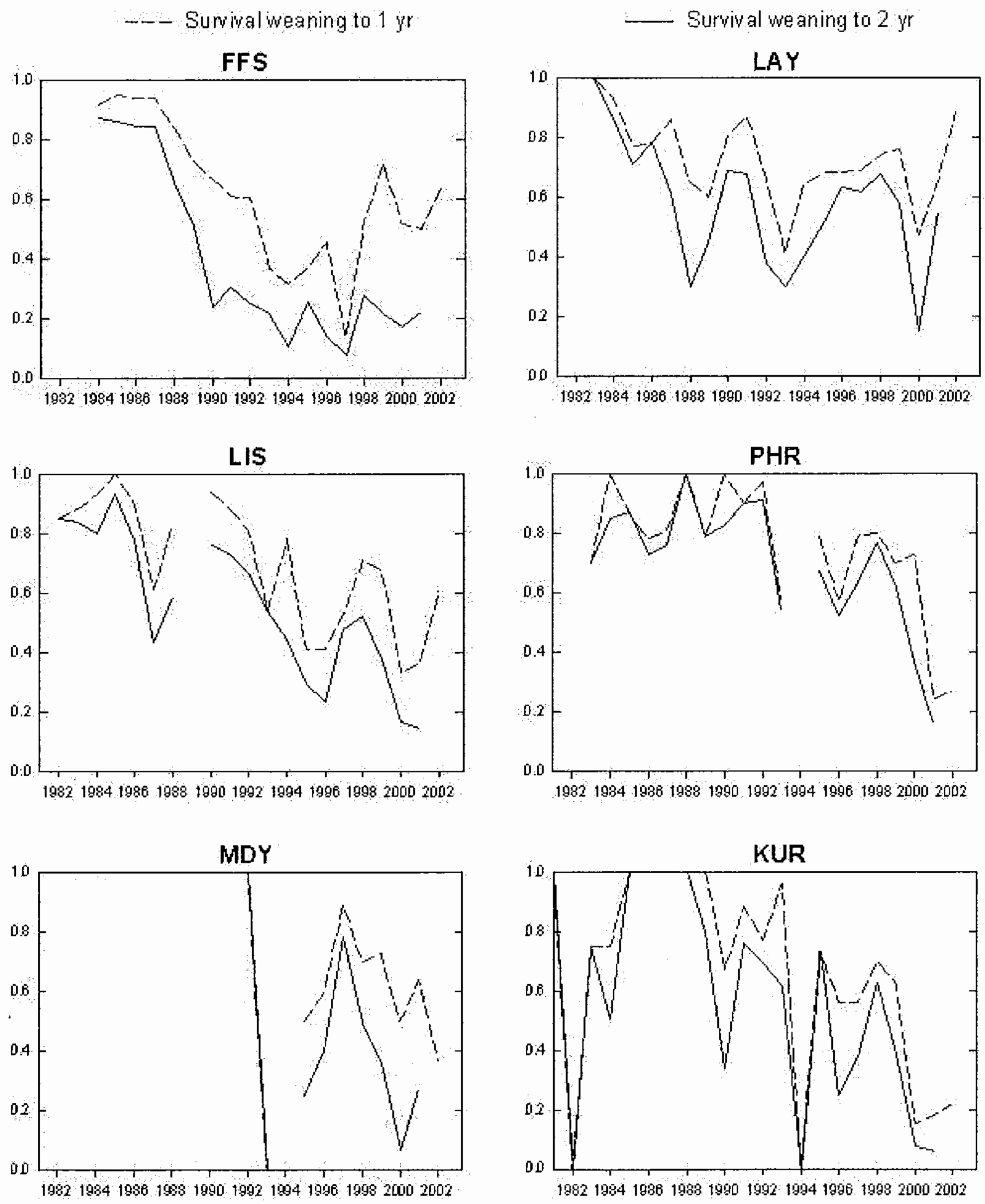
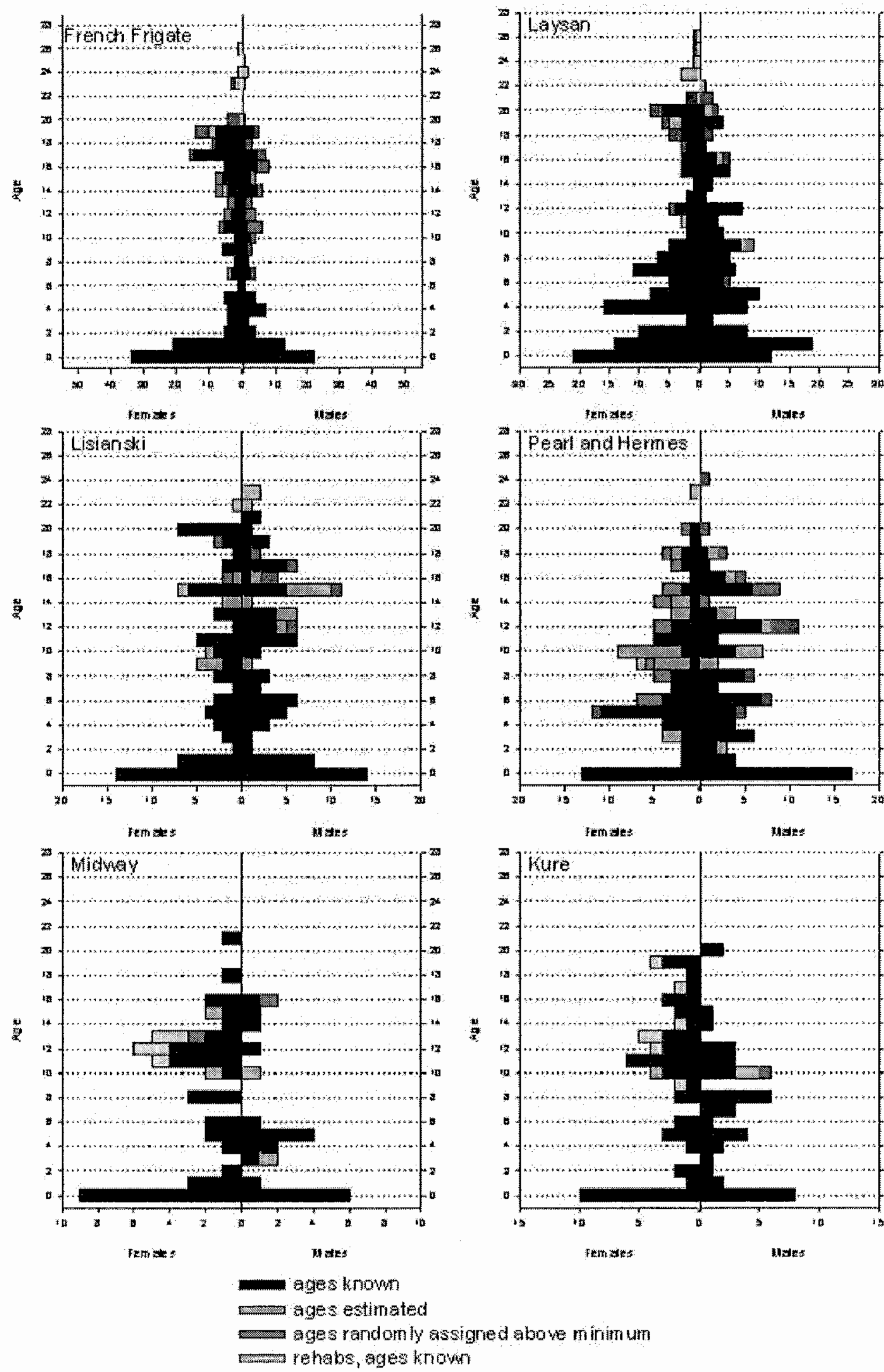
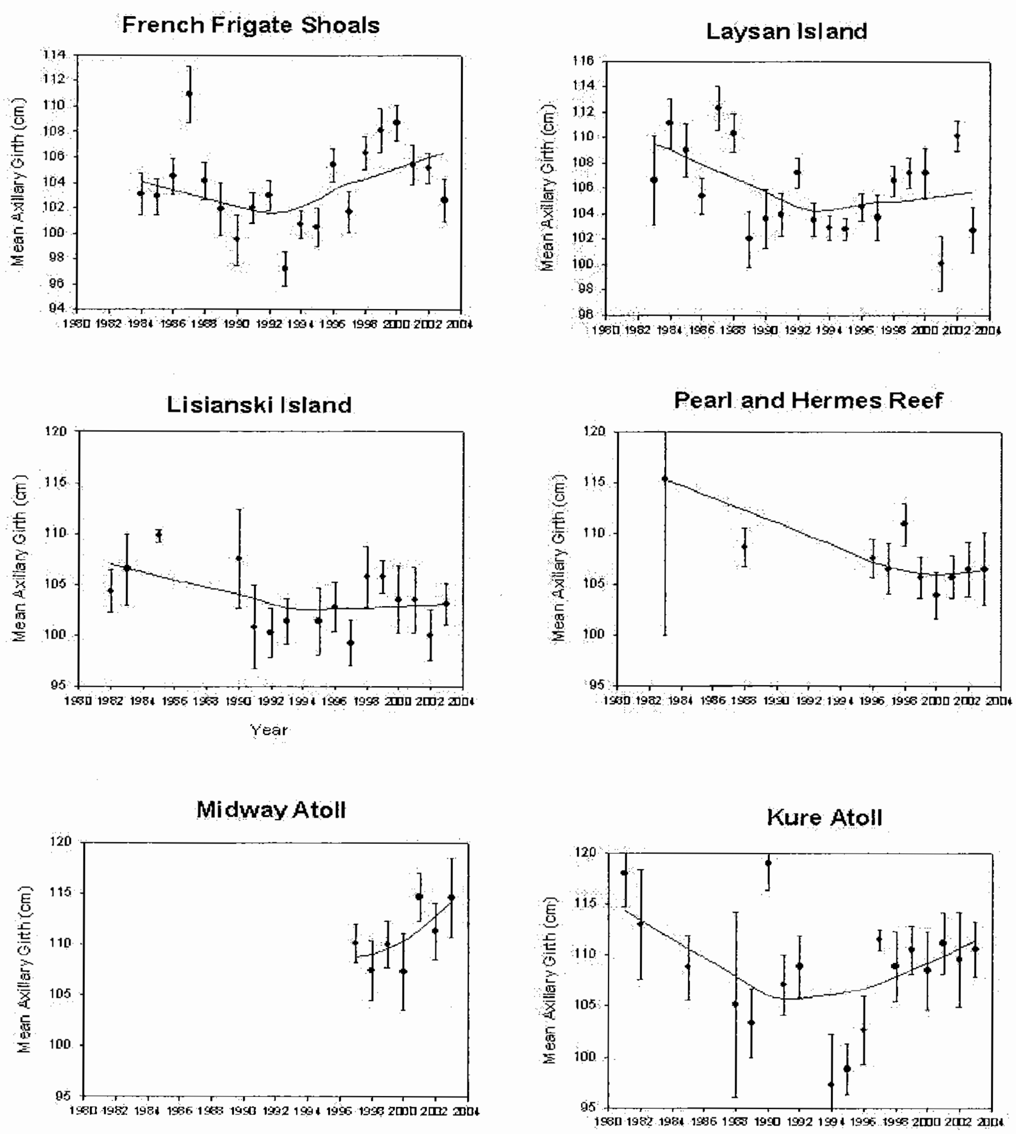


FIGURE 7-10: Age Structure of NWHI Hawaiian Monk Seal Populations in 2003
(Source: PIFSC 2003)



Over the last decade, the causes of the survival for these age classes at FFS have been related to poor condition from starvation, shark predation, and male aggression. A decrease in prey availability may be the result of decadal scale fluctuations in productivity and corresponding or other changes in local carrying capacity for seals at FFS or a combination of factors (Craig and Ragen 1999; Polovina et al. 1994; Polovina and Haight 1999). While other subpopulations of monk seals in the Northwestern Hawaiian Islands are stable, increasing or declining slightly, the overall population status is being driven by the FFS population, which comprises about 25% of the total monk seal population. However, the girth of weaned pups at FFS (Figure 7-11), which may correlate with prey availability to females during gestation and resulting increased ability to nourish pups, has increased in recent years. Mean girth of pups at the other major breeding subpopulations has remained stable or increased in recent years (PIFSC 2003).

FIGURE 7-11: Average Girth of Weaned Hawaiian monk seals at the major NWHI breeding areas (Source: PIFSC 2003)



In sum, beach counts of monk seals have declined by 60% since the late 1950s, and current abundance is estimated at 1300 to 1400 seals. On the basis of systematic beach counts and analyses reported in the draft 2003 SAR, two population trends are evident. From 1985 to 1993 the population declined 4.3% per year. From 1994 to 2001 the population trend was - 0.7% per year (95% confidence bounds: - 2.1% to +0.8% per year). The 0.7% decline is not statistically different from stability. The recent trend results in large part from low beach counts in 2001.

Population trends for this species are determined by the highly variable dynamics of the six main reproductive subpopulations. At the species level, demographic trends over the past decade have been driven primarily by the dynamics of the FFS subpopulation. In the near future, the general population trends for the species will depend on the gains and losses at FFS, the other major reproductive subpopulations, and small subpopulation in the MHI.

7.3A.3.3 Factors Influencing Population Size

This section is a summary of the effects of past and ongoing human and natural factors leading to the current status of the species, its habitat (including designated critical habitat) and ecosystem within the NWHI and the MHI, together with Johnston Atoll the only areas within the Western Pacific Region harboring Hawaiian monk seals..

During the past four decades the Hawaiian monk seal population has been affected by human and natural factors (Marine Mammal Commission 1999). Natural factors have included shark predation, disease, attacks by aggressive adult male Hawaiian monk seals on females and immature seals of both sexes (called "mobbing"), and reduced prey availability. Human factors have included various types of interactions with humans, their structures, contaminants and debris, fishing operations and vessel traffic. At each colony, differing combinations of these factors likely have contributed to local trends in abundance, with the relative importance of individual factors changing over time (Marine Mammal Commission 2000). The reported causes of relatively recent changes in Hawaiian monk seal abundance are described in greater detail below.

Mobbing: Male aggression, including singular or multiple adult males attacking another seal (mobbing), can lead to Hawaiian monk seal injury and death. The deaths can be a direct result of injuries inflicted by the aggressive males or as a result of later shark attacks on wounded seals or pups chased into the water by aggressive males. Mobbing of females and immature seals by adult males is a source of mortality at FFS, Laysan Island and Lisianski Island. Evidence suggests that during the mid- to late-1990s, male Hawaiian monk seal aggression and shark predation contributed significantly to the mortality of weaned and pre-weaned pups at FFS (HMSRT 1999). At FFS, individual adult males have presented more of a problem than groups of males. Individuals which were directly observed injuring or killing pups were removed, either by translocation or euthanasia. At Laysan Island, injuries and deaths have tended to result from massed attacks, or mobbings, by large numbers of adult males. The primary cause of mobbing is thought to be an imbalance in the adult sex ratio, with males outnumbering females (NMFS 1998). Males that were removed from Laysan Island included seals which had been observed participating in mobbings, as well as other animals whose behavioral profile matched that of known "mobbers." Removal was effected either by translocation or by transfer into permanent captivity. Ten males were removed in 1984, 5 in 1987, and 22 in 1994.

Removal of individual male seals from French Frigate Shoals markedly decreased the number of injuries and deaths attributable to adult male aggression (Table 7-13). The results of removing adult males from Laysan Island are less clear. Injuries and deaths from adult male aggression at Laysan Island have diminished, but it is not known how much male removal has contributed to this decline.

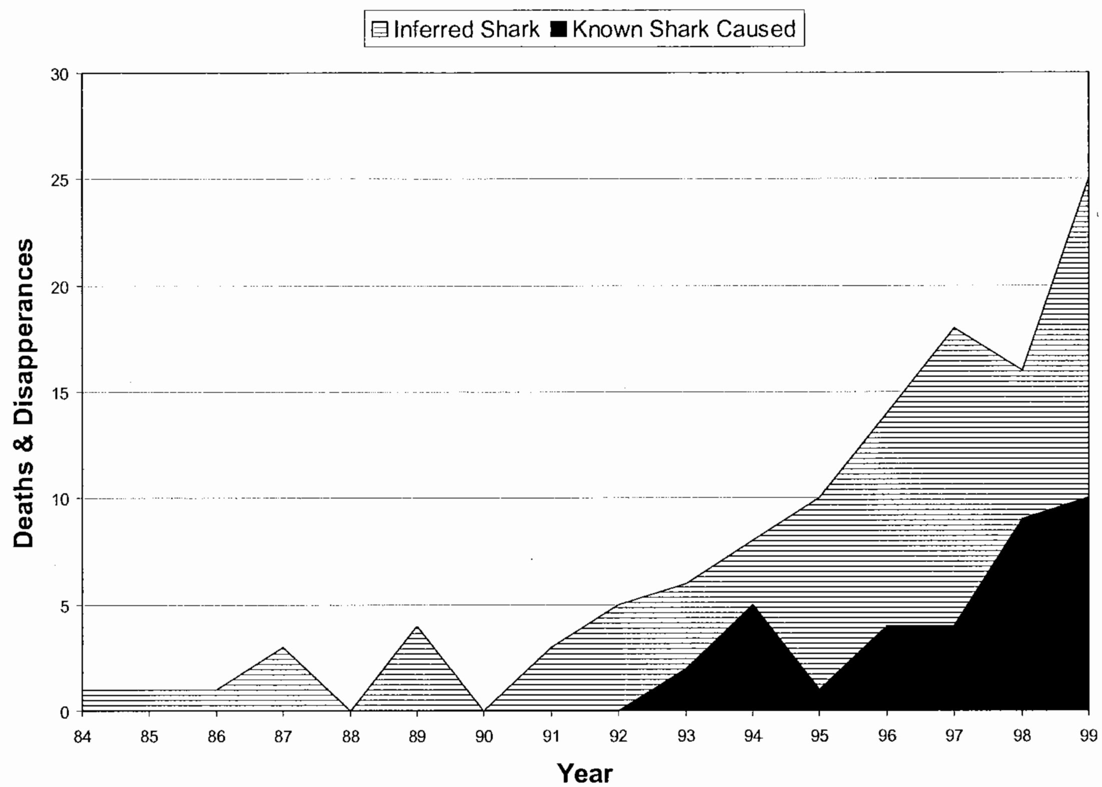
TABLE 7-13: Hawaiian Monk Seal Removals and Pre- and Post-Removal Mobbing Injuries and Mortalities

LOCATION AND YEAR OF REMOVAL	NO. OF INJURIES/ MORTALITIES CAUSED BY ADULT MALE ATTACKS IN YEAR BEFORE REMOVAL	NO. OF MALES REMOVED	NO. OF INJURIES/ MORTALITIES CAUSED BY ADULT MALE ATTACKS IN YEAR AFTER REMOVAL
1984 Laysan	1983: 12 injuries; 3 mortalities	10 removed (9 translocated to Johnston, 1 died)	11 injuries; 5 mortalities
1987 Laysan	1986: 12 injuries; 5 mortalities	5 removed (translocated to permanent captivity)	1988: 25 injuries; 11 mortalities
1991 FFS	9 injuries; 4 mortalities (all mortalities attributable to single male) (as tallied from 1991, prior to male removal)	1 (euthanized)	5 injuries; 1 mortality
1994 Laysan	1993: 1 injury; 0 mortalities , plus an undetermined number of injuries before removal in 1994 for a total pre-removal: 6 injuries; 3 mortalities.	22 (21 translocated to MHI, 1 died)	1995: 3 injuries; 1 mortality
1998 FFS	6 injuries; 11 mortalities	2 (translocated to Johnston Atoll)	2 injuries; 1 mortality

Source: 2002 Biological Opinion

Shark Predation: Predation by Galapagos sharks (*Carcharhinus galapagensis*) and perhaps tiger sharks (*Galeocerdo cuvieri*) of Hawaiian monk seal pups seems to be increasing in occurrence, as 17 (18%), 16 (15%) and 25 (27%) pup mortalities or disappearances were believed to be associated with shark attacks at FFS in 1997, 1998 and 1999, respectively (HMSRT 1999). In 1999, shark predation may have accounted for the deaths of 51% (23 of 45) of the pups born at Trig Island in FFS (2002 Biological Opinion). Overall, 9.4 percent (25 out of 244) of pups born in the NWHI were inferred or known to be preyed upon by sharks in 1999 (Figure 7-12). The PIFSC infers shark related mortality whenever a newborn to approximately three week old pup disappears at FFS, especially during periods when large sharks are observed patrolling near pupping beaches. Shark predation is inferred to be the primary cause of disappearance of these pups because attacks by male adults (the other possible primary cause of mortality) are unlikely because nursing pups are defended by their mothers. However, sharks have been observed killing pups in this age category despite their mother's defense tactics against shark predation. According to the HMSRT (1999), a preliminary analysis of the impacts of shark predation on the recovery of the FFS population of Hawaiian monk seals indicates that the mitigation of this interaction is essential to the recovery of this population. The HMSRT recommended that NMFS undertake a program to remove Galapagos and/or tiger sharks observed patrolling beaches where Hawaiian monk seal pups are present within the FFS atoll. One shark was removed pursuant to a shark removal plan implemented by NMFS in 2000 to improve pup survival and possibly slow the FFS population decline.

FIGURE 7-12: Trends in Number of Known and Inferred Shark-caused Deaths of Hawaiian Monk Seal Pups at FFS (Source: Laurs 2000)



The dramatic increase in deaths and disappearances from shark attacks at FFS has been the result of an increased number of Galapagos sharks (*Carcharhinus galapagensis*) in the immediate vicinity of Hawaiian monk seal pupping areas. The occurrence and escalation of Galapagos shark predation on pups may be related to an episode of adult male Hawaiian monk seal aggression against pups, which resulted in pup deaths and the presence of carcasses remaining in the waters surrounding the pupping area. These carcasses may have attracted sharks to the new prey resource of nursing seal pups. Also, the erosion of Whale-Skate Island (FFS), which had been a large pupping site, may have resulted in more pups being born at Trig Island (FFS) where sharks can easily approach the shoreline.

Disease: Although some information concerning medical conditions affecting the Hawaiian monk seal is available, the etiology and impact of disease on wild animals at the population level is far from clear. There are substantial data gaps regarding the prevalence of disease conditions in populations of Hawaiian monk seals in the wild, and thus their potential impact on population dynamics is unknown. In the wild, even massive epizootics in remote locations may pass undetected (Aguirre et al 1999).

There have been periods of unusually high mortalities in subpopulations located in the NWHI. A die-off occurred in 1978 at Laysan Island (Johnson and Johnson 1981). More than 50 seal carcasses were found in an advanced state of decomposition, and although the cause of the mortality was not identified, it may have been disease related. Also, survival of immature seals severely declined at FFS after 1987, and the reproductive potential of the species was being seriously compromised by the loss of young females. The cause has been attributed to emaciation/starvation; however, the role of endoparasites or disease is unknown. During 1992-93, undersized pup and juvenile seals from FFS were rehabilitated and released at Midway Atoll with poor success.

Health assessment and collection of baseline information on diseases is considered important to the recovery of the Hawaiian monk seal population (Gilmartin 1983; Aguirre et al. 1999). Banish and Gilmartin (1992) summarized pathological conditions found in 42 carcasses recovered from 1981 to 1985. Frequent findings included parasites, trauma, cardiovascular disease, and respiratory infections. Emaciation was a common condition. Banish and Gilmartin (1992) did not assess causes of death from any of their samples, but nonetheless concluded that there was no evidence of any disease phenomenon affecting the population in a manner which would significantly hinder recovery of the species. A series of examinations of 23 dead seals collected from 1989 to 1995 (Work unpubl. data) ascribed causes of death as follows: emaciation (7); emaciation compounded by senescence (1); trauma (2); foreign body aspiration (1); and euthanasia(1). Cause of death was not determined in 11 animals.

The relative significance of disease and related factors and their effect on population trends are poorly understood. Disease processes may be important determinants of population trends through long-term low levels of mortality, or through episodic die-offs. Table 7-14 describes the findings of health and disease studies on Hawaiian monk seals between 1925 and 1997.

TABLE 7-14: Health and Disease Studies in Hawaiian Monk Seals

YEAR	HEALTH CONDITION AND REFERENCE
1925	Internal parasites were first reported (Chapin 1925).
1952	Diphyllobothriid cestodes were first reported (Markowski 1952).
1959	The Acanthocephalan *Corynosoma* sp. was first reported (Golvan 1959).
1969	Diphyllobothriid cestodes were reported (Rausch 1969).
1978	Known as the Laysan epizootic, $\geq$50 Hawaiian monk seals were found dead. Specimens from 19 dead and 18 live seals were collected. All carcasses found with stomach ulceration and heavy parasite burdens and in severe state of emaciation. Livers from two carcasses tested positive to ciguatoxin and maitotoxin. There was serologic evidence of caliciviruses but serum specimens were negative for *Leptospira. Salmonella sieburg* was isolated from a rectal swab. Many parasite ova and products in coprologic exams were identified. Diagnosis was inconclusive (Johnson and Johnson 1981; Gilmartin et al. 1980).
1979	*Contracecum* ulceration of a young seal was first reported (Whittow et al. 1979).
1980	Lung mites from the family Halarechnidae were first reported (Furman and Dailey 1980).
1980	The Hawaiian monk seal die-off response plan was developed with the support of the Marine Mammal Commission (Gilmartin 1987).

YEAR	HEALTH CONDITION AND REFERENCE
1983	The Recovery Plan for the Hawaiian Monk Seal addressed the importance of disease investigations (Gilmartin 1983).
1988	A coprologic survey for parasites was performed from field scats collected in 1985 (Dailey et al. 1988).
1988	The hematology and serum biochemistry of 12 weaned pups collected between 1984 and 1987 for their rehabilitation in Oahu were reported (Banish and Gilmartin 1988).
1992	Pathology of 42 seals collected between 1981-85 was summarized (Banish and Gilmartin 1992).
1992	The FFS relocation of 19 immature seals was initiated. Basic hematology, serum biochemistry, serology for leptospirosis and calicivirus infection, virus isolation, fecal culture for *Salmonella* and coproparasitoscopic examination were performed for their disease evaluation. Two of seven seals died of bacterial and aspiration pneumonia on Oahu, with positive titers to *Leptospira*. Detection of calicivirus by cDNA hybridization probe in 13 seals with viral particles seen by electron microscopy occurred in five seals. It was concluded that endemic disease agents identified in those seals were *Salmonella* and endoparasites (Gilmartin 1993a; Poet et al. 1993).
1993	Inoculation of four Hawaiian monk seals with a killed virus distemper vaccine was experimentally performed on three seals at the Waikiki Aquarium (Gilmartin 1993b; Osterhaus unpubl. data 1997).
1995	An eye disease of unknown etiology was first diagnosed in 12 female Hawaiian monk seal pups that were transported to Oahu for rehabilitation. To date the cause remains unknown (NMFS files 1995-97 unpubl. data).
1996	Histopathology of selected tissues collected from 23 seals between 1989 and 1995 was performed by personnel of the National Wildlife Health Research Center, Honolulu Station (Work unpubl. data 1996).
1997	Two captive seals died of causes unrelated to the eye disease. One seal was diagnosed with *Clostridium* septicemia and another seal with hepatic sarcocystosis (Yantis et al. 1998).
1997	The Monk Seal Captive Care Review Panel developed recommendations to evaluate the health assessment and future disposition of 10 captive seals and the future of captive care and release efforts to enhance the recovery of the species (NMFS unpubl. data 1997).

Source: Aguirre et al. 1999

In April, 2001, an "Unusual Mortality Event[5]" was declared on the basis of four juvenile Hawaiian monk seal deaths within nine days at Laysan Island, a death of a yearling at Midway, discovery of three decomposed carcasses (one subadult, one pup, and two juveniles) and one fresh dead carcass at Lisianski Island, a death of a yearling at FFS, and lethargic, thin juvenile Hawaiian monk seals observed at Laysan and Midway Islands. The relationship of these deaths and observed conditions of the seals is not known at this time (NMFS unpub. data 2001). The Working Group on Unusual Mortality Events (WGUME) reviewed the available information and recommended on February 5, 2002, to close the event. Necropsies and sample analyses have revealed no unusual findings, and there have been no new reports of juveniles exhibiting abnormal behavior or thin body conditions. The WGUME also recommended that measures should be taken so that field teams are fully trained in proper sample collection techniques should any dead seals be found in 2002, to ensure

[5]The MMPA defines an Unusual Mortality Event (UME) to be an occurrence which: 1) is unexpected; 2) involves a significant die-off of a marine mammal population; and 3) demands an immediate response. In addition to the above conditions, an immediate response is warranted under two other circumstances: 1) mass stranding of an unusual species of cetacean; and 2) small numbers of a severely endangered species of marine mammal are affected.

that all possible information can be collected and preserved. The group also recommended performing as many necropsies as possible on fresh carcasses to collect essential data. A report summarizing the event and the results of the subsequent investigation are expected in the near future.

Reduced Prey Availability: One of the potential explanations of the poor juvenile survival at FFS from 1989 to the mid-1990s is limited prey availability and subsequent effects on both adults and juveniles. There are two factors related to food that influence weaned pup survival: 1) the amount of food (milk) pups acquire from their mothers prior to weaning and 2) the amount of food available to pups immediately after weaning (G. Antonelis pers. comm. 2000. NMFS-HL). The first factor is related to the mother's condition and ability to forage successfully prior to parturition and may be viewed as an indicator of prey availability during gestation. The second factor is related to the pup's ability to forage successfully after weaning. Evidence of limited prey availability at FFS included small and, in some cases, emaciated pups, juveniles that were smaller and thinner than those at other colonies and delayed sexual maturity of adult females (Craig and Ragen 1999; Marine Mammal Commission 2000).

Further evidence of limited prey availability at FFS has been provided by satellite-linked, time-depth recorders that have been used to track movements and record diving patterns of Hawaiian monk seals at various locations. All but one of the six juvenile and 18 adult Hawaiian monk seals tracked at Pearl and Hermes Reef foraged either within the fringing reef or just outside the reef (Stewart 1998). Most dives were to depths of 8 to 40 m, though there was a secondary mode at 100 to 120 m. In contrast, Hawaiian monk seals studied at FFS, where the population of seals is considerably larger, exhibited more variation in their habitat use (Abernathy and Siniff 1998; Parrish et al. 2000; Parrish et al. 2002). Abernathy and Siniff (1998) recorded that the most prevalent pattern, particularly among males, was utilization of the banks to the northwest (some of which are more than 200 km from FFS), with daytime diving in the 50 to 80 m range and a nocturnal or crepuscular shift to the 110-190 m range. The next most common group included seals that did not leave the vicinity of FFS and rarely dived deeper than 80 m. Finally, a small number of seals made many dives greater than 300 m. Abernathy and Siniff (1998) suggested that reduced prey availability could account for the greater variety of foraging patterns at FFS as some individuals are forced to venture to new areas and alter their prey base.

The decrease in prey at FFS may have been the result of large-scale natural perturbations in ecosystem productivity and corresponding or other changes in local carrying capacity for seals at FFS or a combination of factors. From the mid-1970s to late 1980s, the central North Pacific experienced increased vertical mixing, with a deepening of the wind-stirred surface layer into nutrient-rich lower waters and probable increased injection of nutrients into the upper ocean. Resulting increased primary productivity likely provided a larger food base for fish and animals at higher trophic levels. In the NWHI changes of 60 to 100% over baseline levels in productivity for lobsters, seabirds, reef fish and Hawaiian monk seals were observed and attributed to deeper mixing during 1977-1988 (Polovina et al. 1994). The variation in the geographical position of this vertical mixing is in turn related to the position of the Aleutian low-pressure system.[6] As this system deviates from its long-term average position, productivity may be more or less affected in the waters around the NWHI.

Polovina et al. (1994) suggested that the average position of the Aleutian low-pressure system moved northward in the mid- to late-1980s. Thus, the "declines" in productivity observed at Midway and FFS after 1988 may actually represent returns to more "normal," lower levels of productivity (Mundy undated). Productivity may have been most affected at FFS, the southernmost reproductive colony of Hawaiian monk seals (Craig and Ragan 1999). Furthermore, the adverse impact of a return to less productive oceanographic conditions on Hawaiian monk seal reproduction and survival could presumably have been greater at FFS because that island's Hawaiian monk seal population was closer to carrying capacity (Ragen and Lavigne 1999).

Goodman-Lowe (1998) examined inter-island variation in the diet of mature and juvenile Hawaiian monk seals and concluded that Hawaiian monk seals are opportunistic foragers. The fact that seals at FFS were apparently unable to find sufficient prey during the late 1980s and early 1990s suggests the occurrence of a phenomenon capable of affecting the seals' entire prey base. For example, changes in the sizes of NWHI populations of reef fish, a known prey of Hawaiian monk seals (Goodman-Lowe 1998), may be linked to the interdecadal changes in ecosystem productivity in the central Pacific (DeMartini and Parrish,1996). In 1992-1993, there was a general decrease in reef fish abundance observed at Midway Atoll and FFS. In 1995, however, a dramatic increase in recruitment and availability of reef fish was detected at the two sites (DeMartini and Parrish 1996). No further increase in apparent abundance of reef fish since that time has been found (DeMartini and Parrish 1998), but from the mid- to late-1990s there was an improvement in the condition of Hawaiian monk seal pups at weaning and in pup births at FFS and other major island populations. Trends in pup girth measurements indicate that prey resources may have increased during the early 1990s, most notably at Laysan Island, Lisianski Island and FFS (HMSRT 1999). Using recent data from Crittercam deployments, Littnan *et al.* (2005 pers. comm.) suggest that cryptic benthic fauna (bothids or flounders) inhabiting open sand fields are a target prey item for young monk seals, and that these prey items are likely important for early monk seal survivorship.

Fisheries may also affect the forage base of Hawaiian monk seals. Hawaiian monk seals have the capability to dive to depths at which many species targeted by the bottomfish fishery occur. In addition, Hawaiian monk seals have been reported to remove hooked bottomfish from handlines and consume them (Nitta 1999). Seals appear to prefer *ʻōpakapaka* but will also steal and eat *onaga*, *butaguchi* and *kāhala*. Monk seals also eat spiny and slipper lobsters, which are targeted in the (inactive) NWHI lobster fishery. However, the results of dietary studies suggest that bottomfish MUS and Crustacean MUS do not constitute a significant component of the natural diet of Hawaiian monk seals (Goodman-Lowe, 1998). In addition, the importance of French

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[6]There are also considerable biological data showing higher fish and zooplankton densities in the Gulf of Alaska during the 1970s and 1980s compared to earlier decades, as well as correlations between biological indices and an index of the strength of the Aleutian low-pressure system (Polovina et al. 1995).

Frigate Shoals to the NWHI lobster fishery is minimal, as only 1.2 percent of the total historical effort was conducted at French Frigate Shoals (Table 7-18).

Human Interactions: Human interactions with Hawaiian monk seals range from unintentional disturbances at haul-out sites to inflicting intentional injuries on seals, and include a variety of interactions by scientists and resource managers. Human disturbance was probably the principal cause of Hawaiian monk seal population declines before the 1980s. Between 1958 and the mid-1970s, Hawaiian monk seal colonies at the western end of the archipelago between Kure Atoll and Laysan Island declined by at least 60 percent, and the colony at Midway Atoll all but disappeared (Marine Mammal Commission 1999). Most human activity was concentrated at the westernmost atolls of the chain during this period, suggesting that human disturbance contributed to the decline. The Navy undertook a major expansion of its air facility on Midway Atoll during the 1950s, and in 1960 the Coast Guard established a LORAN station at Kure Atoll that was occupied year-round. Ownership of Midway Atoll was transferred from the Navy to the U.S. Fish and Wildlife Service in 1996, and the atoll is now managed as the Midway Atoll National Wildlife Refuge. The Coast Guard closed the LORAN station at Kure Atoll in 1992 and removed most of the manmade structures by 1993.

The human population at Midway Atoll has decreased substantially in the last two decades, but year-round human habitation of the atoll has continued. From 1996 until 2001, there was limited eco-tourism and public use within the Midway Atoll National Wildlife Refuge in the form of charter boat and shore fishing, diving and wildlife observation. A privately-owned business was awarded a concession to develop and manage the tourist facilities in the refuge. The number of visitors allowed on the atoll at any one time was limited to reduce impacts to wildlife. A dispute between the contractor and the USFWS has suspended the visitor program. Nevertheless, the HMSRT (1999) indicated that it supports the efforts of the USFWS to provide compatible visitor opportunities and educational programs at the refuge. It is also important to note that the Midway Atoll Hawaiian monk seal population has increased since the atoll was transferred to the USFWS.

As Hawaiian monk seal haul-outs increase in the MHI, human interactions are becoming more frequent (Ragen 1999). Hawaiian monk seals hauled-out on beaches are viewed by tourists and residents who are often unfamiliar with the take prohibitions and/or the normal behavior of Hawaiian monk seals. NMFS receives at least two reports per week of "stranded" Hawaiian monk seals. Some people attempt to haze the animal back into the water. Most often, the animal reported is exhibiting normal haul-out behavior. Another common harassment is people approaching too closely to take photographs of the seal on land or in the water. One female Hawaiian monk seal was intentionally harassed when a resident threw coconuts at it (Henderson pers. comm. 2001). On Kauai, a Hawaiian monk seal was bitten by a pet dog (Honda pers. comm. 2001). In 2004, a tourist was bit after he got too close to a pupping female monk seal. Disturbance to Hawaiian monk seals may result in modified behavior making them unpredictable, more susceptible to predators when forced to enter the water or causing an unnecessary expenditure of energy required for thermal homeostasis or catching prey.

Hawaiian monk seal research activities have also inadvertently resulted in some seal mortality. Since 1982, Hawaiian monk seals have been removed from the wild or translocated between locations by the Marine Mammal Research Program (MMRP) of the NMFS-HL as part of research and management to facilitate recovery of the species.

Pups which wean prematurely from their mothers may be in poor condition, and are known to have a minimal probability of surviving their first year. Some of these animals, as well as emaciated juvenile Hawaiian monk seals, have been collected for rehabilitation and release back into the wild. A total of 104 seals (mostly females) have been so taken: 68 were successfully rehabilitated and released into the wild, 22 died during rehabilitation, and 14 were judged to be unsuitable for release and were placed into public aquaria and oceanaria for research. Of the 68 Hawaiian monk seals which were rehabilitated and released from 1984 through 1993, 19 were alive as of 1999. Some of the surviving 19, most of which are located at Kure Atoll, are pupping. However, the precise number of pups born to these released Hawaiian monk seals is unknown (NMFS unpub. data, 2001; Johanos and Baker 2001).

Of the remaining 49 Hawaiian monk seals that were rehabilitated and released, the following information has been gathered: 5 were found dead within one year of release, 29 disappeared within one year of release, and 15 disappeared from 2-11 years after release.

Adult male Hawaiian monk seals have been documented to injure and kill other Hawaiian monk seals, including adult females, immature Hawaiian monk seals of either sex, and weaned pups. Some of the attacks have been made by groups of adult males, while others were by individual males. To reduce injuries and mortalities, NMFS has removed aggressive adult males from some sites. A total of 40 adult male seals have been taken. Thirty-two were translocated to locations distant from the site where the attacks had occurred (21 were moved to the MHI in 1994 and 11 were moved to Johnston Atoll, 9 in 1984 and 2 in 1998). Five were placed into permanent captivity. Two died while being held in temporary pens for translocation. One was euthanized. Although there is no systematic sighting effort for the 21 adult males translocated to the MHI, one sighting was made on Kauai in April, 2001.[7] None of the adult Hawaiian monk seals translocated to Johnston Atoll have been resighted since the year in which they were translocated.

Hawaiian monk seals have been moved between populations for reasons other than mitigation of adult male attacks. A total of ten seals have been so taken; five healthy female weaned pups were translocated from FFS to Kure Atoll in an effort to bolster the population and increase the reproductive potential at Kure, and four healthy seals born in the MHI were translocated, after having weaned, to areas less utilized by humans to minimize the potential of human harassment.

Of the five Hawaiian monk seals translocated from FFS to Kure Atoll in 1990, two were known to be alive at Kure as of 1999. Of the four Hawaiian monk seals relocated from sites in the MHI, one was observed alive at Kure Atoll in 1999, two were observed alive on Kauai in 2000, and one that

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[7] Salt Pond County Beach Park, Kauai. A Hawaiian monk seal with a red tag # 4A0 was reported acting aggressively toward another Hawaiian monk seal (Freeman pers. comm. 2001). That tag number was confirmed by NMFS to be the tag number of an adult Hawaiian monk seal relocated from Laysan in 1994 (Henderson pers. comm. 2001).

was translocated to Niihau was reported to have been killed sometime after 1994 by a boat propellor, although this report is unconfirmed (Henderson, pers. comm., 2001).

In addition to using unsuccessfully rehabilitated Hawaiian monk seals or aggressive males as captive research animals, some Hawaiian monk seals have been collected from the wild and placed directly into captivity. From 1983 to 1991 a total of four animals were taken; two Hawaiian monk seals were collected from the NWHI, and two Hawaiian monk seals found badly injured in the MHI were treated and placed into permanent captivity (NMFS unpub. data 2001).

In 1995, twelve Hawaiian monk seal pups were taken into captivity by NMFS for the purposes of rehabilitation and eventual return to the wild population. At the time of capture, some of the pups exhibited clinical signs associated with conjunctivitis, red eyes, blepharism, blepharospasm, and photosensitivity. Of the twelve Hawaiian monk seals pups, nine later developed corneal opacities and subsequent cataracts, and one developed cataracts (with no corneal opacities), and two of these total of ten Hawaiian monk seals later died (due to causes unrelated to blindness) (NMFS unpub. data). The remaining 10 Hawaiian monk seals (eight blind and two sighted) were transferred to Sea World of Texas where they are research animals.

The MMRP handles Hawaiian monk seals in the wild as part NMFS' research to monitor the population and facilitate recovery. Takes have included tagging, instrumentation, and sampling for health assessment. The MMRP has handled seals 3,343 times as part of its research activities since 1981. Three seals died during research handling. All three individuals were adult males. Results of necropsies on these seals varied, but in general all three were older seals whose health had been compromised by chronic illness.

Some researchers have expressed concern that continuous human habitation of research field camps in the NWHI could have an adverse effect on Hawaiian monk seals if not carefully controlled (Spalding 2000). Currently, all Hawaiian monk seal research is monitored and regulated under several federal permit systems. A recent assessment of the possible impact of field research activities on Hawaiian monk seals evaluated 4,800 seals handled between 1982 and 1999 and found no significant deleterious effects on the seals' health or behavior (Baker and Johanos 2000).

There is no recent evidence of intentional injuries from acts such as clubbing or shooting of Hawaiian monk seals in the NWHI. The MMRP annually monitors all major breeding populations of Hawaiian monk seals, and collects data on any injuries or other events which could affect the survival of individual seals. The program has not documented any injuries or mortalities in the NWHI that could be attributed to clubbing, shooting, or other intentional wounding of Hawaiian monk seals since the establishment of the Protected Species Zone in 1991 by Amendment 3 to the Pelagics FMP (Johanos and Ragen, 1996a, 1996b, 1997, 1999a, 1999b; Johanos and Baker 2000).

Although a Court Order[8] found that intentional acts to Hawaiian monk seals have occurred in the NWHI, ongoing NMFS' monitoring of Hawaiian monk seal populations indicates that intentional acts in the NWHI have not occurred since the late 1980's.

Tern Island Sea Wall Entrapment: Hawaiian monk seals at Tern Island, FFS, have been entrapped behind a deteriorating sea wall. During World War II, the Navy enlarged Tern Island, one of several small islets at FFS, from its original 4.5 hectares (11 acres) to about 16.2 hectares (40 acres) to accommodate a landing strip (Marine Mammal Commission 1999). To do so, the Navy constructed a sheet metal bulkhead around most of the island and backfilled behind the structure with dredged spoil and coral rubble from the surrounding lagoon. The Coast Guard took over the island from 1952 to 1979 to operate a LORAN station. Since then, it has been used by the U.S. Fish and Wildlife Service as a field station for the Hawaiian Islands National Wildlife Refuge.

The continued existence of the runway and field station at Tern Island – in fact, the integrity of the entire island – is in doubt because the sheet metal bulkhead, now more than 50 years old, is badly deteriorated (Marine Mammal Commission 1999). If the bulkhead fails, the airstrip would be lost, the field station would have to be abandoned, most of the island would erode away, buried debris would be exposed and create entanglement hazards to wildlife, and erosion pockets behind the rusted-out seawall would become serious entrapment hazards for Hawaiian monk seals and other wildlife.

Since recordkeeping began in 1988, a number of Hawaiian monk seals have been entrapped behind the seawall (Table 7-15). Most of these Hawaiian monk seals have been redirected to the water by FWS and NMFS personnel. Two subadult male Hawaiian monk seals have died as a result of becoming entrapped behind the sea wall.

TABLE 7-15: Incidence of Hawaiian Monk Seal Entrapments and Deaths on Tern Island from 1988-2000

#	YEAR												
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
E	1	3	1	6	4	2	3	3	0	0	5	4	4
M	1	0	0	1	0	0	0	0	0	0	0	0	0

Notes: E - entrapped; M - mortalities; Source: USFWS 2001

In 1999, the U.S. Fish and Wildlife Service received $1 million as an initial investment for sea wall construction at Tern Island. The total cost of the project is estimated to be about $15 million

[8]The Order Granting in Part and Denying In Part Plaintiffs' Motion for Summary Judgement, Granting in Part and Denying in Part Defendants' Cross-Motion for Summary Judgement, and Granting in Part Plaintiffs' Motion for a Permanent Injunction Motion for Summary Judgement in Greenpeace Foundation, *et. al.*, v. Norman Mineta, *et. al.* Civil No. 00-00068SPKFIY. U.S. District Court of Hawaii, November 15, 2000, p. 30.

(Marine Mammal Commission 1999). At the 123rd Council meeting (June 21-24, 2004), the USFWS reported that the project began in March 2004 and is 35% complete, and is focused on the most damaged and vulnerable sections. NMFS has conducted an ESA Section 7 consultation on the project and, together with the FWS, has devised monitoring and other measures designed to avoid any take by harassment or otherwise of Hawaiian monk seals and other protected species during the construction activities. The completed restoration of the sea wall is expected to eliminate any future entrapment hazards to Hawaiian monk seals and turtles (USFWS 2001).

Contaminants: Contaminants in the marine and terrestrial environment also pose a potential but unknown risk to monk seal recovery and survival. Effects on monk seals are unknown at this time. The analysis of tissue samples from monk seals at FFS indicate that PCB levels and specific forms (congeners) known to be toxic were found to be lower than PCB levels in other pinnipeds, and the values at FFS are below similar samples obtained from monk seals at Midway Islands (MNFS unpub. Preliminary data, 1999). The significance of these levels to monk seals health is unknown at this time. However, the ecological effects of contaminant clean-up operations at Tern Island (FFS), Johnston Atoll, and Midway Island may have short-term adverse effects on the surrounding corals, fish and invertebrates if an exposure event were to occur. Reductions in prey abundance due to clean-up efforts could reduce foraging success and survival rates of monk seals near these areas.

Fisheries: Several fisheries operate or have operated in the areas utilized by the Hawaiian monk seal. Some of the fisheries are federally managed. These are: the bottomfish fishery, the pelagic longline fishery (transit only), the crustacean fishery (currently suspended), and the deep water precious corals fishery (no participants currently). Other fisheries that operate in areas utilized by the Hawaiian monk seal include fisheries managed by the State of Hawai'i. These fisheries include the state-managed MHI bottomfish fishery, commercial and recreational nearshore fisheries (including gillnet fisheries), recreational *ulua* fishery, coastal *opelu* and *akule* fisheries, and collection for the aquarium trade.

The Hawai'i-based pelagic longline fishery targets pelagic species of tunas and swordfish. Under the Fishery Management Plan for the Pelagic Fisheries in the Western Pacific Region (Pelagics FMP), NMFS permits up to 164 vessels, but only about 100 vessels have been active during the past two years.

There was some evidence in the early 1990s that longline operations were adversely affecting the Hawaiian monk seals, as indicated by the sighting of a few animals with hooks and other non-natural injuries. Amendment 2 to the Pelagics FMP required longline permit holders to notify NMFS if intending to fish within 50 miles of any NWHI and required all vessel operators to attend a training session. These measures were later deemed insufficient. In 1991, Amendment 3 established a permanent 50-mile Protected Species Zone around the NWHI that closed the area to longline fishing. Establishment of this zone appears to have eliminated Hawaiian monk seal interactions with the longline fleet. Since 1993, no interactions with Hawaiian monk seals in the pelagic longline fishery have been reported. Longline observers recorded only one sighting of a

Hawaiian monk seal during transit through the Protected Species Zone near Nihoa Island in 1995 (NMFS unpubl. data).

The NWHI lobster fishery began in the 1970s and annual landings peaked at 1.92 million lobsters in 1985. Since then, landings have decreased. The number of vessels participating in the lobster fishery has ranged from 0 to 17, with only five and six vessels participating during 1998 and 1999, respectively (A. Katekaru pers. comm. 2001. NMFS-PIRO).

Historically, effort has been concentrated near the islands and atolls of the NWHI where Hawaiian monk seals occur, however FFS, the area with the most observed monk seals represented only 1.2 percent of the total effort of the lobster fishery (Table 7-27). Observer reports[9] show no Hawaiian monk seal entanglements or other interactions. However, in 1986 near Necker Island, one Hawaiian monk seal died as a result of entanglement with a bridle rope from a lobster trap. In 1983 a precautionary measure was taken to redesign the entrance cone to ensure that Hawaiian monk seals could not get caught in lobster trap entrances.[10]

Lobster is a known prey item of the Hawaiian monk seal, but the importance of lobster in their diet has not been quantified. Ongoing foraging and prey identification studies will help understand the effect, if any, of the lobster fishery on Hawaiian monk seal populations in the NWHI. It has been theorized that octopus are an important monk seals prey item and that the lobster fishery has depleted NWHI octopus populations. Recent studies by NOAA regarding this issue have found that only 83 individuals were captured during the entire 1986-2003 study period and examination of the data shows no significant decline or increase in octopus abundance over time. Based on the data, the study found that it is unlikely that lobster trapping activities have lowered octopus abundance to such a degree that monk seal populations would be negatively impacted (Dinardo 2005, Moffit 2005).

The lobster fishery was closed in 1993 based on the harvest quota set for the fishery under Amendment 7 of the Crustaceans FMP. The fishery re-opened in 1994 with five vessels participating in the fishery. In 1995 the fishery was again closed; however, one vessel was allowed to fish under an experimental fishing permit issued by NMFS to obtain scientific information on the lobster stock. From 1996 through 1999 the fishery had five, nine, five, and six vessels participating, respectively. Although the lobster fishery was not overfished, NMFS closed the fishery in 2000 through 2001 because of an increased level of uncertainty in the model assumptions used to estimate the lobster harvests (65 FR 39314). Harvest guidelines for the 2001 through 2005 fisheries were not issued by NMFS (66 FR 11156, Feb. 22, 2001; 67 FR 11678,

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[9]The lobster fishery was "observed" on a voluntary basis starting in 1997. NMFS scientific data collectors were dispatched on each of the lobster trips during 1997 through 1999. In 2000 and 2001 the lobster fishery was closed.

[10]Plastic dome-shaped single-chambered traps with two entrance funnels or cones located on opposite ends are employed in the lobster fishery. All traps are required to have escape vents (for smaller lobster). The traps are usually set in strings of about one hundred, with several strings fished at a time.

March 15, 2002; 68 FR 8490, Feb. 21, 2003; 69 FR 12303, March 16, 2004; 70 FR 8544, Feb 22, 2005).

Precious corals are harvested under the Fishery Management Plan for Precious Corals Fisheries of the Western Pacific Region (Precious Corals FMP). NMFS has determined that the harvest would not adversely affect the Hawaiian monk seal (NMFS 2000). Regulatory changes to the Precious Corals FMP recommended by the WPRFMC in 2000 are intended to, among other things, protect precious coral beds that provide foraging habitat for some Hawaiian monk seals in the NWHI (65 FR 53692).

The contribution of coral beds to prey aggregation and prey availability for Hawaiian monk seals remains unclear. As discussed previously, Hawaiian monk seal diet studies indicate that Hawaiian monk seals are opportunistic and feed on a wide variety of prey (Goodman-Lowe 1998). Research from Parrish et al. (2000) and Abernathy and Siniff (1998) indicate that some seals forage at depths where precious coral beds occur. However, the absence of deep diving activity at Pearl and Hermes Reef suggests that Hawaiian monk seals at French Frigate Shoals may vary their foraging behavior depending on the availability of prey resources.

Until recently, a U.S. Fish and Wildlife Service concessionaire operated an ecotourism station at Midway Island. Recreational fishing was allowed in the lagoon and waters around the island. No adverse interactions (e.g., entanglements or hookings) with Hawaiian monk seals in this recreational fishery have been reported. However, a study conducted in 1998 recorded Hawaiian monk seal interactions at six locations during fishing activities (Bonnet and Gilmartin 1998). Inquisitive, newly weaned pups sometimes approach fishing activities, presumably to investigate human activity (Shallenberger pers. comm. 2001. FWS). However, three Hawaiian monk seals were reported to have been hooked as a result of recreational fishing during the operation of the U.S. Coast Guard station at Kure Atoll, which closed in 1993 (Forney et al. 2000).

In the MHI, the state-regulated bottomfish fishery operates off-shore of shoreline areas where Hawaiian monk seals are sometimes observed. There have been no reported interactions between Hawaiian monk seals and this fishery. Some areas off-shore of regularly utilized Hawaiian monk seal haul-out areas have been closed to bottomfish fishing operations due to concerns about local depletion.

The fisheries for big game (*ulua*) and small game (*papio* and other smaller fish) are two of the largest components of the shore-based recreational fisheries in Hawaii. The term *ulua* mainly refers to two species: the white *ulua* (*Caranx ignobilis*) and the black *ulua* (*C. lugubris*). *Ulua* can also be used to refer to any larger *Caranx* (ten or more lbs). The term *papio* can refer to *Caranx ignoblis* and *C. lugubris* under 10 lbs as well as to six to eight other smaller Carangids commonly found in near-shore waters. The two fisheries differ more in the gear used than the target species. Any of the species can be and are taken in both fisheries. The two predominant fishing methods employed are the "slide-bait" and "shore casting" fisheries.

Big game shorefishing, primarily targeting large *ulua* (jacks), usually utilizes slide-baiting techniques. Slide bait rigs have a large hook tied or crimped to a short length of wire or heavy monofilament leader which is in turn tied or crimped to a "slide bait" swivel. The slide-bait fishery almost exclusively employs circle hooks of sizes corresponding to Mustad #14/0 and larger. This leader and hook set up is independent of the wired weight set up. These two independent sets of gear combine to make a whole slide bait rig. The weight is cast out and anchored before the slide bait hook rig is attached to the mainline and allowed to "slide" down and out to its final fishing position. The preferred baits are moray eels, "white eel" or "tohei" (conger eel), and octopus. Live reef fish of all kinds are also among the preferred baits.

The mainline (line on the fishing reel) used in slide baiting varies according to the individual, but is generally heavy line in the 80-100 lb plus test weight. The fishing weights generally have 4-5 inch soft wires extending from the terminal end. These wires are bent into a grapnel shape to snag onto rocks and coral to provide a solid anchoring point from which to suspend the large baits off the bottom and prevent the rig from moving with the current or swell. The limited movement prevents tangling with other rigs. The wires used are malleable enough to be straightened with pressure from the rod. The line connecting the weight to the swivel is of a lesser strength than the mainline and designed to break should the weight become inextricably stuck on the bottom.

Small game fishing uses a rig in which a hook(s) and lead is attached to a swivel and is cast as a single unit. It uses smaller hooks and lighter leaders. The major differences between big game fishing and small game fishing are the kind of rig used, the size of the gear, and the general kinds of areas that are preferred by each. The slide-bait fishery is generally associated with close proximity of deep water (20-100 ft) because the technique depends on gravity or the live bait to take the bait down the mainline to the strike zone. Shorecasting for small game is done anywhere along the shoreline.

The third shore based fishery is locally referred to as "whipping." Whipping involves standing on the shore, usually a rocky area, and casting and quickly retrieving an artificial lure into breaking waves headed towards shore. The lure usually has treble or double hooks attached. Fishing line in the 20-50 lb test weight range is commonly used in this fishery. Often the leader, the first few feet of line directly attached to the lure, is a thicker line for protection from chafing on the fish's teeth or the reef and rocks. Whipping is also successfully done from boats.

Ulua are also fished from boats. A variety of gear may be employed; typical are the trolling set-up, with down riggers or trolling planes, and surface plugs or casting jigs. Artificial lures, e.g., plugs and lead-head jigs, are used just outside the breaking surf.

The gear used in these recreational fisheries varies, but the most popular gear composition is a circle hook with a slide bait swivel on a wire leader. There is some overlap with the type of hook used (circle hooks) in the bottomfish fishery although the size of the *ulua* circle hook tends to be larger than that used in the bottomfish fishery. Some of the hooks embedded in Hawaiian monk seals have been identified as gear used in the state *ulua* fishery based on gear, size of hook, and location of the Hawaiian monk seal when discovered, while other hooks have been identified as bottomfish fishery hooks. Table 7-16 compiles all available information of Hawaiian monk seal hookings and net entanglements from all fisheries. There is only one report of a hooking of a Hawaiian monk seal on bottomfish gear being actively fished.

TABLE 7-16: Opportunistically Observed Hawaiian Monk Seal Entanglements in Fishing Gear

DATE AND LOCATION	DESCRIPTION	OUTCOME
1976 MHI - Kaua'i	Seal drowned in nearshore gillnet	Mortality
1982 FFS	Adult female was observed with bottomfish hook in mouth.	Resighted without hook at FFS.
1985 NWHI - Kure Atoll	Female weaned pup hooked in lip.	Hook removed by NMFS personnel; small hook and rig characteristic of on-site recreational fishery.
1986 NWHI - Necker	Monk seal caught in bridle rope of lobster trap.	Carcass not retrieved
1990 MHI - Kaua'i	Juvenile observed with hook.	NMFS response included capture and hook removal. Hook identified as type used in the *ulua* shore-based fishery.
1991 NWHI - FFS	Adult male observed with hook, trailing monofilament line, in chest.	Hook removed,. Reported to be a longline hook.
1991 NWHI - FFS	Adult male observed with hook, trailing monofilament line, in lower jaw.	Hook removed. Reported to be a longline hook.
1991 NWHI - Kure Atoll	Weaned female pup observed with hook in lip.	NMFS personnel captured seal and removed hook. Hook was small, characteristic of on-site recreational fishery.
1991 NWHI - Kure Atoll	Subadult female observed with hook in corner of mouth.	Seal subsequently seen without hook; hook never recovered or identified.
1993 MHI - Kaua'I (Kipu Kai Ranch)	Adult male observed with ulua hook, trailing monofiliament line and swivel, in mouth	Seal later seen to have lost hook without intervention.
1994 NWHI- FFS	Pregnant female with hook.	Hook stated by observers to be a swordfish fishery hook. No confirmation of report.

DATE AND LOCATION	DESCRIPTION	OUTCOME
1994 NWHI	Seal reported taken and released injured.	Reported in longline logbook.
1994 MHI, Kaua'i	Seal observed with hook, trailing monofilament line, in mouth.	Outcome unknown.
1994 MHI - O'ahu	Dead seal found entangled by gillnet off Waianae.	Necropsy conducted, condition of lungs consistent with drowning.
1994 NWHI-"No Name Bank"	Active hooking of adult seal during bottomfishing; seal had stolen catch and had become hooked.	Fisherman pulled seal to boat and cut leader 12"-18" from the seal.
1995 MHI - Kaua'I (Hanama'ulu Bay)	Juvenile male found dead, necropsy revealed fishhook in lower esophagus.	Mortality; hook was a "slide rig" characteristic of shore-based *ulua* fishery.
1996 MHI - O'ahu (Ala Moana Beach) (first sighted on Maui)	Adult male observed with hook in base of tongue. The seal was identified as a seal that had been translocated from Laysan Island, NWHI.	Hook removed by NMFS. Hook identified as from slide rig, shore based *ulua* fishery.
1996 NWHI - FFS	Adult male observed with hook in mouth.	Independent researchers identified hood as ulua or bottomfish hook. No identifying gear attached to hook.
1996 MHI - Maui	Adult hooked during fishing tournament.	Cut loose, probably with hook in mouth or jaw.
1996 MHI Oahu	Weaned male pup born on Kaneohe Marine Corps Base observed with 1" long hook in foreflipper.	Hook removed by bystander; hook not retained.
1998 MHI - Maui (Hana)	Hooked seal reported to NMFS; Juvenile female. Observers stated it was a #7 or #9 *ulua* hook.	NMFS response included capture and physical exam, No hook was found, but some minor trauma was observed in mouth where hook had been present.

DATE AND LOCATION	DESCRIPTION	OUTCOME
2000 MHI - Molokaʻi	Juvenile male observed with 2 hooks and line embedded in chest (ventral) area.	NMFS response included capture and physical exam of seal. No hooks or line present, but slight injury was documented by veterinarian.
2000 MHI - Kauaʻi (Haʻena Beach)	Adult female observed with hook in mouth.	NMFS response included capture and hook removal. Hook identified as type used in the *ulua* shore-based fishery.
2001 MHI - Kauaʻi (Mahaʻulepu Beach)	Juvenile female with hook in lower lip and base of jaw.	Hook removed by DLNR personnel. Hook and leader determined to be from shore casting ulua fishery.
2001 MHI - Kahoʻolawe	Adult male with hook, trailing line, in abdomen or front flipper.	Sightings ceased. Seal disappeared or hook lost.
2001 MHI - Hawaiʻi (South Point)	Weaned pup from Kau area reported hook on back.	NMFS dispatched personnel but could not locate seal. Seal later located when hooked in lip and showed no signs of hook injury to back.
2001 MHI - Hawaiʻi (South Point)	Weaned pup from Kau hooked in lip.	NMFS removed hook; Hook identified as type used in the *ulua* shore-based fishery.
2002 MHI - Oʻahu (Makua)	Seal tangled in nearshore gillnet.	Seal released by recreational divers.
2002 MHI - Kauaʻi	Seal hooked in neck, line trailing.	DLNR sighted seal.
2002 MHI - Oʻahu (Ewa)	Seal hooked in lower lip, steel leader trailing.	NMFS removed hook, *ulua* slide rig.
2003 MHI Kauaʻi (Kapaʻa)	Seal hooked in back corner of mouth training lightweight monofilament.	NMFS removed hook; gear characteristic of *sabiki* rig.

DATE AND LOCATION	DESCRIPTION	OUTCOME
2003 MHI - Kauaʻi (Poipu)	Seal hooked in mouth, trailing line.	NMFS contractor cut part of trailing line; seal observed 2 weeks later without hook.
2003 Molokai (Laʻau Pt.)	Seal hooked in mouth outside mandible.	Fisherman pulled in seal and cut line; NMFS removed hook 2 weeks later; *ulua* slide rig.
2003 MHI - Kauaʻi (Poipu)	NMFS contractor notified that shorecasting fisherman had hooked seal.	Fisherman cut line; no subsequent sightings of hooked seal.
2003 MHI - Kauaʻi (Ahukini Pier)	Multiple reports to NMFS of *kawakawa* fisherman hooking seal in mouth/lip.	Fisherman cut line; no subsequent sightings of hooked seal.
2004 MHI Kauaʻi (Kapaʻa)	Seal hooked in lower lip by hook still baited with squid. Hook training leader which subsequently became caught on nearshore gillnet (see below).	Fisherman cut line.
2004 MHI Kauaʻi (Kapaʻa)	Seal entangled in nearshore gillnet; point of entanglement was monofilament leader from incident above.	Fisherman cut net, releasing seal; later in day NMFS removed hook, leader, and net fragment.
2004 MHI Kauaʻi (Larsen's)	Seal ingested hook and slide rig.	NMFS captured seal and surgically removed hook/rig; seal recovered and was released.
2004 MHI - Kauaʻi (Poipu)	Seal hooked in mouth.	NMFS capture attempt failed; seal later observed to have lost hook.
2004 MHI - Oʻahu (Mokuleia)	Seal observed by camp counselor with hook in lip; reported to NMFS.	No subsequent sightings of hooked seal.

Source: NMFS unpub. data 2004 (J. Henderson, PIFSC, pers. comm.)

NMFS researchers and veterinarians have responded to some of the above reports and have treated the Hawaiian monk seals and provided descriptions of the wounds caused by the hook. Based on these descriptions and outcome (when known), the injuries sustained by Hawaiian monk seals from embedded hooks have been classified into injuries or serious injuries. An embedded hook was considered a serious injury if it hooked in the mouth deeper than the lip. Thus, hooks embedded inside the mouth, in the tongue, the mandible or upper jaw, throat, or deeper are classified as serious injuries, whereas "lip hookings" and other shallow embedded hooks are considered nonserious. The rationale for this division is that foraging would likely be impeded by the serious injuries. Hooks embedded in the lip or shallowly embedded hooks in other body areas would most likely fall out and would not impair feeding or other activities. Considering the information available, the above classification approach is consistent with the views expressed by researchers and veterinarians in a workshop held to discuss the serious injury guidelines.[11]

Marine Debris: Marine debris, particularly derelict fishing nets, poses a serious risk of injury and death to Hawaiian monk seals. The inquisitive nature of seals, particularly pups and juveniles, tends to make them attracted to debris. Subsequent interactions can lead to entanglement and, unless they are able to free themselves quickly, entangled seals risk drowning or death through injuries caused by the entangling gear. Between 1982 (the year NMFS first began to collect information on marine debris entanglement) and 2000 a total of 204 entanglements were documented. In 1999, a record 25 Hawaiian monk seals were reported to have been found entangled in marine debris (HMSRT 1999). Most of the net debris in the NWHI appears to be trawl webbing. Although its origin is unclear, no trawl or gillnet fishing occurs in the NWHI, and it is assumed that virtually all of this debris has been transported by ocean currents from distant fisheries around the rim of the North Pacific Ocean (Marine Mammal Commission 2000).

In 1998, NMFS organized a multi-agency cleanup effort to remove derelict fishing nets and other debris from the reefs surrounding FFS and Pearl and Hermes Reef. NMFS was able to remove only a small proportion of this debris and estimated that 38,000 pieces of netting remained in the waters surrounding each of these locations (Marine Mammal Commission 2000). In 1999 the NMFS-HL led a multi-agency effort to survey and remove derelict fishing gear from Lisianski Island and Pearl and Hermes Atoll (Donohue et al. 2001). Reef debris density ranged from 3.4 to 62.2 items/km^2. Fourteen tons of debris were removed from these two islands. The 2000 data include the first examination of marine debris at Kure Atoll, as well as estimations of accumulation rates at Lisianski Island and Pearl and Hermes Atoll. These three locations were resurveyed in 2001 allowing refinement of accumulation rate estimates. Additionally, in 2001 a fleet of three chartered vessels again worked to clean the reefs around Kure Atoll and Pearl and Hermes Atoll. About 62 tons of debris was removed from the two sites, with Kure essentially cleaned of derelict fishing gear during this effort (Laurs 2002). These efforts continued in 2002 and 2003, and are underway in the summer of 2004. To date, five sites have been surveyed: FFS,

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[11]"Injury of pinnipeds: A brief discussion of injuries reported for pinnipeds indicated that an animal hooked in the mouth (internally) or trailing gear should be considered seriously injured. Some participants felt that an animal hooked in its body would likely not be seriously injured." (Differentiating Serious and Non-Serious Injury of Marine Mammals Taken Incidental to Commercial Fishing Operations: Report of the Serious Injury Workshop held in Silver Spring, MD, April 1-2, 1997).

Lisianski Island, Pearl and Hermes, Kure and Midway Atolls. Approximately 330 tons of marine debris have been removed from NWHI reefs during these surveys. Net samples collected from the NWHI between 1998 and 2002 were about 86% trawl/seine nets. These types of fisheries do not exist in Hawaii, and it is presumed that this debris originates in various fisheries in the northern Pacific. Gillnet made up about 8% of the total. Longline gear comprised about 1.4%.

Information on marine debris entanglement and injuries, including mortalities, has been collected by NMFS since 1982 Seven categories of debris have been defined: nets (of fishery origin), lines or ropes (not necessarily of fishery origin), net/line combinations (of fishery origin), cones (from hagfish traps), rings (circular items of unknown origin), plastic packing straps (of fishery and non-fishery origin), and other /unknown. A total of 204 entanglements was documented, 96 by fishery items (5.05 per year), 96 by non-fishery items (5.05 per year), and 12 by unknown items (0.64 per year). From the total number of entanglements, 47 serious injuries were documented, including 27 by fishery items (1.42 per year), 8 by non-fishery items (0.42 per year), and 12 by unknown items (0.64 per year). Seven mortalities from entanglement were documented: 6 from fishery items (0.32 per year) and 1 from a non-fishery item (0.05 per year) (Table 7-17). Five of the six debris-related mortalities were caused by trawl netting and the other from unidentified line. Trawl fishing does not occur in areas under Council jurisdiction. Assigning the unknown items to either the fishery or non-fishery categories on a proportional basis results in a minimum estimated rate of 2.48 serious injuries and mortalities per year attributable to fishery-related marine debris.

TABLE 7-17: Known Marine Debris Related Monk Seal Mortalities: 1982-2000

YEAR AND LOCATION	DESCRIPTION
1986– FFS	Weaned male tangled in wire which was relic of USCG or Navy occupation; in water
1987–Lisianski Is.	Pup (uncertain if nursing or weaned) dead in aggregate of trawl net and line on shore
1987–FFS	Juvenile dead in aggregate of trawl net and line on shore
1988–Lisianski Is.	Weaned pup dead in large trawl net on shore
1995–Pearl and Hermes Reef	Bones of adult found scattered in line awash on shore
1997-FFS	Subadult dead in trawl net on reef
1998–Laysan Island	Weaned pup dead in trawl net on nearshore reef

Source: NMFS unpub. data 2001

Vessels: Hawaiian monk seals may be injured by collisions with vessels or indirectly by vessel groundings that result in the release of hazardous or toxic chemicals or gear that creates an entanglement hazard. Collisions are much more likely with small high-powered vessels. For example, a pup born at the Pacific Missile Range Facility on Kauai was reported dead in 1999.

There was an anonymous and unconfirmed report that the pup may have been hit by a zodiac-type vessel employed in the tourist industry.

In August 1998, Tesoro Hawaii Corporation tanker offloading operations resulted in a spill of about 5,000 gallons of bunker fuel off Barber's Point, leeward O'ahu. The waters and shoreline of Kaua'i were affected, and oiled Hawaiian monk seals were reported in the area. During September 1998, up to five oiled Hawaiian monk seals were observed. One Hawaiian monk seal had its entire oral mucosa coated with red, blood-like fluid. This Hawaiian monk seal was later resighted and exhibited signs of a respiratory infection. Another Hawaiian monk seal exhibited "gagging behavior." As there were no physical exams conducted on the animals observed, the wildlife resource agencies could not reach a conclusion about the effects of the oil on the Hawaiian monk seals (Natural Resources Trustees 2000).

In October 1998, the lobster fishing vessel *Paradise Queen II* rand aground near Kure Atoll. Nearly 4,000 gallons of diesel fuel was estimated to be released into the nearshore environment as well as hundreds of lobster traps. No monk seals were reported to be impacted from the vessel grounding.

In April 1999, a longline vessel (*F/V Van Loi*) grounded on a reef off of Kapa'a, Kaua'i. The vessel had 6,000 gallons of diesel fuel on board and was carrying three tons of bait and gear. All fuel, bait and gear (including monofilament line and hooks) went overboard into the marine environment. Monk seals and sea turtles were observed in the area, but no adverse interaction with fuel or gear was reported by wildlife resource managers on scene.

7.3A.4 Other Pinniped: The Northern Elephant Seal

Although uncommon in the action area of the bottomfish fishery, the northern elephant seal (*Mirounga angustirostris*) has been observed in the MHI and the NWHI. In 2002 a yearling appeared on the island of Hawai'i, was captured, and transported to the Marine Mammal Center in California for rehabilitation and reintroduction to the wild.

7.3B Sea Turtles

All sea turtles are designated as either threatened or endangered under the Endangered Species Act. The five species of sea turtles known to be present in the Hawaii EEZ are: the leatherback (*Dermochelys coriacea*), the olive ridley (*Lepidochelys olivacea*), the hawksbill *(Eretmochelys imbricata*), the loggerhead (*Caretta caretta*), and the green turtle (*Chelonia mydas*). However, only the hawksbill and green sea turtles are observed in Hawaii's nearshore areas.

Leatherbacks have the most extensive range of any living reptile and have been reported circumglobally from latitudes 71°N to 42°S in the Pacific and in all other major oceans. The diet of the leatherback turtle generally consists of cnidarians (i.e., medusae and siphonophores) in the pelagic environment. They lead a completely pelagic existence, foraging widely in temperate waters except during the nesting season, when gravid females return to beaches to lay eggs.

Typically, leatherbacks are found in convergence zones and upwelling areas in the open ocean, along continental margins, and in archipelagic waters.

The loggerhead turtle is a cosmopolitan species found in temperate and subtropical waters and inhabiting continental shelves, bays, estuaries and lagoons. Major nesting grounds are generally located in warm temperate and subtropical regions, generally north of 25°N or south of 25°S latitude in the Pacific Ocean. For their first several years of life, loggerheads forage in open ocean pelagic habitats. Both juvenile and subadult loggerheads feed on pelagic crustaceans, mollusks, fish and algae. As they age, loggerheads begin to move into shallower waters, where, as adults, they forage over a variety of benthic hard and soft bottom habitats.

The olive ridley is one of the smallest living sea turtles (carapace length usually between 60 and 70 cm) and is regarded as the most abundant sea turtle in the world. Since the directed take of sea turtles was stopped in the early 1990s, the nesting populations in Mexico seem to be recovering, with females nesting in record numbers in recent years. The olive ridley turtle is omnivorous and identified prey include a variety of benthic and pelagic items such as shrimp, jellyfish, crabs, snails and fish, as well as algae and sea grass.

The hawksbill turtle is rapidly approaching extinction in the Pacific, primarily due to the harvesting of the species for its meat, eggs and shell, as well as the destruction of nesting habitat. Hawksbills have a relatively unique diet of sponges.

Green turtles in Hawai'i are genetically distinct and geographically isolated which is uncharacteristic of other regional sea turtle populations (Balazs and Chaloupka 2004). Both nesting and foraging populations of green turtles in Hawai'i appear to have increased over the last 20 years. In Hawai'i, green turtles nested historically on beaches throughout the archipelago, but now nesting is restricted for the most part to beaches in the NWHI. More than 90% of the Hawaiian population of the green turtle nests at FFS. Satellite tagging of these animals indicates that most of them migrate to the MHI to feed and then return to breed. The four other species of sea turtles are seen in the waters of the NWHI only on rare occasions.

During the 1940s, green sea turtle nesting habitat in the NWHI experienced severe destruction (WWII and U.S. military operations), which is thought to have ceased in the 1950s. The direct harvest of green sea turtles became illegal in 1978 due the promulgation of the ESA. Because of the ESA and reduction in habitat degradation, the Hawaiian green sea turtle population has grown substantially. As reported by Balazs and Chaloupka (2004), the Hawaiian green sea turtle population has shown a 30 year recovery trend and may now be approaching carrying capacity.

7.3C Seabirds

The NWHI are home for around14 million seabirds and provide important nesting habitat for around 5.5 million breeding pairs (USFW 2004). The only ESA-listed seabird found in NWHI is the Short-tailed albatross (*Phoebastria albatrus*), with 1-3 individuals observed to visit Midway each year. Other seabirds found in the NWHI include, but are not limited to the black-footed albatross (*Phoebastria nigripes*), the Laysan albatross (*Phoebastria immutabilis*), the Masked booby (*Sula dactylatra*), brown booby (*Sula leucogaster*), red-footed booby (*Sula sula,*), wedge-tailed shearwater (*Puffinus pacificus*), and the Christmas shearwater (*Puffinus nativitatis*). More than 95 % of the world's Laysan and black-footed albatross nest in the NWHI. Population trends for most seabird species in the NWHI appear stable or increasing, but nonetheless there is continuing concern for albatross species. Threats to NWHI seabirds include introduced and invasive species, contaminants, marine debris, oil pollution, climate change, and fishery interactions.

7.3C.1 Short-tailed Albatross (*Phoebastria albatrus*)

General Description: The short-tailed albatross is the largest seabird in the North Pacific with a wingspan of more than three meters (nine feet). The short-tailed albatross bill is larger than the bills of Laysan and black-footed albatrosses and is characterized by a bright pink color with a light blue tip and defining black line extending around the base. The juvenile plumage is brown, and at this stage, except for the bird's pink bill and feet, the seabird can be easily mistaken for a black-footed albatross. As the juvenile short-tailed albatross matures, the face and underbody become white and the seabird begins to resemble a Laysan albatross. In flight, however, the adult short-tailed albatross is distinguished from the Laysan albatross by a white back and by white patches on the wings. As the short-tailed albatross continues to mature, the white plumage on the crown and nape changes to a golden-yellow.

Distribution: The short-tailed albatross is currently known to breed only in the western North Pacific Ocean, south of the main islands of Japan. Although at one time there may have been more than ten breeding locations (Hasegawa, 1979), today there are only two known active breeding colonies, Minami Tori Shima Island ("Torishima") (30º 29′ N., 140º 19′ E.) and Minami-Kojima Island (25º 56′ N., 123º 42′ E.). A few short-tailed albatross have been observed attempting to breed, although unsuccessfully, at Midway Atoll. Midway lies roughly 1,750 miles east and slightly to the north of Torishima.

Today, the breeding population of the short-tailed albatross is estimated at approximately 326 breeding pairs: 276 pairs on Torishima and 50 pairs on Minami-Kojima. The short-tailed albatross have an annual survival rate of 96% and a population growth rate of 7.8% (65 FR 46643, July 31, 2000; Hasegawa, 1997). Because of the robust growth of the population at Torishima, and the fact that short-tailed albatrosses do not return to the colony until three or four years of age, a large number of these birds are dispersed at sea. At least 25% of the reproducing adults also remain at sea during each breeding season (Cochrane and Starfield, 1999). As a consequence, the exact number of individuals in the population is difficult to assess and at this time is unknown. The population size has been estimated at about 1,900 individuals (P. Sievert, pers. comm.).

It is unknown if short-tailed albatrosses historically bred in the NWHI. Visits to the NWHI by short-tailed albatrosses were first recorded on Midway in 1938, when a female was seen incubating an infertile egg (Haden, 1941; Munro, 1944). Sighting and banding records show that between 1938 and 2003, at the most, 22 short-tailed albatrosses visited the NWHI, with only one or two sighted on the same island at any one time. The first time two short-tailed albatrosses were known to be present on Midway at the same time, although located at different locations, occurred in February 1981. No more than four short-tailed albatross have been observed at Midway in one breeding season. Since 1998, however, a female has returned each year has laid four infertile eggs (USFWS 2004).

7.3C.2 Black-footed Albatross (*Phoebastria nigripes*)

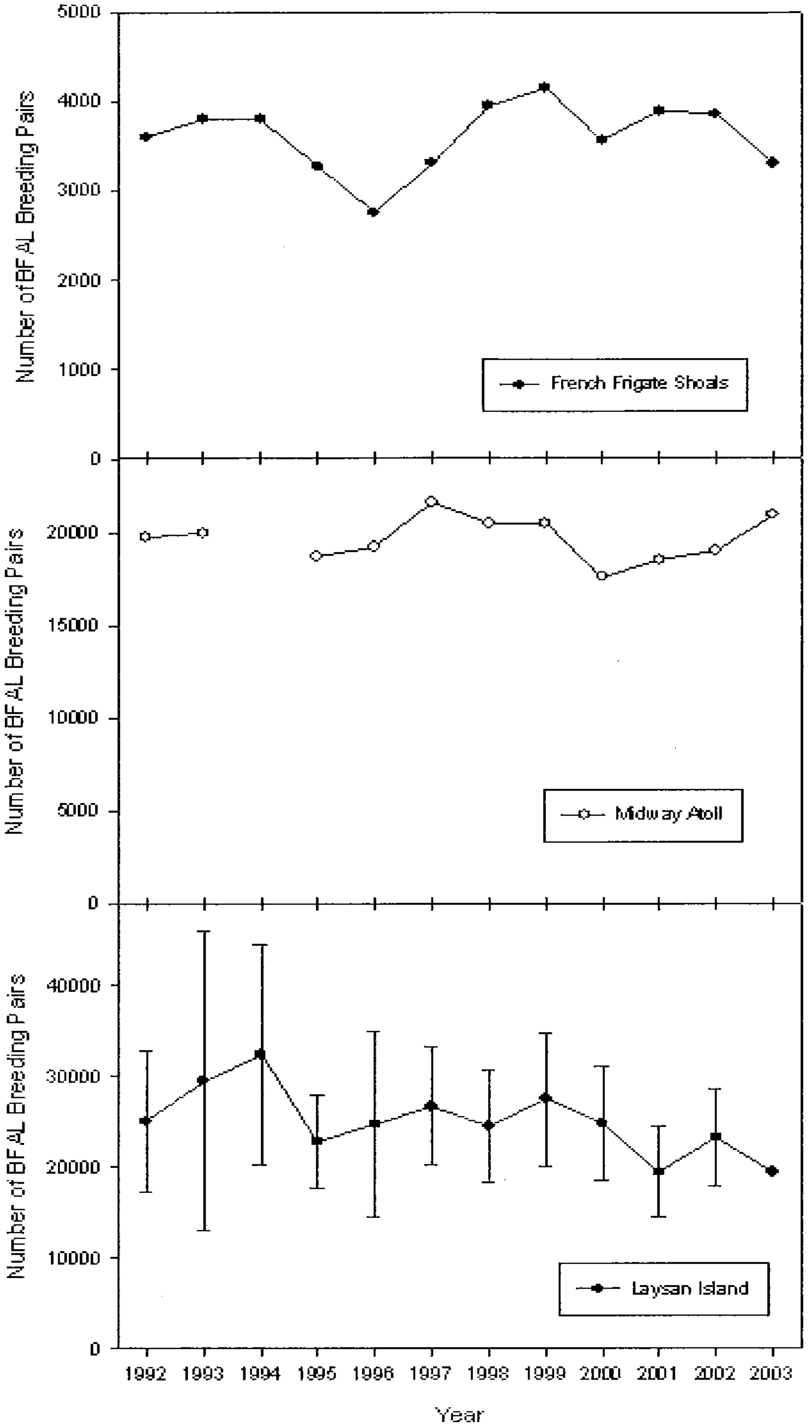
General Description: The black-footed albatross is characterized by dark plumage, bills, legs, and feet at all stages of their development. Comparatively, the black-footed albatross is slightly larger and heavier than the Laysan albatross, but for same-sex birds there is no significant difference between the two species (Harrison *et al.*, 1983; Whittow, pers. comm.). The plumage coloration for both the immature and adult black-footed albatross is extremely similar; brown with a white band at the base of their bill and a white sweep defining their eyes. One of the distinguishing features between adult and juvenile (i.e., young-of-the-year) black-footed albatross are that the juveniles lack the white plumage at the base of their tail. The plumage of the immature birds can be, but is not always, slightly darker in coloration than the adult birds. Generally, as the juvenile black-footed albatross mature, they tend to become more gray or dusty in appearance (Whittow, 1993a; Miller, 1940).

Distribution: The current world population of breeding black-footed albatross is estimated at approximately 327,753 individuals, with 58,898 breeding pairs in 12 colonies (Flint and Hasegawa, unpub. data). Nine colonies are located in the NWHI comprising the majority of the breeding population (55,775 breeding pairs). Seventy-nine percent of the NWHI breeding pairs nest in three colonies that are routinely surveyed by the FWS: Laysan Island, Midway Atoll, and French Frigate Shoals. The largest black-footed albatross colony, accounting for approximately 36 percent of the world population, is on Laysan Island. Midway Atoll has the second largest black-footed albatross colony with 32 percent of the world population. French Frigate Shoals only accounts for less than 7 percent of the world population. Three black-footed albatross colonies are also located in the western Pacific (estimated 2,244 breeding pairs) accounting for approximately 4 percent of the world population. On Torishima, six black-footed albatross chicks were successfully reared in 1957, and since then the number of chicks reared has increased to 914 in 1998 (H. Hasegawa, unpub. data). The black-footed albatross populations on Bonin and Senkaku Islands have also modestly increased.

Under the IUCN criteria for identification of threatened species, the conservation status of the black-footed albatross is currently listed as Vulnerable (BirdLife International, 2000; Croxall and Gales, 1998). The Vulnerable status was given because the taxon "is not critically endangered or endangered but is facing a very high risk of extinction in the wild in the near future" (Croxall and Gales, 1988). To obtain the Vulnerable conservation status, the black-footed albatross population must show declines of greater than 20 percent over three generations - 45 years in the case of the black-footed albatross. Since there are not good census data from 45 years ago, the IUCN evaluates the average annual rate of decline over the period of time that data do exist and extrapolates to 45 years.

The USFWS was recently petitioned to list the black footed albatross under the ESA (Earthjustice 2004). However, the USFWS rejected the petition in a letter to Earthjustice, dated December 3, 2004, stating that emergency listing was not warranted at this time. The petition painted a dismal picture of the prospects for black-footed albatrosses, arguing that the Pacific population is in decline and that this decline is exacerbated by human threats, particularly pelagic longline fishing. However, Harrison (1990) reports that in the early 1980s, black-footed albatross populations in the NWHI ranged from 36,240 to 49,410 nesting pairs, or taking the average, about 43,000 pairs. The most recent nesting population estimate for the NWHI is about 55,775 nesting pairs (NMFS 2004). The difference represents an increase of 12,775 nesting pairs or an increase of 30% over this time period. Midway's black-footed albatross population has increased to over 20,000 nesting pairs, from a population in the early 1980s of 6,500-7,500 nesters - an increase of 300% in less than two decades. Using an even more conservative estimate from the early 1960s of 7,000 pairs (Robbins 1961) indicates a tripling of the black-footed albatross population size over the past 40 years. The Midway nesting population of black-footed albatrosses in 2005 amounted to 21,829 nesting pairs, or a 7% increase on the 2004 total (USFWS 2005) Similarly, both the black-footed albatross nesting populations at French Frigate Shoals and Laysan Island in 2003 appeared to be at the high end of the population sizes observed in the early 1980s (Harrison 1990). In addition, the overall increase of black-footed albatross nesting pairs in the NWHI increased by 7.2% between 2001 and 2003 (USFWS 2004b). The most recent information indicates that NWHI nesting numbers have remained stable since 1991(USFWS 2005). Taken together, these observations strongly suggest either an increasing population, or at worst, a stable population.

FIGURE 7-13: Numbers of black-footed albatross breeding pairs at major NWHI nesting sites (Source: USFWS, 2003)



7.3C.3 Laysan Albatross (*Phoebastria immutabilis*)

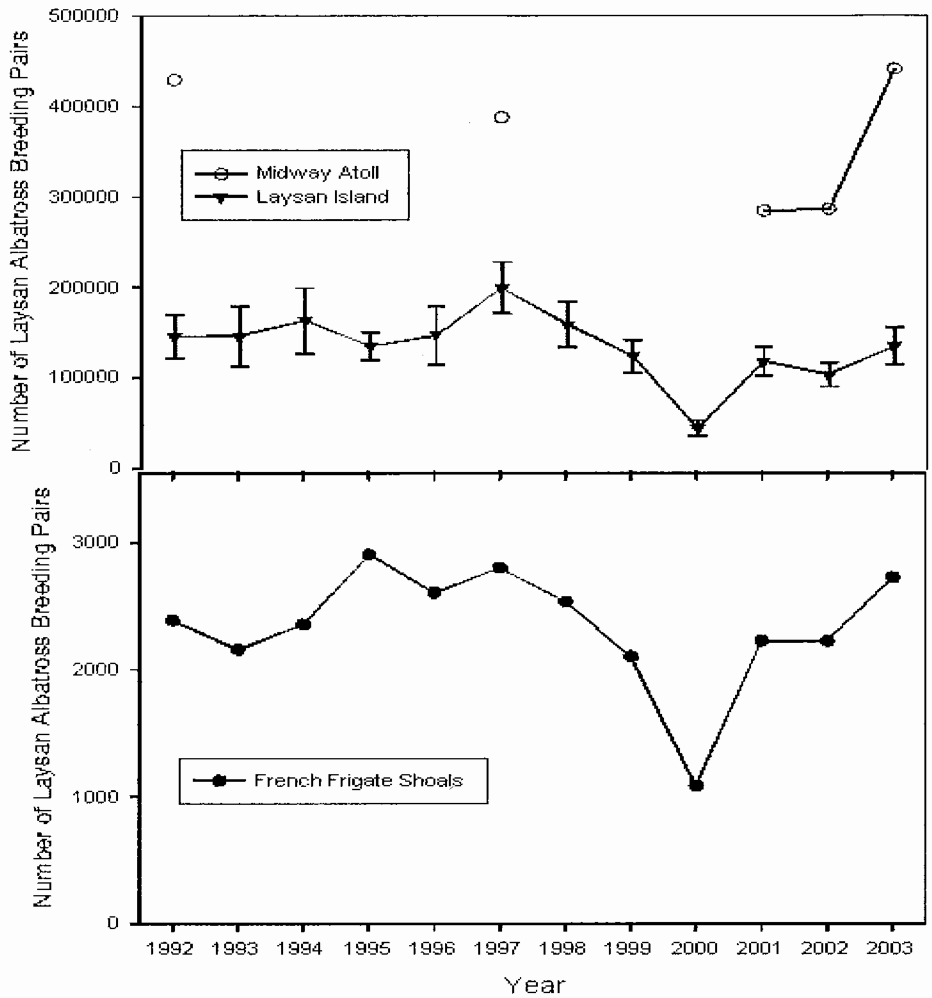
General Description: Laysan albatross are characterized by white plumage on their head, neck, and chest, and sooty brown plumage on their upper wings, back, and tail. The Laysan albatross underwings have variable patches of dark and white plumage and are distinguished by dark leading edges and wing tips. Laysan albatross have fleshy-pink colored legs and webbed feet, and in flight the feet project beyond the tail. The Laysan albatross eye is gray, and black plumage extends in a thin line behind the eye. There are no distinguishing characteristics between sexes or between adult and immature phases (Whittow, 1993b).

Distribution: It is estimated that before feather hunters reached Marcus Island, the island had a population of one million Laysan albatross (Rice and Kenyon, 1962). Feather hunters also raided Laysan albatross colonies in the NWHI taking at least 300,000 birds from Laysan Island in 1909 (Dill and Bryan, 1912). Today, it is estimated that the Laysan albatross population is 3.4 million individuals, with 623,622 breeding pairs in 15 colonies. Twelve of the colonies are located in the NWHI comprising of the majority of the breeding population (623,495 breeding pairs). The largest Laysan albatross colony (71% of the world population) is on Midway Atoll (Figure 7-14). A complete direct nest count on Midway Atoll in 2003 found that the number of nesting pairs of Laysan Albatrosses had increased by 53.9% since 2001 (USFWS 2004b). Laysan Island has the second largest colony representing nearly 22% of the world population (Figure 7-14).

The most recent census in 2004 showed that the number of nesting pairs was still elevated but had declined by 7.5% as compared to the previous year (USFWS 2005). Laysan Island has the second largest colony (22% of the world population). The most recent information indicates that NWHI nesting numbers for these populations remain stable (USFWS 2005). Taken together, therefore, these observations suggest either an increasing population or at worst a stable population.

A serious problem for the Laysan albatross population is lead poisoning of chicks from weathering lead-based paint on old buildings on Midway Atoll. Chicks raised in nests close (< 5 meters) to buildings ingest deteriorating paint directly from the buildings or paint chips that have fallen in and around their nests. Blood lead concentrations in chicks near buildings average 440 μg/dL, compared to an average blood lead of 6 μg/dL in chicks nesting more than 100m from buildings. For comparison, the Centers for Disease Control's blood level of concern for children is 10 μg/dL. The chicks near buildings frequently exhibit a condition of peripheral neuropathy called "droopwing." These chicks cannot raise their wings, leading to broken bones and open sores. They die either as a direct result of lead poisoning or from starvation when their parents stop feeding them. It is estimated that chicks suffering significant detrimental effects from lead exposure on Midway's Sand Island could number in the thousands per year (Finkelstein, 2004).

FIGURE 7- 14: Numbers of Laysan Albatross Breeding Pairs at Major NWHI Nesting Sites
(Source:USFWS, 2003)



7.3C.4 Boobies (Order Pelecaniformes, Family Sulidae)

Three species of boobies breed in the NWHI and forage in the North Pacific: the masked booby *(Sula dactylactra)*, the brown booby *(S. leucogaster)*, and the red-footed booby *(S. sula)*. Currently, the IUCN classifies boobies as "not globally threatened." Like the albatrosses, the boobies are also long-lived and have a delayed maturity. Unlike the albatrosses, which are primarily surface feeders, the boobies are plunge divers and also tend to take flying fish (*Cypselurus* spp.) just above or at the surface of the water. To date, there have been no reports of lethal interactions between boobies and the Hawai'i-based longline fishery, but boobies are reported to sit on vessel decks and watch the baited hooks as they are being set or hauled back.

NMFS observers report boobies hovering over baited hooks and some birds may actually attempt a dive, however, no boobies have been reported hooked. Although the foraging behavior of boobies may differ from that of the albatrosses, such that they do not interact with longline fishing vessels or gear in the same manner, boobies are present during fishing operations and the potential for fatal interactions does exist.

Masked, brown, and red-footed boobies range throughout the tropical and subtropical waters of the world's oceans. All three booby species breed throughout the NWHI and on rocky remnants offshore of the main Hawaiian Islands. Generally, the boobies that breed in the Hawaiian Archipelago are year-round residents (Harrison, 1990) and forage close to the breeding colonies. Relatively large red-footed booby colonies (>500 breeding pairs; Harrison, 1990) are located on O'ahu, Kaua'i, and Lehua Islands while only a few masked and brown boobies are known to breed on Lehua and Moku Manu Islands (Harrison, 1990).

Adult masked and red-footed boobies tend to remain close to their breeding colonies while the younger and immature birds roam up to 150 km offshore (Nelson, 1978). Masked boobies, in particular, tend to return to land to roost at night. Some red-footed boobies, as well as brown boobies, are known to range as far as Wake Atoll and the Marshall Islands, but the resident masked boobies tend to remain in the Hawaiian Archipelago (Harrison, 1990).

Although boobies breed throughout the Hawaiian Archipelago, apparently only three localities have been routinely monitored by FWS. Harrison (1990) reported breeding pair numbers from surveys of booby colonies completed between 1981 and 1988. From the surveys completed in the 1980s, it was estimated that there were about 14,000 masked boobies, 1,500 brown boobies, and 11,000 red-footed boobies (Harrison, 1990). The population sizes and composition of the three booby species are currently unknown, but are thought to be healthy.

7.3C.5 Masked Booby (*Sula dactylatra*)

General Description: Adult masked boobies, also called white boobies, blue-faced boobies, or whistling boobies, are mostly white with dark plumage on their tail and tips of their wings. This booby is distinguished by a dark 'mask' around the eyes and bill. The 'mask' is actually the featherless bluish skin of the bird. There is some variation in the color of the bill and feet, such that the bill varies in color from a deep orange to a pink and the feet are a dark grey to olive green (Nelson, 1978). During the breeding season, the male's bill becomes a brighter yellow than the female's bill (Nelson, 1978). Juvenile masked boobies differ from the adults in that they are predominantly brown with a white underbelly, throat, and neck (Anderson, 1993).

7.3C.6 Brown Booby (*Sula leucogaster*)

General Description: The adult brown booby is recognizable by chocolate brown to dark plumage on the head, neck, upper surface of the wings, and tail, with a sharp line across the upper breast defining the white plumage of the lower breast and abdomen. The undersurface of the wing has a distinctive white bar extending out from the white of the body toward the wing tip. In the Pacific, the head and neck plumage can vary with some birds being slightly darker and others, such as those in the eastern Pacific being pale grey to white (Nelson, 1978). The color of the bill, face, and feet also vary with region, sex, and breeding condition (Nelson, 1978). In general, the female bill is a light greenish-yellow with a white or greyish-green tip, whereas, the male bill is greenish-grey with a white tip. The feet vary in color from a pale green to a bluish-green. Juvenile brown boobies are similar to the adults except that the plumage is paler and the undersurface is a pale, dirty grey color.

7.3C.7 Red-footed Booby (*Sula sula*)

General Description: In flight, the adult red-footed booby, also known as the white-tailed or Webster's booby, resembles the masked booby, in that the plumage is mostly a brilliant white with black wing tips and a light yellow crown and nape. The diagnostic features for the species are a blue bill, reddish facial skin, and bright red legs and feet (Schreiber *et al.*, 1996). In some regions, there are adult red-footed boobies with ashy-brown plumage, but these birds are rare in the NWHI (Harrison, 1990). The juvenile characteristics differ greatly from the adult, such that the plumage is a pale brown, the bill is a dark brown, the facial skin is purple, and the legs and feet are yellow. About eight months after hatching, the legs and feet will become redder (Nelson, 1978). Overall, it takes about two or three years for the juveniles to mature to the adult form (Woodward, 1972).

7.3C.8 Wedge-tailed Shearwater (*Puffinus pacificus*)

The wedge-tailed shearwater is one of the largest of the tropical shearwters with an overall length of 43 cm, and body mass of 390 g (Whittow, 1997). The bird has grayish brown plumage on its back and white on its belly and underparts except for dark edge to the wings and dark undertail coverts. The sexes are indistinguishable and there are a light and a dark morph to this species.

The wedge-tailed shearwater has migratory behaviors. From September to November, large flocks of the species gather offshore before migrating near the Hawaiian Islands (King, 1974). Often during this period there may be rafts of birds with up to 700 individuals. The wedge-tailed shearwater breeds between February and November in the Northern Hemisphere and August and October to May and June in the Southern Hemisphere.
The wedge-tailed shearwater breeds from Kure Island in the NWHI to Maui Island in the main Hawaiian Islands (Ainley et al., 1997). The wedge-tailed shearwater also breeds on other islands spread throughout the Northeast and South Pacific, including Johnston Atoll and Christmas, Bonin, Volcano, Marshall, and Caroline Islands, and the Indian Ocean where it is known to breed as far west as Madagascar (Whittow, 1997).

A female wedge-tailed shearwater lays a single white egg in a burrow at sea level. The bird may use ledges and rock piles on rocky islands such as Necker in the NWHI (Harrison, 1990), or use shell debris or crevices under coral ledges (Gallagher, 1960). Both adults share in the excavation of the burrow, incubation of the egg, and feeding of the young (Shallenberger, 1973; Shallenberger, 1984). First breeding is at four years of age (Floyd and Swanson, 1983), and a wedge-tailed shearwater may live as long as 29 years (E. Flint in Whittow, 1997).

7.3C.9 Christmas Shearwater (*Puffinus nativitatis*)

Christmas shearwaters are slender-bodied with a length of 35-38 cm and body mass of 354 g. (Harrison,1983). Their plumage is dark brown with their underparts being lighter than their upperparts. The sexes are indistinguishable.

The Christmas shearwater breeds primarily in the tropical Pacific ranging as far north as the Hawaiian Islands to as far south as Easter Island (Harrison, 1996). The species usually breeds on remote, small, flat and sandy islands under dense vegetation such as naupaka (Scaevola sericea). Christmas shearwaters also breed on a steep grass covered slope on Motu Nui (Johnson et al., 1970).

Breeding adults return to the NWHI from early to late February (Naughton, 1982). A breeding pair will occupy a nest site in early to late March (Seto, 2001). The nest is a shallow scrape or depression in the ground, and usually located under vegetation. The female lays a single white egg each breeding season, and both parents share incubation of the egg and feeding of the chick (Seto, 2001). Chicks fledge between September and October on Midway Atoll The oldest record of a banded Christmas shearwater was 17 years on Laysan Island (K. Swift in Seto, 2001).

7.3C.10 Oceanographic Factors Influencing Seabird Food Availability

The region of greatest interactions between seabirds and the Hawai'i-based longline fleet is a latitudinal band from 25° N. to 40° N., from the dateline to about 150° W. longitude (NMFS, unpub. data). This region is often termed the North Pacific Transition Zone and contains a broad, weak, eastward flowing surface current composed of a series of fronts situated between the Subtropical Gyre to the south and the Subarctic Gyre to the north (Roden, 1980; Polovina, in press; Seki *et al.*, in prep.). During the winter and spring, westerlies in the northern portion of the Transition Zone and trade winds to the south result in wind-driven transport of surface waters creating fronts as colder, more dense northern water converges with warmer and lighter water from the south (Roden, 1980). North of Hawai'i, convergent fronts have been observed during winter to persist at about 28° N., 31° N., and 34° N. latitude (Niiler and Reynolds, 1984; Roden, 1980; Seki *et al.*, in prep.). These fronts represent sharp boundaries in a variety of physical parameters including temperature, salinity, chlorophyll, and sea surface height (geostrophic flow) (Niiler and Reynolds, 1984; Roden, 1980; Seki *et al.*, in prep.).

Biologically, these convergent fronts appear to represent zones of enhanced trophic transfer (Bakun, 1996; Olson *et al.*, 1994). The dense, cooler phytoplankton-rich water sinks below the warmer water creating a convergence of phytoplankton (Roden, 1980). Buoyant organisms such as jellyfish, as well as vertically swimming zooplankton, can maintain their vertical position in the weak down-welling, and aggregate in the front to graze on the down-welled phytoplankton (Bakun, 1996; Olson *et al.*, 1994). The concentration of these organisms in turn attracts the higher trophic level predators, and ultimately a complete pelagic food web is assembled (Olson *et al.*, 1994) and available to foraging fish and seabirds.

Although the oceanographic conditions described above are typical for the region, periodic anomalies dramatically alter these regimes. Events such as the *El Niño*-Southern Oscillation (ENSO) can have widespread and long-lasting impacts, disrupting trophic transfer with far-reaching consequences within the food chain. In addition, poorly understood phenomena such as the Pacific Decadel Oscillation (PDO) are now increasingly believed to play a significant role in oceanographic conditions and resultant variability in the distribution and abundance of pelagic food web assemblages.

7.3C.11 Ecological Interactions Affecting Seabirds

A variety of human activities other than fisheries are known to affect seabirds. Marine pollution has long been identified as a source of negative impacts to seabirds and their populations (e.g., Bourne, 1976; Tanabe *et al.*, 1984). Of greatest concern for albatrosses in the North Pacific Ocean is ingestion of marine debris, especially plastics (Day, 1980; Furness, 1983; Morris, 1980; Petit *et al.*, 1981). Plastic ingestion seems to be significant, especially for albatross chicks. Up to 50 percent of the weight of material regurgitated by albatross chicks consists of plastics, and plastics have been found in 97.6 percent of Laysan albatross chicks at Midway Atoll. For reasons not clearly understood, Laysan albatross seem to consume more plastics than black-footed albatross. Although there is not consensus within the scientific community about the population-level impacts of plastics ingestion by albatrosses, the problem seems to be increasing and could escalate to serious levels despite international conventions (e.g., International Convention for the Prevention of Pollution from Ships (MARPOL).

7.3C.12 Seabird Foraging Behavior

Given their capability of flying long distances, seabirds have some ability to adapt to temporal and geographic changes in forage availability. During the non-breeding season, most pelagic seabirds have sufficient energetic reserves to travel whatever distances are required to reach areas with adequate forage.

During the breeding season, however, seabirds are tied to terrestrial colonies for pre-breeding behavior, egg-laying, incubation, and protection and care of hatchlings and juveniles. This is often an extended period, and the need for nearby forage food is considerable during much of this stage of the breeding season. It is especially high when hatchlings are young and require frequent provisioning. As chicks grow older and require less frequent feeding, adults tend to forage longer distances and remain away from the colony for longer periods of time. This pattern of feeding close to colonies at times of peak food demand, then gradually extending foraging forays is well-known for albatrosses.

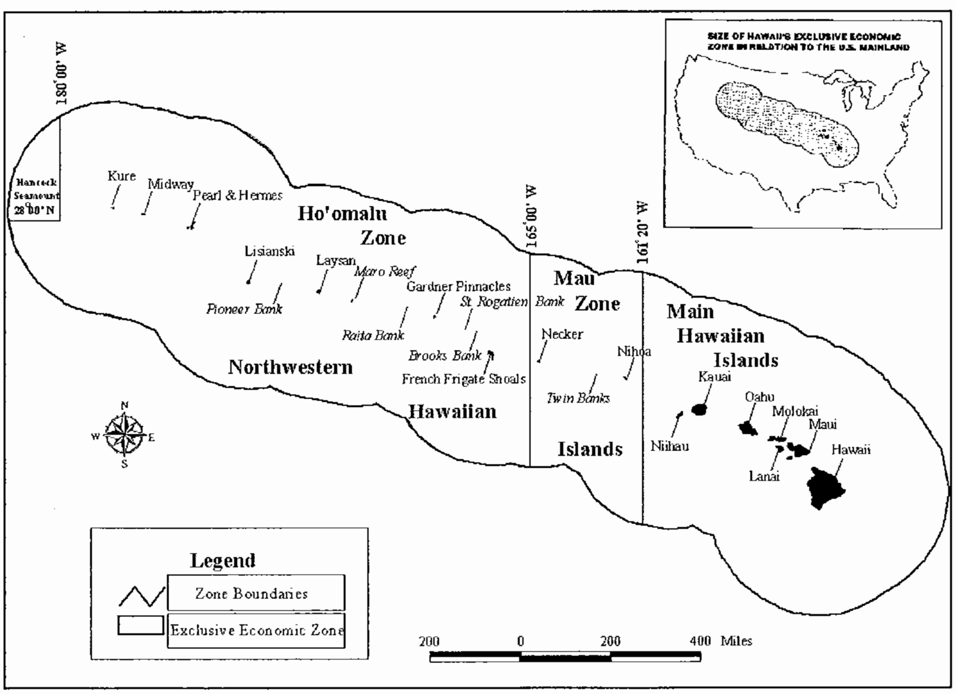
7.4 HAWAII'S COMMERCIAL, RECREATIONAL, AND CHARTER FISHING SECTORS

7.4A.1 Bottomfish and Seamount Groundfish

The deep-slope bottomfish fishery in Hawai'i concentrates on species of eteline snappers, carangids and a single species of grouper concentrated at depths of 30-150 fm. The fishery can be divided into two geographical areas (Figure 7-15): the inhabited main Hawaiian Islands (MHI) with their surrounding reefs and offshore banks; and the Northwestern Hawaiian Islands (NWHI), a chain of largely uninhabited islets, reefs and shoals extending 1,200 nm across the North Pacific. In the MHI approximately 80% of the bottomfish habitat lies in state waters. Bottomfish fishing grounds within federal waters around the MHI include Middle Bank, most of Penguin Bank and approximately 45 nm of 100-fathom bottomfish habitat in the Maui-Lāna'i-Moloka'i. For management purposes the NWHI fishery has been separated into the Mau Zone, closer to the MHI, and the Ho'omalu Zone.

In addition to the deep-slope fisheries in the MHI and NWHI, there is a potential seamount groundfish fishery in the Hawaiian Islands. A trawl and bottom longline fishery targeting alfonsin and armorhead at the southeast Hancock Seamount in the NWHI was started by Russian and Japanese fishing vessels in the late 1960s (Okamoto 1982). Large catches were made by foreign fishing vessels for about 10 years until overfishing caused the fishery to collapse. A moratorium on the harvest of alfonsin and armorhead on the Hancock Seamounts has been in effect since 1986 in an effort to rebuild the stocks. The moratorium was reissued by the Council and NMFS in September 2004 and therefore in effect until 2010 (69 FR 51400). Because periodic reviews of the stocks indicate that no recovery has occurred and it is unlikely that the moratorium will be lifted in the near future, the seamount groundfish fishery will not be discussed further.

FIGURE 7-15: Bottomfish Fishery Management Subareas in the Hawaiian Archipelago



7.4A.2 History

Bottomfish fishing was a part of the economy and culture of the indigenous people of Hawaiʻi long before European explorers first visited the islands. Descriptions of traditional fishing practices indicate that Native Hawaiians harvested the same deep-sea bottomfish species as the modern fishery and used some of the same specialized gear and techniques employed today (Iversen et al. 1990). The *poʻo lawaiʻa* (expert fishermen) within the community knew of dozens of specific *koʻa* (fishing areas) where bottomfish could be caught (Kahaulelio 1902). As Beckley (1883:10) noted, each *koʻa* could be precisely located:

> *Every rocky protuberance from the bottom of the sea for miles out, in the waters surrounding the islands, was well known to the ancient fishermen, and so were the different kinds of rock fish likely to be met with on each separate rock....[They] took their bearing for the purpose of ascertaining the rock which was the habitat of the particular fish they were after, from the positions of the different mountain peaks.*

European colonization of the Hawaiian Islands during the early nineteenth century and the introduction of a cash economy led to the development of a local commercial fishery. As early as 1832, fish and other commodities were sold near the waterfront in Honolulu (Reynolds 1835). Other fish markets were established on the islands of Maui and Hawaiʻi. John Cobb (1902), who investigated Hawaiʻi's commercial fisheries in 1900 for the U.S. Fish Commission, reported that the bottomfish *ʻulaʻula*, *uku* and *ulua* were three of the five fish taken commercially on all the Hawaiian Islands.

Initially, the commercial fishing industry in Hawaiʻi was monopolized by Native Hawaiians, who supplied the local market with fish using canoes, nets, traps, spears and other traditional fishing devices (Jordan and Evermann 1902; Cobb 1902). However, the role that Native Hawaiians played in Hawaiʻi's fishing industry gradually diminished during the latter half of the nineteenth century as successive waves of immigrants of various races and nationalities arrived in Hawaiʻi. Between 1872 and 1900, the non-indigenous population increased from 5,366 to 114,345 (OHA 1998). Kametaro Nishimura, credited by some to be the first Japanese immigrant to engage in commercial fishing in Hawaiʻi, began his fishing career in the islands in 1885 harvesting bottomfish such as *ʻōpakapaka*, *ulua* and *uku* (Miyaski 1973). By the turn of the century, Japanese immigrants to Hawaiʻi dominated the bottomfish fishery using wooden-hulled "sampans" propelled by sails or oars (Cobb 1902). The sampan was brought to Hawaiʻi by Japanese immigrants during the late nineteenth century, and over time Japanese boat-builders in Hawaiʻi adapted the original design to specific fishing conditions found in Hawaiʻi (Goto et al. 1983). The bottomfish fishing gear and techniques employed by the Japanese immigrants were imitations of those traditionally used by Native Hawaiians, with slight modifications (Konishi 1930).

During the early years of the commercial bottomfish fishery, vessels restricted their effort to areas around the MHI. Cobb (1902) records that some of the best fishing grounds were off the coasts of Molokaʻi and notes that large sampans with crews of 4 to 6 men were employed in the fishery. Typically, the fleet would leave Honolulu for the fishing grounds on Monday and return on Friday or Saturday. The fishing range of the sampan fleet increased substantially after the introduction of motor powered vessels in 1905 (Carter 1962). Fishing activity was occurring around the NWHI at least as early as 1913, when one commentator recorded: "Fishing for *ulua* and *kāhala* is most popular, using *bonito* for bait, fishermen seek this [sic] species in a 500 mile range toward Tori-Jima [NWHI]" (Japanese Consulate 1913, as cited in Yamamoto 1970:107). Within a few years more than a dozen sampans were fishing for bottomfish around the NWHI (Anon. 1924; Konishi 1930). Fishing trips to the NWHI typically lasted 15 days or more, and the vessels carried seven to eight tons of ice to preserve their catch (Nakashima 1934). The number of sampans traveling to the more distant islands gradually declined due to the limited shelter the islands offered during rough weather and the difficulty of maintaining the quality of the catch during extended trips (Konishi 1930). However, during the 1930s, at least five bottomfish fishing vessels ranging in size from 65 to 70 ft continued to operate in the waters around the NWHI (Hau 1984). In addition to catching bottomfish, the sampans harvested lobster, reef fish, turtles and other marine animals (Iversen et al. 1990).

During World War II the bottomfish fishery in Hawai'i virtually ceased operations, but it recommenced shortly after the war ended (Haight et al. 1993b). The late 1940s saw as many as nine vessels fishing around the NWHI, but by the mid-1950s, vessel losses and depressed fish prices resulting from large catches had reduced the number of fishery participants. During the 1960s, only one or two vessels were operating around the NWHI.

There was renewed interest in harvesting the bottomfish resources of the NWHI in the late-1970s following a collaborative study of the marine resources of the region by state and federal agencies (Haight et al. 1993b). The entry of several modern boats into the NWHI fishery and the resultant expanding supply of high-valued bottomfish such as *'ōpakapaka* and *onaga* made possible the expansion of the tourism-linked restaurant market by allowing a regular and consistent supply of relatively fresh fish (Pooley 1993a). Markets for Hawai'i bottomfish further expanded after wholesale seafood dealers began sending fish to the U.S. mainland. By 1987, 28 vessels were active in the NWHI bottomfish fishery, although only 12 were fishing for bottomfish full time. Some of the non-full time vessels also engaged in the pelagic or lobster fisheries (Iversen et al. 1990). In 1989, the Council developed regulations that divided the fishing grounds of the NWHI bottomfish fishery into the Ho'omalu Zone and Mau Zone. Limited access programs were established for the Ho'omalu Zone and Mau Zone in 1988 and 1999, respectively, to avoid economic overfishing (Pooley 1993b; WPRFMC 1998b).

The 1970s also saw major changes in the composition and operations of the bottomfish fishery around the main Hawaiian Islands. The fishery changed from one dominated, in terms of catch and effort, by a relatively small number of full-time professional fishermen to one dominated by hundreds of part-time commercial and recreational fishermen. This change was the result of a number of factors. The popularity of offshore fishing increased in Hawai'i with the increase in the availability of locally-built and imported small fiberglass boats. In addition, the rise in fuel prices during the 1970s made fishing for bottomfish particularly attractive to fishermen as it consumed less fuel than trolling and generated higher-value fish catches to offset fuel costs. Finally, as navigation systems, bottom-sounders and hydraulic or electric powered reels became more affordable, the skill level and experience necessary to fish bottomfish successfully was reduced and the labor associated with hauling up the long lines was considerably lightened.

During the early 1980s, with the development of a much larger market for bottomfish, bottomfish fishermen fishing around the main Hawaiian Islands were able to obtain premium prices for their catches, and thus were motivated to increase their landings (Pooley 1993a). However, the number of vessels participating in the MHI fishery declined after reaching a peak of 583 in 1985. The decrease in fishing effort suggests that some bottomfish fishermen perceived a growing shortage of bottomfish in the MHI fishery and switched to other fisheries. In 1998, concerns about decreasing catch rates led the State of Hawai'i to close certain areas around the MHI to bottomfish fishing, including areas of Penguin Bank within the EEZ[12]. In addition, new state rules established a recreational bag limit of five *onaga* or *ehu*, or a mix of both, per person.

Hawai'i's sportfishing charter boat fleet began to develop during the early 1950s as Hawai'i became an increasingly popular tourist destination (Markrich 1994). What started as a few charter boats operating out of harbors such as Kewalo Basin and Kona has evolved into a highly competitive industry involving nearly 200 vessels state-wide (Hamilton 1998; Walker 1996). The charter boat fleet mainly targets pelagic game fish such as billfish and tuna. However, a few charter boats take bottomfish fishing trips if patrons are interested (Hamilton 1998). Most of the charter boats engaged in bottomfish fishing are based on the islands of Maui and Kaua'i.

7.4A.3 Fishing Methods and Current Use Patterns

The basic design of the handline gear used in Hawai'i's bottomfish fisheries has remained essentially unchanged from gear used by early Native Hawaiians (Haight et al. 1993b). The gear consists of a main line with a 2-4 kg weight attached to the terminus. Several 40-60 cm sidelines with circle hooks are attached above the weight at 0.5-1 m intervals. A chum bag containing chopped fish or squid may be suspended above the highest of these hooks. The gear is pulled after several fish are hooked.

Circle hooks used in the bottomfish fishery are flat by design. "Kirbed" hooks (bent or offset to the side) are also available but are not generally used. The flat circle hooks are designed to be self-setting and work well for fish that engulf the bait and move off with it in their mouth. As a fish moves off with the baited hook, the line will trail out of the corner of the fish's mouth. The hook will be drawn into the corner of the mouth where the motion of the fish in relation to the pull of the line will rotate the hook through the corner of the jaw. Circle hooks, unlike "J" type hooks, are generally not effective for fish that pick at the bait or mouth the bait and spit it out (Kawamoto pers. comm.).

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[12]The State of Hawai'i claims the authority to manage and control the marine, seabed and other resources within "archipelagic waters." These archipelagic waters encompass a number of bottomfish fishing grounds, such as parts of Penguin Bank, that lie inside the EEZ. An October 24, 1997 memorandum from NOAA/General Counsel Southwest Region to the Council Chairman declared that, despite any contentions by the State of Hawai'i to the contrary, for purposes of federal fishery management, state waters do not extend beyond three miles from the coast.

Fishermen use the circle hook for its self-setting ability and for its curved design with its long inward pointing hook point that makes it difficult for the fish to rid itself of the hook once it is embedded. The circle hook shank is typically thicker and round in cross section (unlike the thinner straight J type hooks), which tends to minimize ripping or wearing a hole in the fish's jaw. An additional characteristic of the circle hook design that appeals to fishermen is that it's less prone to snagging on rocky or hard substrate bottoms and very difficult to snag flat or smooth surfaces. This characteristic minimizes the loss of gear (Kawamoto pers. comm.).

All bottomfish fishermen in Hawai'i target the same assemblage of bottomfish species. The ability to target particular species varies widely depending on the skill of each captain. Electronic navigation and fish-finding equipment greatly aid fishermen in returning to a particular fishing spot and catching desired species with little incidental catch (Haight et al. 1993). According to Hau (1984), *'ōpakapaka* is one of the primary target species due to the relatively high price it commands as a result of its constant demand at the fish auction. *Hāpu'upu'u* and white *ulua* are sought because of their sturdiness and ability to retain good flesh quality. In addition, white *ulua* can be caught in rough sea conditions when other species are difficult to capture. *Kāhala* are one of the least valuable bottomfish because large specimens have a reputation for carrying ciguatera toxin.

7.4A.4 MHI Bottomfish Fishery and Participation

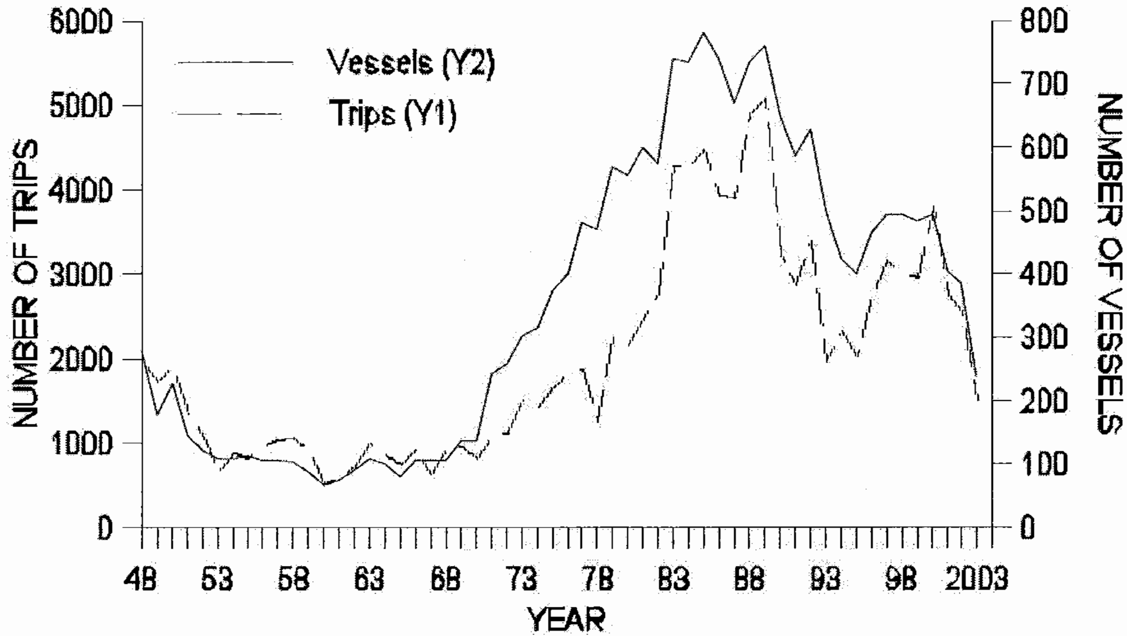
In the small boat fishery around the MHI the distinction between "recreational" and "commercial" fishermen is extremely tenuous (Pooley 1993a). A state-wide survey of small boat fishermen conducted in 1995-96 indicated that of the 42 fishermen interviewed who predominately use bottomfish fishing gear, 80 percent sell a portion of their catch (WPRFMC 1996). However, most of those selling fish are just trying to cover fishing trip expenses and do not expect a profit from their operation.

The number of fishermen engaged in bottomfish fishing in the MHI increased dramatically in the 1970s and 1980s but then declined in the early-1990s, rebounded somewhat in the late 1990s, but in 2002 reached its lowest level since 1977 (Figure 7-16). The decline in vessels and fishing effort may be due to the long-term decrease in catch rates in the bottomfish fishery and a shift of fishing effort towards tuna and other pelagic species

The individuals participating in the MHI fishery who make trips longer than 24 hrs are mostly full-time commercial fishermen. They typically operate larger boats than the part-time commercial/recreational fishermen and are able to fish during rough weather and venture further from port to fish less-exploited areas off Kaua'i, Ni'ihau and east Maui that are less accessible to the small boat fishermen.

The majority of participants in the MHI fishery shift from species group to species group and from the bottomfish fishery to other fisheries, primarily the pelagics fishery, in response to seasonal fish abundance or fluctuations in price. Except for those individuals who fish commercially on a full-time basis, most fishermen usually fish for bottomfish no more than 60 days a year (WPRFMC 1996).

FIGURE 7-16: MHI Bottomfish Fishery Participation and Effort (Source: WPFMC 2004)



Seasonal price variability causes part-time commercial fishermen to concentrate their bottomfish fishing effort during December, when they can take advantage of the year-end holiday demand for red snappers. Pelagic species are often an important secondary target during bottomfish fishing trips regardless of the season.

Data from various surveys indicate that the importance of the MHI fishery varies significantly among fishermen of different islands. According to a 1987 survey of boat fishing club members, bottomfish represented roughly 13% of the catch of Hawai'i fishermen, 25% of the catch of O'ahu and Kaua'i fishermen and 75% of the catch of Maui fishermen (Meyer Resources 1987). A survey of licensed commercial fishermen conducted about the same time indicated that the percentage of respondents who used bottomfish fishing methods was 25% on Hawai'i, 28% on Kaua'i, 29% on O'ahu, 33% on Lāna'i, 50% on Moloka'i and 51% on Maui (Harman and Katekaru 1988). Presumably, the differences among islands relate to the proximity of productive bottomfish fishing grounds.

Favored grounds in the MHI include banks off Moloka'i, Maui, Lāna'i and Kaua'i. These grounds account for more than about two-thirds of the bottomfish harvested in the MHI. Specific bottomfish fishing locales favored by fishermen vary seasonally according to sea conditions and the availability and price of target species. Historically, Penguin Bank is one of the most important bottomfish fishing grounds in the MHI, as it is the most extensive shallow shelf area in the MHI and within easy reach of major population centers. Penguin Bank is particularly important for the MHI catch of *uku*, one of the few bottomfish species available in substantial quantities to Hawai'i consumers during summer months. Penguin Bank is frequented mostly by bottomfish fishermen residing on O'ahu, while Middle Bank is especially popular among fishermen living on O'ahu and Kaua'i. The Maui-Lāna'i-Moloka'i complex is frequented mostly by bottomfish fishermen residing on Maui, Moloka'i and O'ahu.

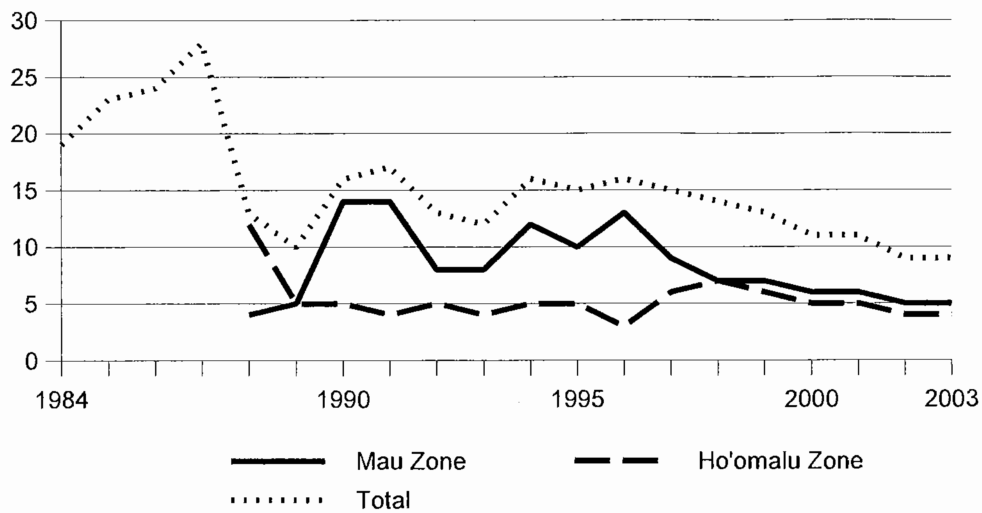
7.4A.5 NWHI Bottomfish Fishery and Participation

In contrast to the MHI fishery, bottomfish fishing in the NWHI is conducted solely by part-time and full-time commercial fishermen. The vessels venturing into the NWHI tend to be larger than those fishing around the MHI, as the distance to fishing grounds is greater (Haight et al. 1993b). As the number of vessels participating in the NWHI fishery increased during the 1980s, the fleet characteristics of the fishery became more diverse. Pooley and Kawamoto (1990) divided the fleet into three groups based on size and mode of propulsion: motor sailors, medium-sized powered vessels and large-sized powered vessels. The motor sailors are 46 to 66 ft long and are more streamlined in hull design than the standard powered vessels. The sail can be used to save on fuel costs, but it also limits the hold capacity compared with powered vessels of similar length. The powered vessels generally share one characteristic: a large working area on the back deck. The medium-sized powered vessels are 42 to 49 ft long. Because their smaller size limits fishing range and hold capacity, they usually operate in the lower (southeastern) end of the NWHI (Mau Zone) or in the MHI. The larger powered vessels are 47 to 64 ft long. With an average fuel capacity of 1,500 gallons, the vessels have a maximum range (round-trip) of 1,800 miles. The average maximum hold capacity is 4,000 pounds.

Many of the boats that fish in the Mau Zone switch to different fisheries and move to other fishing grounds during the year. The majority of vessels fish in the Mau Zone during a season that generally extends from November to April. Figure 7-17 provides the trend in number of bottomfish vessels operating in the NWHI since 1984.

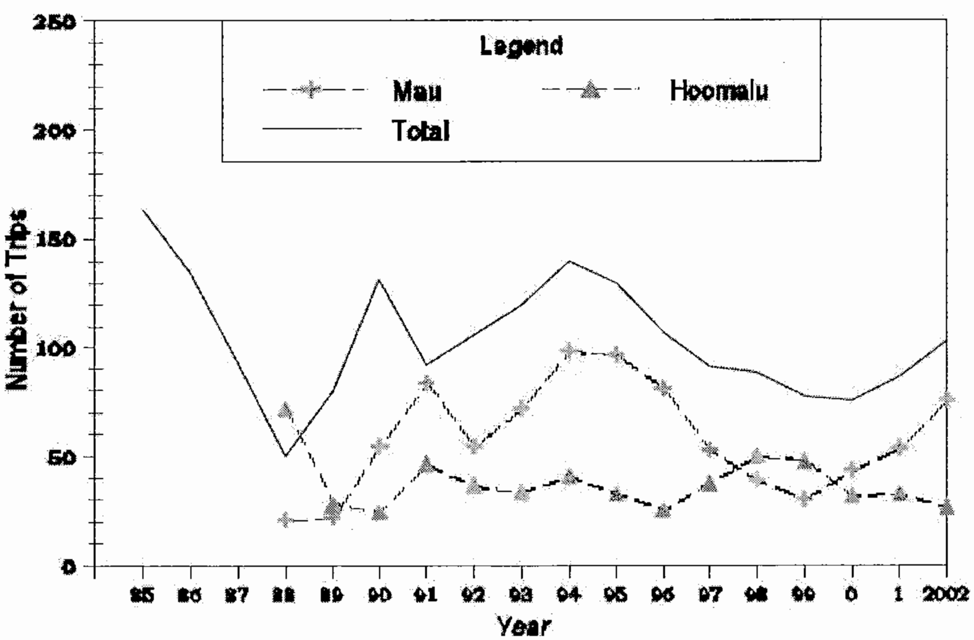
A 1993 survey of participants in the NWHI fishery found that vessels fishing in the Mau Zone made an average of 12.7 trips to the area to target bottomfish and 3.4 trips to target pelagic fish or a mixture of pelagic species and bottomfish (Hamilton 1994). In addition, during that year an average of 5.6 trips were made by these vessels to bottomfish fishing grounds around the MHI. Although bottomfish fishing in the Mau Zone is not the only activity of these boats, it may be vital to the year-round operations of some fishermen.

FIGURE 7-17: NWHI Bottomfish Fishery Participation (# of vessels).



The fishing strategies and catch levels of vessels fishing in the Hoʻomalu Zone tend to be fairly uniform (Pan 1994). The 1993 survey referred to above found that all boats fishing in the Hoʻomalu Zone were engaged exclusively in commercial bottomfish fishing (Hamilton 1994). They averaged 9 trips per year to the zone, and the average trip length was about three weeks (Figure 7-18).

FIGURE 7-18: Trend in number of trips/year for NWHI bottomfish fishery permit holders (source:WPFMC 2004).



Popular fishing grounds in the Mau Zone include the waters around Nihoa Island and Necker Island (Table 7-18). Especially productive fishing areas in the Hoʻomalu Zone are Brooks Bank, Laysan Island and Gardner Pinnacles.

TABLE 7-18: Approximate Percentage of Total Catch in NWHI Bottomfish Fishery from Selected Areas Based on Historical Fishing Data

AREA	PERCENT OF TOTAL CATCH
Nihoa Island and Twin Banks	16.6
Brooks Bank and St. Rogatien Bank	14.2
Laysan Island	13.6
Necker Island	13
Gardner Pinnacles	12.9
Lisianski Island	6.8
French Frigate Shoals	5.6
Kure Atoll	4.4
Maro Reef	4.2
Pioneer Bank	4
Raita Bank	2.6
Pearl and Hermes Reef	2.1
Midway Atoll	0

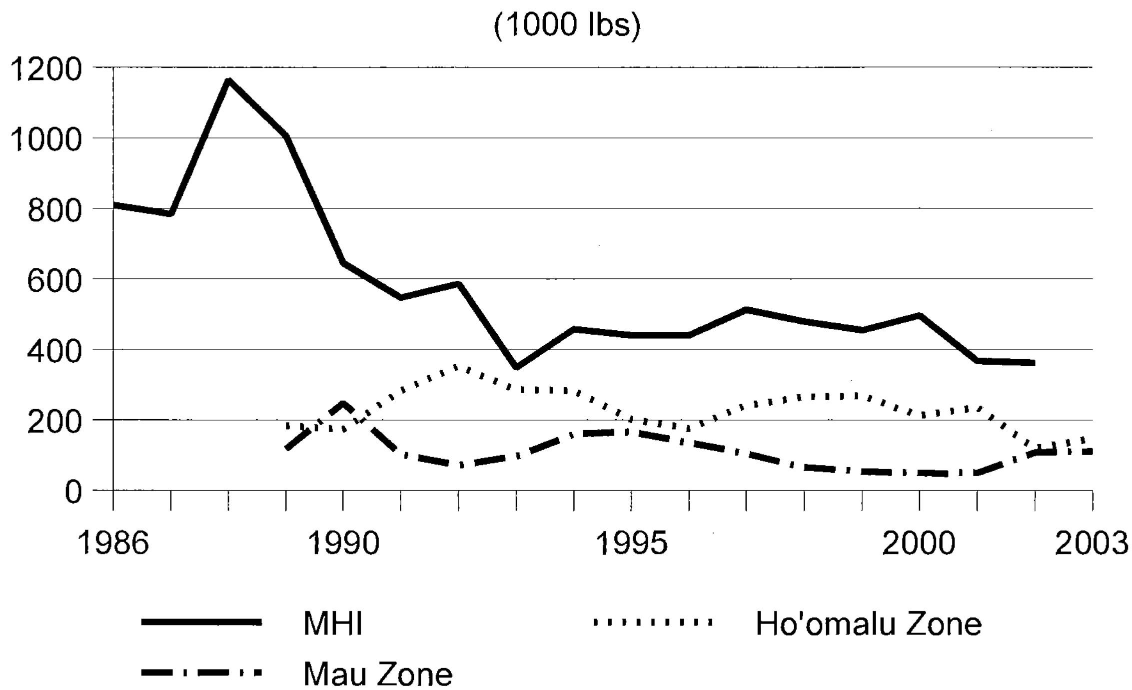
Note: Percentages from NMFS landings data for 1997-1999.
Source: M. Mitsuyasu pers. comm. 2000. WPRFMC

7.4A.6 Harvest of BMUS

Only commercial landings data are available for the MHI fishery because the State of Hawaiʻi does not require a saltwater recreational fishing license and there are no state or federal reporting requirements for recreational fishing in the waters around Hawaiʻi. It is estimated that the recreational/subsistence catch in the MHI bottomfish fishery is about equal to the commercial catch (WPRFMC 1999). Charter boat operators are considered to be commercial fishermen under Hawaiʻi statute and therefore are required to submit monthly catch reports. Consequently, charter boat catches are included in estimates of commercial landings.

Based on recent (1998-2002) harvest data, commercial bottomfish catches in the MHI fishery represent approximately 60 percent of the total commercial bottomfish harvest in Hawai'i (WPRFMC 2004). The annual bottomfish harvest in the MHI has been fairly stable for the past 10 years (Figure 7-19; Table 7-19).

FIGURE 7-19: Trends in MHI and NWHI Bottomfish Landings (Source: WPFMC 2004)



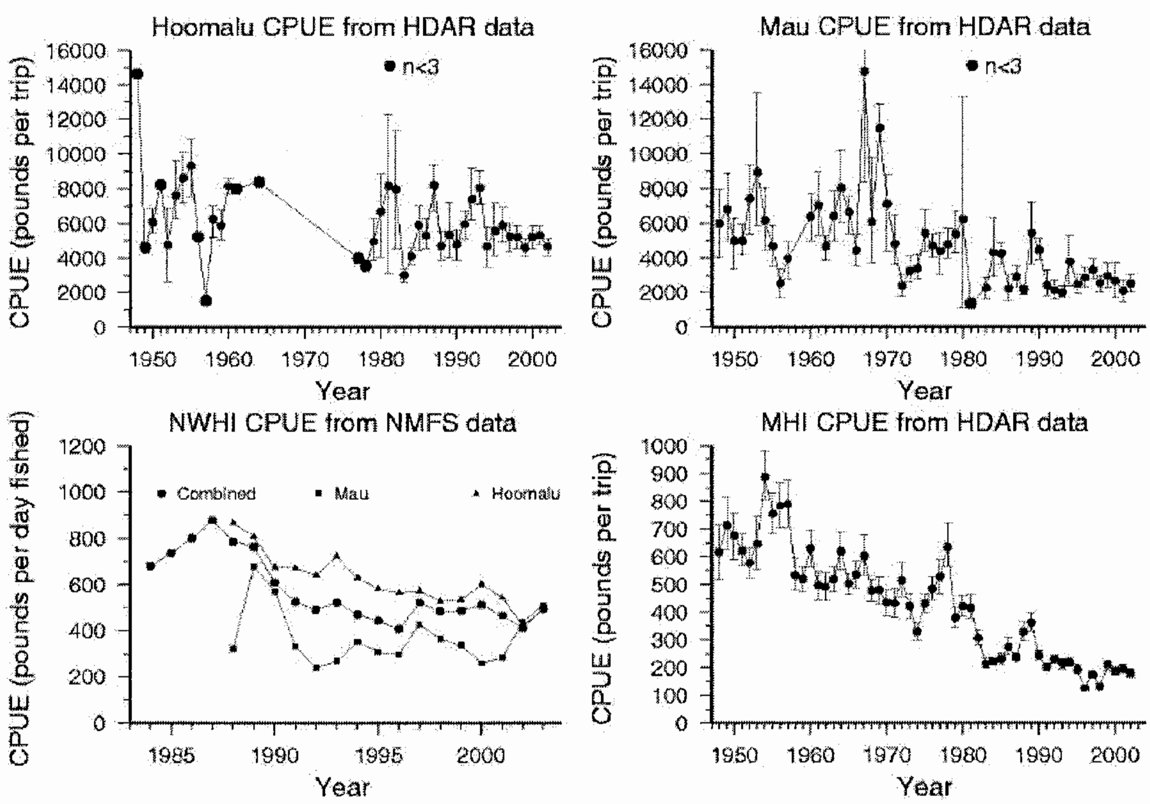
MHI bottomfish landings peaked in 1987 and then declined to relatively stable levels since. Much of this decline was caused by reductions in fishing participation (vessels and trips) due to limited entry and to a weak market for fresh bottomfish since the 1990s. In 2003, landings continued to decline, by 5% from the previous year.

However, the catch per unit effort (CPUE, in pounds landed per trip) in the MHI fishery shows a long-term decreasing trend, with current values approximately 25% that of the first recorded estimates (Figure 7-20; Table 7-19). MHI CPUE values decreased in 2002 by about 8% from the 2001 level, but remained above the 1996-1998 values, which were the lowest on record. The 1999 increase in MHI CPUE was due primarily to a large increase in *uku*, and to a lesser degree *onaga*, catches and catch rates. This relative peak in CPUE is similar to that of the late 1980s, which was due to increased *uku* catch rates alone, and may not indicate an increase in abundance of other species in either case. Rapid decreases in CPUE from the 1989-90 *uku*-derived peaks appear to be a return to the prevailing slow decline (WPRFMC 2004).

Bottomfish landings from the Mau Zone has increased over recent years to over 100,000 lbs in 2002 while the number of trips increased by 38% (Figure 7-19;Table 7-20). The Mau Zone 2002 average landings per trip increased by about 500 lbs (Table 7-20) or 54% over 2001. Most of the major BMUS landings increased substantially, with only *ehu* and *butaguchi* landings categories decreasing (WPRFMC 2004). Trip lengths varied by vessel and trip strategy/target. Most of the trips incorporated some trolling activity. The Ho'omalu Zone 2002 bottomfish landings per trip fell by 19%, as one highliner vessel dropped out of the fleet (Table 7-21). Up until 2002 the Ho'omalu Zone fleet had very stable participation and landings for the last 7-8 years (Figure 7-19).

In the Mau Zone, trip CPUE dropped 14 percent from 1999 values to about 42 percent of early values. On a catch-per-day basis[13] (Table 7-20), the 2000 Mau Zone CPUE dropped 23 percent to 61 percent of earliest values. Declines in CPUE for this zone may be largely due to the departure of highliners and greater concentration on other fishing methods, e.g., trolling, by participants. Hoomalu Zone CPUE trends have remained stable in recent years (Figure 7-20).

FIGURE 7-20: CPUE Trends in MHI and NWHI Bottomfish Fisheries
(Source: WPFMC 2004)



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[13]Data collected by HDAR and used for the MHI CPUE estimates do not include trip length. The NWHI bottomfish trip logs collected by NMFS include trip length, and this provides a more standardized measure of CPUE.

TABLE 7-19: Historical Annual Statistics Main Hawaiian Islands (Source: WPFMC 2004)

Year	Total Landings (lbs)	CPUE (lbs/trip)	Inflation Adjusted Revenue	Price per Pound	Number of Vessels	SPR Average
1986	810348	274	$3,432	$4.53	538	33
1987	783569	237	$3,733	$5.00	535	25
1988	1164492	329	$4,940	$4.46	572	37
1989	1006142	361	$4,396	$4.68	537	40
1990	645802	245	$2,978	$4.99	501	27
1991	547800	202	$2,123	$4.15	469	24
1992	587471	228	$2,180	$4.02	407	25
1993	347960	213	$1,762	$4.13	403	24
1994	457956	217	$2,009	$4.09	423	24
1995	439625	193	$1,992	$3.81	400	22
1996	439867	125	$1,719	$4.23	487	21
1997	512554	176	$1,703	$3.63	502	20
1998	478802	130	$1,631	$3.73	498	20
1999	455131	209	$1,482	$3.65	483	25
2000	496989	187	$1,717	$3.84	495	21
2001	366997	194	$1,309	$3.79	404	20
2002	361774	179	$1,396	$4.13	386	20
2003*	272569	190	$1,460	$4.35	325	17
Ave.	565325	216	$2,331	$4.18	465	25
s.d.	236660	59	$1,093	$0.42	66	6

*Indicates incomplete data.

TABLE 7- 20: Historical annual statistics for Mau zone bottomfish fishery (Source: WPFMC 2004)

Year	Total Landings (lbs)	CPUE (lbs/trip)	Inflation Adjusted Revenue	Price per Pound	Number of Vessels	SPR Average
1986	NA	2206	NA	NA	NA	41
1987	NA	2889	NA	NA	NA	50
1988	NA	2136	NA	NA	4	37
1989	118000	4463	$443,680	$3.76	5	91
1990	249000	3435	$836,640	$3.36	14	77
1991	103000	1199	$372,860	$3.62	14	42
1992	71000	1273	$248,500	$3.50	8	38
1993	98000	1321	$306,740	$3.13	8	36
1994	160000	1573	$537,600	$3.36	12	68
1995	166000	1635	$509,620	$3.07	10	45
1996	135000	1543	$449,550	$3.33	13	53
1997	105000	1976	$384,300	$3.66	9	61
1998	66000	1689	$196,680	$2.98	7	42
1999	54000	1808	$182,520	$3.38	7	51
2000	49000	1053	$173,460	$3.54	6	42
2001	50000	916	$144,500	$2.89	6	36
2002	108000	1416	$342,360	$3.17	5	45
2003*	77000	2070	$222,530	$2.89	5	57
Ave.	107267	1922	$356,769	$3.31	8	51
s.d.	53957	894	$183,346	$0.28	3	15

*Indicates incomplete data

TABLE 7-21: Historical annual statistics for Hoomalu zone bottomfish fishery

Year	Total Landings (lbs)	CPUE (lbs/trip)	Inflation Adjusted Revenue	Price per Pound	Number of Vessels	SPR Average
1986	NA	5301	NA	NA	NA	75
1987	NA	8187	NA	NA	NA	113
1988	NA	4702	NA	NA	12	66
1989	184000	5481	$631,120	$3.43	5	70
1990	173000	5403	$576,090	$3.33	5	64
1991	283000	5871	$914,090	$3.23	4	82
1992	353000	9464	$1,221,380	$3.46	5	98
1993	287000	8412	$984,410	$3.43	4	109
1994	283000	6903	$996,160	$3.52	5	64
1995	202000	6130	$650,440	$3.22	5	73
1996	176000	6216	$621,280	$3.53	3	78
1997	241000	6351	$802,530	$3.33	6	65
1998	266000	5315	$837,900	$3.15	7	66
1999	269000	5611	$989,920	$3.68	6	62
2000	213000	5909	$832,830	$3.91	5	62
2001	236000	5757	$769,360	$3.26	5	64
2002	120000	4638	$433,200	$3.61	4	59
2003*	145000	3713	$494,450	$3.41	4	59
Ave.	228733	6076	$783,677	$3.43	5	74
s.d.	63033	1416	$217,036	$0.20	2	17

*Indicates incomplete data

Bycatch: The NWHI bottomfish fishery is strictly a commercial fishery in the NWHI, while the MHI bottomfish fishery is a mixed commercial, recreational and subsistence fishery. Although these fisheries use the same gear and operational methods, the motivation of the fishermen is different between the commercial operators and recreational or subsistence fishermen. This results in different bycatch characteristics. The NWHI commercial fishermen seek the highest economic return on their catch and therefore may discard lower valued species, especially early in a trip, thereby conserving both ice and hold space. Recreational or subsistence fishermen, on the other hand, are more inclined to retain a greater variety of species for home consumption or distribution to relatives and friends. For this reason, the bycatch of the NWHI commercial fleet is likely larger than that of the MHI fishery. In addition, because Hawai'i has no permit, logbook, or catch reporting system for non-commercial marine fishermen, there are no data on bycatch by this sector. Data on bycatch in the NWHI commercial fishery is available from the logbook program, from limited observer data, and from NMFS research cruises in the NWHI.

Bottomfish gear types and fishing strategies are highly selective for desired species and sizes. Measures that serve to further reduce bycatch in the botomfish fishery include prohibitions on the use of bottom trawls, bottom gillnets, explosives and poisons.

Logbook data (State of Hawai'i), and observer programs conducted by NMFS indicate that total discards (including damaged target species) account for approximately 8 to 23% of the total catch in bottomfish fisheries in the Hawaiian archipelago (Nitta 1999, WPRFMC 1998a). Carangids, sharks, and miscellaneous reef fish (pufferfish, moray eels, etc.) are the most numerous discard species. Two species in particular, kāhala (Seriola dumerili) and butaguchi (Pseudocaranx dentex), make up the majority of the bycatch. Most species are not kept by vessels because of their unpalatability, however some carangids (large jacks and amberjacks) are also discarded because of concerns of ciguatera poisoning[14]. Butaguchi, which commands a low price in the Hawai'i market, may be discarded in the early days of a fishing trip to avoid reducing vessel hold space for more valuable bottomfish and because this species has a poor on-board "shelf-life." The major discard species in the NWHI bottomfish fishery are given in Table 7-22. It should be noted that a large percentage of the snappers and the grouper listed there are included as bycatch because of damage from sharks.

In bottomfish fishing operations the largest proportion of lost fish and gear is attributable to interactions with sharks (Nitta 1999). Some fishing areas are so plagued with sharks that a majority of hooked fish are either stolen or damaged. The estimated economic losses experienced by fishermen as a result of shark interference with fishing operations are substantial (Kobayashi and Kawamoto 1995). In the NWHI the gray reef shark (*Carcharhinus amblyrhnchos*) is the worst offender. When shark interactions become a problem, some fishermen will attempt to kill sharks by catching and/or shooting them. During the late 1990s, an increase in the market demand for

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[14]Ciguatera fish poisoning results from eating a fish containing a neurological toxin produced by a microscopic dinoflagellate algae. The algae grow epiphytically on benthic macroalgae (seaweeds) and are ingested by herbivorous fish which in turn are eaten by larger carnivorous fish, with each step concentrating the toxin. In humans, ciguatera poisoning may cause severe illness or even death.

shark fins resulted in some bottomfish vessels "finning"[15] the sharks that were killed. In 2000 however, both the State of Hawaiʻi and the federal government implemented legislation that required the entire shark carcass to be landed along with the fins (HRS § 188.40.5 and CFR 600.1023, respectively). This legislation has curtailed shark-finning in the bottomfish fishery. Limitations in hold space and limited marketability preclude most bottomfish vessels from retaining shark carcasses.

TABLE 7-22: Discards from Bottomfish Fishing Trips with NMFS Observers, 1990-1993

SPECIES	TOTAL NO. CAUGHT	TOTAL NO. DISCARDED	TOTAL % DISCARDED
Kāhala	2438	2266	92.9
Kalekale (yellowtail)	40	22	55
Sharks	176	92	52.3
Misc. fish	115	59	51.3
Ulua (white)	127	62	48.8
Misc. snapper/jack	189	91	48.1
Butaguchi	3430	1624	47.3
Ulua (black)	23	10	43.5
Taʻape	110	40	36.4
Misc. fish unidentified	174	26	14.9
Kalekale	874	52	6
ʻōpakapaka	5092	107	2.1
Ehu	1185	20	1.7
Uku	2209	28	1.3
Hāpuʻupuʻu	1593	19	1.2
Gindai	459	3	0.7
Onaga	1141	8	0.7
Alfonsin	1	0	0

[15]"Finning" is the practice of removing the fins from a shark and discarding the remainder of the carcass at sea.

SPECIES	TOTAL NO. CAUGHT	TOTAL NO. DISCARDED	TOTAL % DISCARDED
Armorhead	1	0	0
Lehi	3	0	0

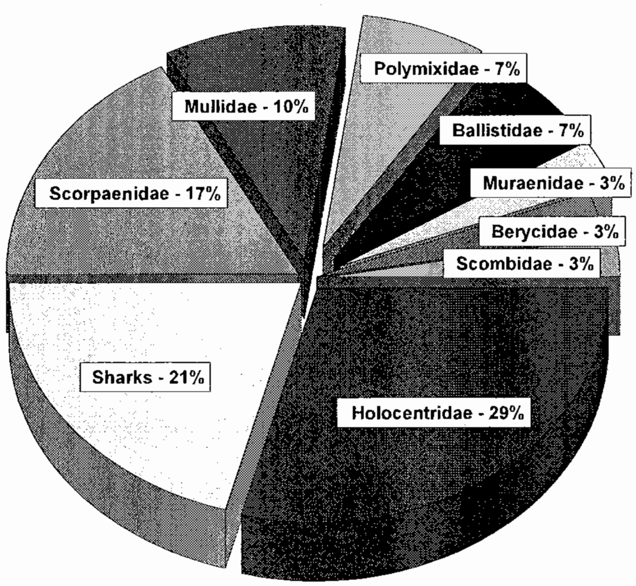
Source: Nitta 1999

Data collected by NMFS during research bottomfish fishing cruises indicate the potential species composition of bycatch in the NWHI bottomfish fishery (Figure 7-21). Research bottomfish fishing is less likely to exclusively successfully target commercial species, however, Figure 7-21 indicates other species that may be caught in association with bottomfish fishing operations.

The most recent data available (WPRFMC 2004) reinforce the trends described above, including the differences in strategy between Mau and Ho'omalu Zone operations. In both zones in 2002, 100% of the sharks and kāhala were discarded. In the Mau Zone, butaguchi was frequently discarded in 2002 (22%), unlike in 2001 when only 1% was discarded. The only other significant discard was 'ōmilu (*Caranx melampygus*) at 9%, down from 38% in 2001.

In the Ho'omalu Zone, several lesser valued species were commonly discarded, including kalekale (48% in 2002, 24% in 2001), butaguchi (20% in 2002, 32% in 2001) and white ulua (*C. ignoblis*) (63% in 2002, 70% in 2001).

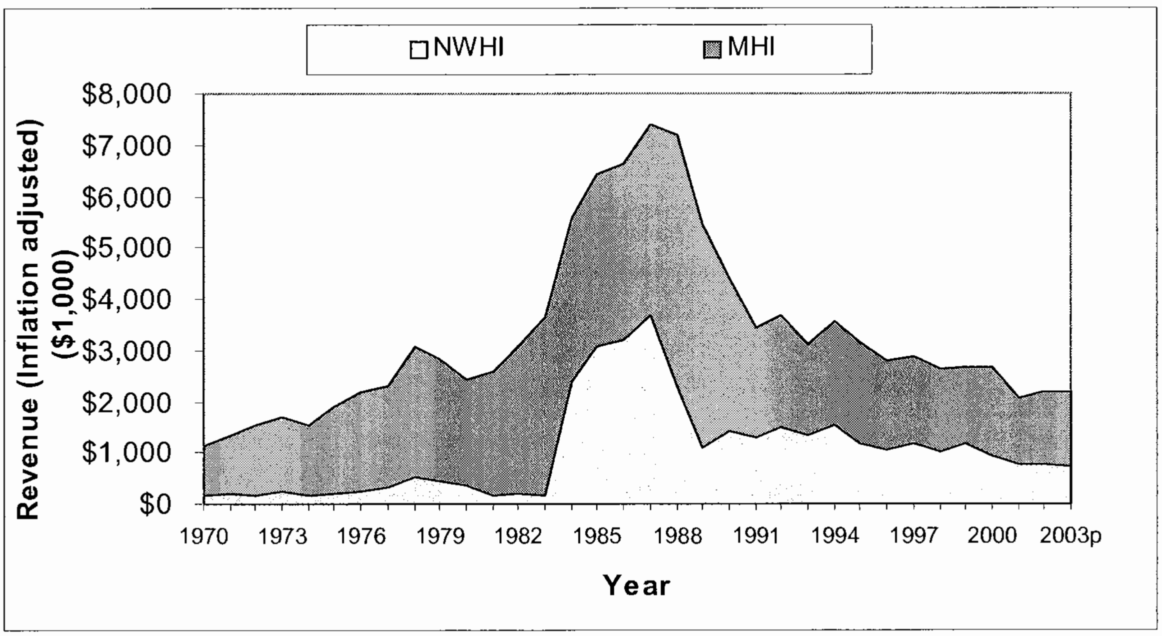
FIGURE7-21: NMFS Research Cruise Estimates of Composition of Bottomfish Bycatch in Hawai'i (Percent of total number; Source: WPRFMC 1998a)



7.4A.8 Economic Performance

MHI: Inflation-adjusted gross revenue in the MHI bottomfish fishery grew steadily in the 1980s (Figure 7-22) as a result of increases in both real prices and landings (WPRFMC 2003). However, between 1988 and 1993, revenue in the MHI fishery decreased sharply as both MHI bottomfish prices and landings declined. In the late 1990s, the prices appeared to converge, perhaps due to the softness of the upscale part of the Hawaiʻi market as the state's economic recession continued (WPRFMC 1999). In recent (1995-2000) years, the annual ex-vessel value of bottomfish landings in the MHI fishery has averaged about $1.7M.

Figure 7-22: Hawaii bottomfish landings revenue (inflation adjusted) by area: NWHI vs. MHI, 1970 - present (Source: WPFMC 2004)



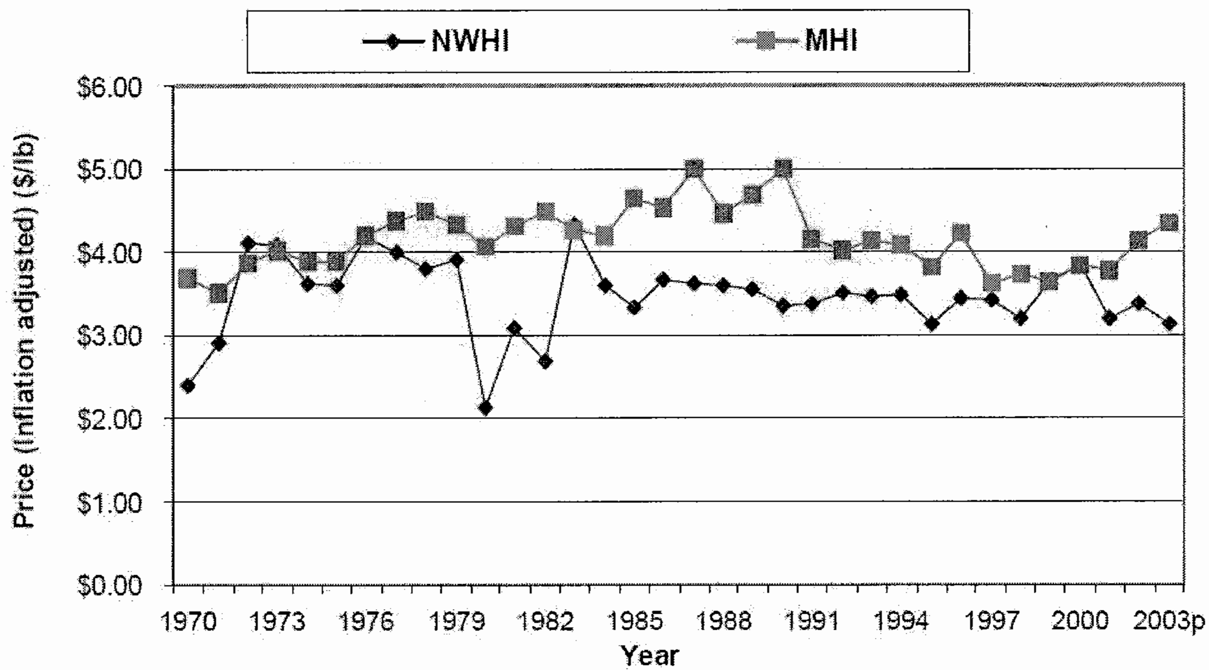
As shown in Figure 7-22 the inflation-adjusted gross revenue in the NWHI fishery grew dramatically in the mid-1980s and then declined as landings fell. Inflation-adjusted revenue in 2002 was only 20% of the 1987 peak. In recent years, the annual ex-vessel value of bottomfish landings in the NWHI fishery has averaged about $1,000,000.

Historically, bottomfish caught in the main Hawaiian Islands tended to have higher aggregate prices, reflecting both species composition and greater freshness. However, the MHI price declined in general in 1990s, while NWHI price was relatively steady during the same period. This relative lowering of the MHI bottomfish prices may have reflected the softness of the upscale part of the Hawaii market. As a result, it brought the prices of the two areas to a similar range in 1999, and slightly converge in 2000 as NWHI price was $3.76 and MHI was $3.75.

In 2001, the prices from both areas drops, but to a greater degree for bottomfish caught in the Northwestern Hawaiian Islands. In 2002, the prices from both areas increased slightly, but in a greater degree for the MHI price. In 2003, the MHI price continued the increase trend from 2002, while the MWHI price fell slightly. As a result, the MHI price was higher substantially, $1.22 per pound, than NWHI in 2003.

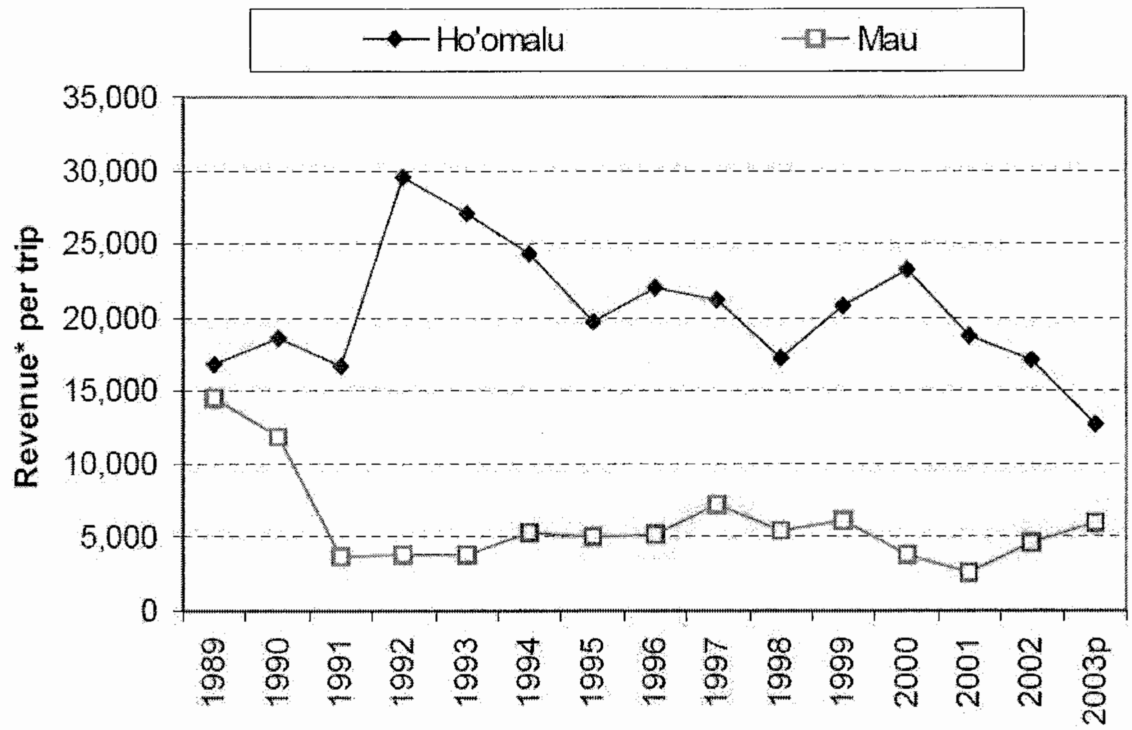
Onaga and opakapaka comprise the largest valued landings in each area for most years (ignoring the highly fluctuating landings of uku); NWHI ex-vessel prices were $4.53 and $4.79 per pound respectively in 2003 while MHI were $5.89 and $5.01, respectively (Figure 7-23). However, the NWHI landings are comprised of a higher percentage of these higher priced species compared to the MHI, so the difference in price for individual species by area is ironed out by the different species compositions between the two areas.

FIGURE 7-23: Average price/lb for BMUS landed in NWHI and MHI bottomfish fisheries
(Source: WPFMC 2004)



Independent, owner-operator fishing operations prevail in both zones of the NWHI bottomfish fishery. In 1988, a limited access program was established for the Ho'omalu Zone, the primary motivation for which was avoidance of economic overfishing (Pooley 1993b). When the limited access program provisions began to take effect in 1989-91, the revenue per trip for Ho'omalu Zone vessels rose dramatically (Figure 7-23);. Since that time the revenue per trip in the Ho'omalu Zone has consistently been higher than that of the Mau Zone.

FIGURE 7-24: Mau Zone and Ho'omalu Zone participant's average revenues per trip
(Source: WPFMC 2004)



The two trends in inflation-adjusted revenue per trip show the distinct difference between Ho'omalu and Mau zone operations. When the limited entry provisions began to take effect in the Ho'omalu zone in 1989-91, revenue rose dramatically but has subsequently declined to slightly more than its average for the period. Revenue (inflation-adjusted) in the Mau zone initially fell (as the limited entry vessels could no longer fish in the Mau zone, only smaller boats remained in the Mau zone). After that initial drop, however, revenue per trip in the Mau zone rose for several years, but has subsequently declined from 1997 to 2001. Revenue per trip in Mau rose again in 2002 and 2003, while it declined in Ho'omalu. The limited entry program, which was implemented in the Mau Zone in 2001, may has improved the economic performance for the vessels that have a permit to fish in the Mau Zone.

Estimates of annual net revenue for vessels operating in the Mau Zone and Hoʻomalu Zone were first presented in a 1993 cost-earnings profile of the NWHI bottomfish fishery (Hamilton 1994). The study revealed that on average Hoʻomalu Zone vessels realized a positive economic return of $2,238 per vessel in 1993 while Mau Zone vessels averaged an economic loss of $21,947 per vessel. The principal factor explaining the disparity in the economic performance of vessels operating in the two zones was the difference in catch rates (Pan 1994). In comparison to boats fishing in the Mau Zone, boats operating in the Hoʻomalu Zone caught more fish per fishing day and more of their catch consisted of high-valued bottomfish such as *onaga* and *ʻōpakapaka*.

Since 1993 however, the revenues of Hoʻomalu Zone vessels have shown a downward trend due to decreasing catch rates for some species, particularly the high-priced *ʻōpakapaka* (Figure 7-24). As a result of this decrease in revenues, in recent years the average vessel fishing in the Hoʻomalu Zone has failed to cover its total annual economic costs through bottomfish fishing (WPRFMC 2003). In 2000, Hoʻomalu vessels averaged an economic loss of $38,047 per vessel (Table 7-23). The average vessel earned a positive return on operations, and presumably vessel owners derive sufficient income from other economic activities to cover fixed costs.

TABLE 7-23: Average Income Statement for Vessels Fishing in the Mau Zone and Hoʻomalu Zone, 2000 (Source: WPRFMC 2003)

CATEGORY	MAU ZONE VESSELS	HOʻOMALU ZONE VESSELS
Revenue	$38,639	$148,522
Fixed Costs:		
Capital	$4,093	$18,056
Annual Repair	$4,840	$12,694
Vessel Insurance	$2,833	$31,516
Administrative	$1,535	$7,441
Other	$0	$1,970
Total	**$13,301**	**$71,678**
Operating Costs:		
Fuel and Oil	$4,158	$9,958
Ice	$1,094	$2,298
Bait	$1,641	$5,253
Handling	$3,900	$14,900
Provisions	$1,751	$7,113
Gear and Supplies	$2,407	$8,426
Other (trip basis)	$3,283	$10,943
Crew's Income	$6,100	$35,000
Captain's Income	$8,800	$21,000

CATEGORY	MAU ZONE VESSELS	HO'OMALU ZONE VESSELS
Total	**$33,134**	**$114,892**
Net on Operations	**$5,505**	**$33,631**
Total Cost	**$46,435**	**$186,569**
Net Revenue	**- $7,796**	**- $38,047**

Updated cost-earnings data for vessels operating in the Mau Zone indicate that the net economic returns to the average boat is still negative (Table 7-23). The poor economic performance of a substantial number of Mau Zone vessels has resulted in a considerable turnover pattern of entry and exit (Hamilton 1994). Between 1989 and 1997, over 15 vessels entered and left the fishery. Because access to the Mau Zone was unrestricted, economic failure of vessels in the fishery did not reduce fishing effort to more appropriate levels (WPRFMC 1998b). Bankrupt vessels were sometimes bought for a fraction of their initial capital cost and returned to the Mau Zone with new owners who believed that reduced capital servicing obligations would give them a competitive edge over other fishermen. In addition, vessels displaced from overfished U.S. mainland fisheries arrived in Hawai'i at a steady rate on a "look-see" basis. These owners and captains were largely unaware of the economic performance of those vessels already fishing in the Mau Zone.

In 1999, a limited access program was established for the Mau Zone to support long-term productivity of bottomfish resources in the zone and to improve the economic stability of the fishery (WPRFMC 1998b). The limited access program is intended to decrease the large reserve of potential effort that could threaten the resources and allow attrition due to market forces and freedom of choice to reduce the Mau Zone fleet to more economically rational levels.

7.4A.8 Markets

A market for locally caught bottomfish was well-established in Hawai'i by the late nineteenth century. Today, fresh bottomfish continues to be an important seafood for Hawai'i residents and visitors. Nearly all bottomfish caught in the NWHI fishery are sold through the Honolulu fish auction (United Fishing Agency, Ltd.). Prices received at the auction change daily, and the value of a particular catch may even depend on the order in which it is placed on the floor for bidding (Hau 1984). Bottomfish caught in the MHI fishery are sold in a wide variety of market outlets (Haight et al. 1993b). Some are marketed through the fish auction in Honolulu and intermediary buyers on all islands. Sales of MHI bottomfish also occur through less formal market channels. For example, local restaurants, hotels, grocery stores and individual consumers are important buyers for some fishermen. In addition to being sold, MHI bottomfish are consumed by fishermen and their families, given to friends and relatives as gifts, and bartered in exchange for various goods and services.

Historically, the demand for bottomfish in Hawai'i has been largely limited to fresh fish. Seventy years ago Hamamoto (1928) remarked on the fact that fish dealers in Honolulu refused to buy fish that had been harvested in the NWHI and frozen on-board because the demand for this product was so low. In the last few years the price differential between frozen and fresh product has narrowed for some species of bottomfish, but it remains substantial for *onaga* and *ehu*, the two highest priced fish. Until the market for frozen bottomfish develops, participants in the NWHI fishery will be caught in the same on-going dilemma – they must stay out long enough to cover trip expenses, but keep the trips short enough to deliver a readily saleable, high-quality product (Pan 1994). In the past, bottomfish catches from the MHI have tended to command higher aggregate prices than those caught in the NWHI, reflecting a larger proportion of preferred species and greater freshness. Bottomfish caught around the MHI are iced for only one to two days before being landed, whereas NWHI fresh catches may be packed in ice for ten days or more. By the late 1990s, however, the prices appeared to converge, perhaps due to the softness of the upscale part of the Hawaiʻi market as the state's economic recession continued (WPRFMC 1999).

Catches of bottomfish around the MHI typically consist of plate-sized fish preferred by household consumers in Hawaiʻi and by restaurants where fish are often served with the head on. Bottomfish caught around the NWHI tend to be the medium to large fish (over 5 pounds) preferred for the restaurant fillet market. Because the percent yield of edible material is high, handling costs per unit weight are lower and more uniform portions can be cut from the larger fish.

According to U.S. Customs data for the Port of Honolulu, 801,000 pounds of snapper were imported in 2003 worth $2.26 million ($2.82 per pound). This amounts exceeded domestic supply and thus was a significant factor in ex-vessel prices. Tonga and Australia were the largest sources of fresh snapper, with Fiji and New Zealand also being major sources. Not only has the quantity of foreign-caught fresh fish increased during the last few years, but the number of countries exporting fresh fish to Hawaiʻi has also increased. A decade ago, for example, fresh snapper was exported to Hawaiʻi mainly from within the South Pacific region. In recent years, Tonga and Australia were the largest sources of imported fresh snapper, with Fiji and New Zealand also being major sources, and Viet Nam, Chad (fresh-water fish) and Madagascar as minor sources. Although other locations would fill the market demand in Hawaii, many Hawaii restruarant owners and chefs would prefer to have fresh locally caught bottomfish on their menus due to their marketable qualities , i.e. "fresh island fish" (Coffman 2004).

7.4B Crustacean Fisheries

Most of the information in this section pertains only to the lobster fishery occurring in the NWHI. Because there are few shallow banks in the EEZ around the MHI, the MHI lobster fishery occurs almost entirely within State of Hawaii waters. One federally permitted vessel began to operate in the EEZ surrounding the MHI in 1997, but has since discontinued operations.

7.4B.1 History

Ula (lobster) was a traditional source of food for Native Hawaiians and was sometimes used in early religious ceremonies (Titcomb 1978). After the arrival of Europeans in Hawaiʻi, the lobster fishery became by far the most productive of Hawaiʻi's commercial shellfish fisheries. Early in the twentieth century, Bryan (1915:469) wrote of the local market for spiny lobster: "The lively demand for them, owing to their excellent food qualities, brings large numbers of them fresh and sprawling into the markets every day." Bryan (1915:469) also noted that the slipper lobster was "quite common in the markets" and "is a favorite food of the native people." Cobb (1902) reported that the commercial lobster catch in 1901 was 131,200 lbs. The majority of the catch at that time was probably composed of the near-shore species P. penicillatus because fishing was confined to coastal waters around the MHI (Shomura 1987). According to Cobb (1902), lobster were taken with nets set around rocks, snared with a pole to which a noose was attached or captured by hand.

A rapid and substantial increase in Hawaiʻi's population during the first decades of the twentieth century was accompanied by increased local demand for seafood and an expansion of the fisheries. The many immigrants to Hawaiifrom Asia possessed a strong fishing tradition and brought with them a culture in which fish was an integral part of the diet. Early commentary suggests that heavy fishing pressure soon depleted the lobster resources adjacent to the more populated areas of the MHI. In 1925, for example, Lorrin Thurston (1925), President and General Manager of The Honolulu Advertiser, wrote:

> In some of the out-districts of the other islands lobsters are still found; but on Oʻahu they are so scarce that they are hardly ever found in the market. The few which are caught are monopolized by the higher class restaurants and hotels, and bring extravagant prices … So far as the general community is concerned, lobsters are practically locally extinct as an article of food.

By the early 1950s, the commercial catch of P. penicillatus around the MHI had dropped by 75 to 85% (Shomura 1987). The depletion of the fishery resources in the coastal areas of the MHI encouraged Hawaii's fishermen to search for alternative fishing grounds. In particular, the Honolulu-based "sampan" fleet began to venture north to fishing grounds around the NWHI. The boats traveling to these remote islands primarily targeted bottomfish, but they also harvested lobster and other marine animals (Iversen et al. 1990). The commercial potential of a NWHI lobster fishery was recognized by Bell and Higgins (1939), who wrote: "Doubtless there are unexploited aquatic resources of unsuspected size throughout the great expanse of islands and atolls in the Hawaiian Archipelago extending westward from Kauai. For example, abundant supplies of two species of spiny lobster (Palinuridae) are reported from the French Frigate Shoals and to the westward." However, full exploitation of the marine resources of the NWHI was hindered by the dangers of traveling to the more distant islands and the difficulty of maintaining the quality of the catch during extended trips (Konishi 1930; Shinsato 1973).

It was not until the late-1970s that the development of the NWHI lobster fishery was fully realized. NMFS, U.S. Fish and Wildlife Service and Hawaii Division of Aquatic Resources joined in a cooperative agreement to conduct a five-year assessment of the biotic resources of the NWHI (Grigg and Pfund 1980). The University of Hawaii Sea Grant College Program joined the study in 1977. Among the resource surveys conducted during the "tripartite-Sea Grant" investigation was a survey of the P. marginatus resource conducted at 26 sites. Of these study sites, only Necker

Island and Maro Reef were reported to have sufficiently large stocks for commercial exploitation (Uchida and Tagami 1984).

Shortly after the survey began several commercial vessels began lobster trapping operations. The fishery was primarily developed by new fishermen coming to Hawaii from areas such as the Pacific Northwest where crustacean fisheries were experiencing declining catches (Clarke and Pooley 1988; Pooley 1993a). These newcomers came with large vessels, some over 100 ft in length, with advanced technology freezing and processing equipment (Pooley 1993a). In addition, a number of smaller, multi-purpose boats began fishing for spiny lobsters in the NWHI, combining that operation with bottomfish fishing (HDAR 1979).

A period of low catches was followed by a rapid increase in landings as more vessels entered the fishery and markets were developed (Polovina 1993). In the mid-1980s, the NWHI lobster fishery was Hawai'i's single most lucrative fishery (Pooley 1993b). Changing gear from wire to plastic traps introduced from the U.S. mainland led to significant catches of slipper lobster, which had been essentially unexploited with wire traps, and an increase in fishing efficiency (Boehlert 1993; Pooley 1993a).

Trapping activity fell in 1987 principally due to the exit of several large vessels from the fishery (Samples and Sproul 1988), but landings reached a record high in 1988 when wind and sea conditions allowed for an extended period of fishing in the upper bank areas where spiny lobsters tend to congregate (Clarke 1989).

In 1990, however, lobster catch rates fell dramatically. Overfishing is not thought to be responsible for the decline (Polovina and Mitchum 1992). Rather, the decrease was likely due to a climate-induced change in oceanic productivity (Polovina et al. 1994). Nevertheless, the 1990 season showed that there was excessive fishing capacity in the industry given the reduced population size and raised concern that an economic threshold might not prevent overfishing (Polovina and Haight 1999). Responding to this concern, the Council established a limited access program and a fleet-wide seasonal harvest quota in 1991 that significantly altered fishing operations (Kawamoto and Pooley 2000). During the 1980s, fishery participants had averaged three trips per year to the NWHI, each trip lasting about two months (Polovina 1993). With the implementation of a fleet-wide harvest quota vessels no longer fished for lobster year round, but instead shifted from other Hawai'i-based fisheries or moved from fisheries in Alaska or the West Coast to participate in a short-term (less than one month) lobster fishery concentrated on the banks around Necker Island, Gardner Pinnacles and Maro Reef that were the historic mainstays of the fishery. The lobster fishery was open from July to December but it typically closed earlier because the harvest quota was reached. Given the derby-style fishing conditions there was no incentive for fishermen to operate on secondary or marginal banks. From 1992 through 1997, Necker Island accounted for 48 to 64% of the total effort and Gardner Pinnacles and Maro Reef accounted for most of the remaining effort (WPRFMC 1999b). In 1998, the quota was allocated among four fishing areas (Necker Island Lobster Grounds, Gardner Pinnacles Lobster Grounds, Maro Reef Lobster Grounds and General NWHI Lobster Grounds) to prevent localized depletion of the lobster population at the most heavily fished banks and encourage fishermen to broaden the geographical distribution of their effort. In 2000, NMFS closed the NWHI lobster fishery due to concerns about the potential for overfishing the lobster stocks based on uncertanity in its population assessment models.

7.4B.2 Fishing Methods and Use Patterns

Two distinct types of vessels have historically operated in the NWHI lobster fishery (Maine Aquaculture Innovation Center 2000). About one-third of the permit holders operate North Pacific catcher-type crab vessels that travel to Hawaii for the lobster season. The other two-thirds operate Honolulu-based vessels that were also used in the pelagic longline fishery. The North Pacific crabbers are larger than the longline boats, but every vessel had the capability to carry and deploy the maximum number of traps allowed (1200).

All participants in the 1999 NWHI fishery use a plastic dome-shaped, single-chambered traps with two entrance funnels located on opposite sides (Polovina 1993). Although the minimum size limit established in 1985 was revoked in 1996, traps are still required to have escape vents. The traps are typically fished in strings of several hundred traps per string. The traps are set before sunset in depths from 20 to 70 m, and retrieved the next day. Both spiny and slipper lobsters may be caught in the same trap, but fishermen can alter the proportion of each species by selecting the trapping area and depth (Polovina 1993). Almost all lobsters harvested were sold as a frozen tail product. Catch was processed, packed and frozen at sea by the individual vessels, in contrast to most other lobster fisheries in which each vessel's catch is held live on-board and transported to shore-side plants for processing and packing (Sample and Gates 1987). From 1996 to 1998, the fleet also landed a significant quantity of live lobsters.

This is a seasonal fishery with vessel operators participating in other Hawaiior U.S. mainland fisheries during the remainder of the year. In 1999, the average vessel fished for lobster for 42 days (WPRFMC 2000). Although all participants in the lobster fishery engage in other fisheries, the lobster fishery occurs during a comparatively slow season for alternate fishing activities (NMFS 2000). Therefore, the lobster fishery may represent an important component of the participants' annual fishing operations and income.

Fishing beyond September involves the risk of encountering severe weather. Poor sea conditions increase operational problems, increase trap losses and reduce the fishing effectiveness of traps (Maine Aquaculture Innovation Center 2000).

Necker Island, Gardner Pinnacles and Maro Reef are the most productive banks in the NWHI lobster fishery (Table 7-24). Since 1998, the first year that area-specific quotas were established, fishermen have spread out their effort over a larger area (Kawamoto and Pooley 2000). During both the 1998 and 1999 seasons all four subareas received fishing pressure. In 1999, the Necker Island, Gardner Pinnacles and Maro Reef Lobster Grounds were closed within two months while the "all other banks" area (General NWHI Lobster Grounds) remained open until the fishery was closed at the end of the year. Five of the six vessels that participated in the fishery that year fished in the General NWHI Lobster Grounds. Three vessels fished on Necker Bank and Gardner

Pinnacles and four vessels fished on Maro Reef. The harvest from Necker Island, Gardner Pinnacles and Maro Reef accounted for about 75% of the total landings.

TABLE 7-24: Approximate Percentage of Total Catch at Selected Areas in the NWHI Lobster Fishery Based on Landings Data

AREA	PERCENT OF TOTAL CATCH
Necker Island	38.5
Maro Reef	34.0
Gardner Pinnacles	14.3
Pearl and Hermes Reef	6.7
Kure Atoll	2.8
Lisianski Island	1.5
French Frigate Shoals	1.2
Nihoa Island	0.6
St. Rogatien Bank	0.3
Pioneer Bank	0.1
Brooks Bank	0.0
Raita Bank	0.0
Twin Banks	0.0
Laysan Island	0.0
Midway Atoll	0.0

Source: M. Mitsuyasu, pers. comm. 2000. WPRFMC

7.4B.3 Harvest

Between 1985 and 1991, total landings showed an overall downward trend (Figure 7-24). Since 1992, landings have been largely determined by a harvest quota. The catch per unit effort (CPUE) expressed as number of lobsters caught per trap haul showed an overall decrease between 1983 and 1991 (Figure 7-25). There was an increase in CPUE in 1996 and 1997, followed by another decline. It is uncertain, because of the lack of catch size data, if the increased CPUE in 1996 and 1997 resulted from the 1995 implementation of Amendment 9, which instituted the "retain-all" policy.

FIGURE 7- 24: Landings of Spiny and Slipper Lobsters in the NWHI Lobster Fishery, 1983-1999 (Source: PIFSC 2002)

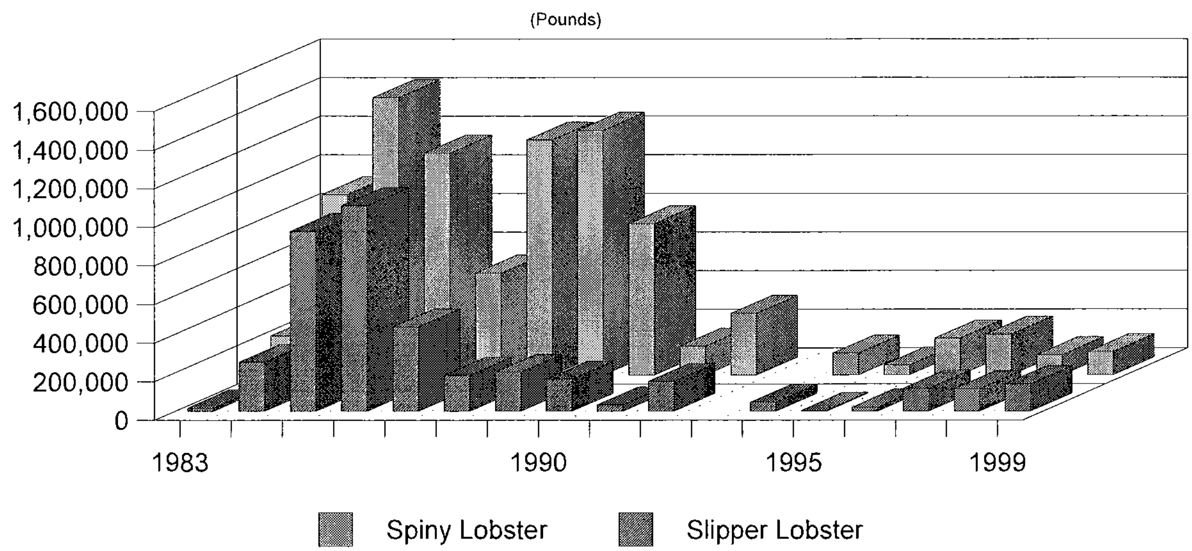
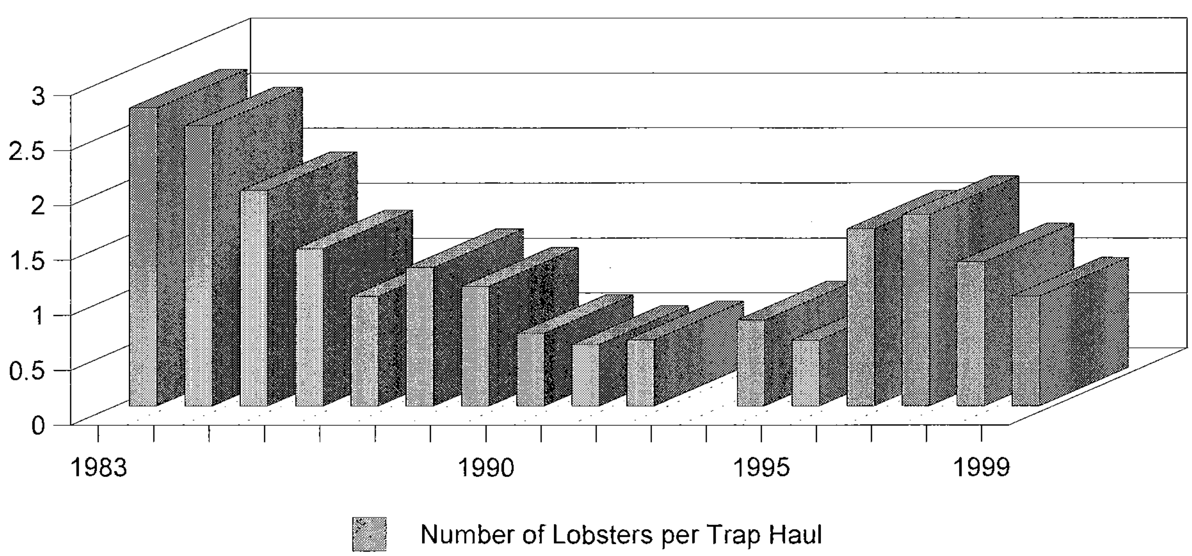


FIGURE 7-25: Catch per Unit Effort in the NWHI Lobster Fishery, 1983-1999 (Source: PIFSC 2002)



The retain all policy was put into place to offset the high lobster mortality associated with the handling and discarding (e.g. predation) associated with the NWHI lobster fishery. Using an equilibrium yeild-per-recruit model, Kobayashi (2001) found that that the reporductive potential of the NWHI lobster population more than doubled and mean weight per individual increased by 22 percent if the mortality rate of lobsters was above 75 percent. In 1996, the fishery had a discard rate of 62 percent with the discard mortality presumed to be above 75 percent (Dinardo et al. 2002). The Council amended the Crustaceans FMP in 1996 to allow the retention of all lobsters caught in the NWHI lobster fishery subject to the quota on total catch.

7.4B.4 Bycatch and non-target species

Non-targeted species account for a small percentage of the total catch in the NWHI lobster fishery, as the traps are designed for high selectivity. Also, all NWHI lobster traps are required to be equipped with escape vents. Using data from 1976-1991 (wire traps) and 1986-2003 (plastic traps) from research cruises in the NWHI, Moffit et. al (2005) examined the diversity of catch composition from the study over time. The traps used for the research do not have escape vents but otherwise conform to fishery regulations. Both wire and plastic traps were found to be highly selective, that is, they primarily catch lobsters. Wire traps caught a total of 82 species, of which the two target species of lobsters accounted for 90.5% by number. Plastic traps contained 258 species of which 73.1% were the two target species. Because lobsters are one of the larger organisms captured, they would be an even larger percentage if measured by weight. Of the organisms which were caught incidentally, hermit crabs made up the largest component followed by moray eels and small reef fish.

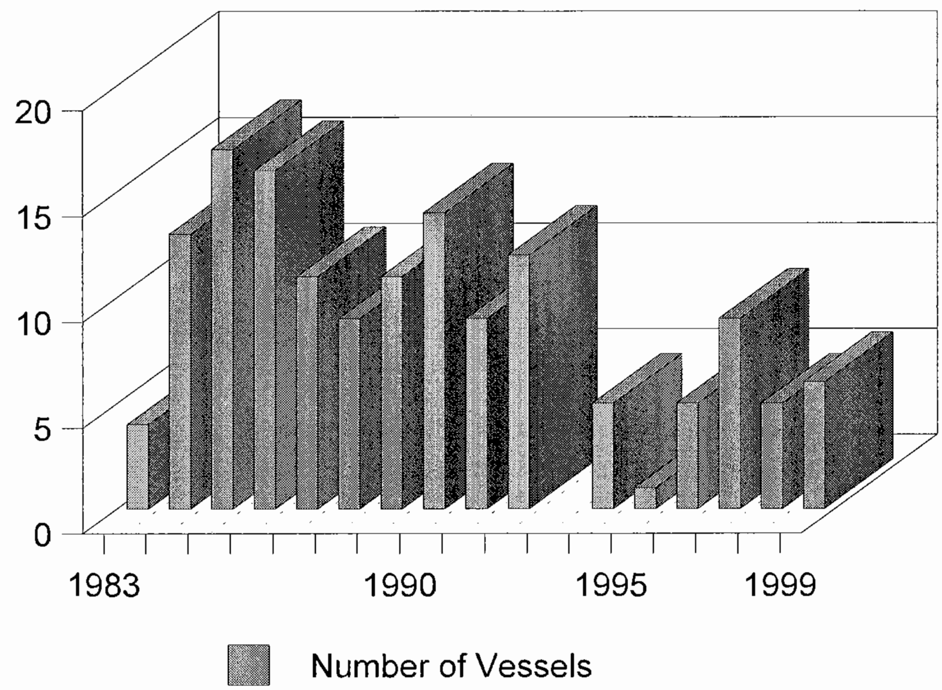
Octopus abundance was also evaluated due to its potential as a prey species for the Hawaiian monk seal. Only 83 individuals were captured during the entire 1986-2003 study period and examination of the data shows no significant decline or increase in abundance over time. Based on the data, the study found that it is unlikely that lobster trapping activities have lowered octopus abundance to such a degree that monk seal populations would be negatively impacted.

Overall, Moffit et. al (2005, in review) concluded that lobster trapping activities are responsible for changes in abundance of a few species (target species have declined and some crab species have increased due to competitive replacement) of the benthic community in the NWHI, but do not appear to have resulted in major changes to the ecosystem. Moffit et. al. also state that gear lost in this fishery has not been found to be ghost fishing (still catching organisms), and that although direct damage to the benthic habitat by the traps has not been studied, it is not likely to be substantial due to the low relief, hard substrate that characterizes the fishing grounds.

7.4B.5 Participation

At present, the 15 federal limited access permits for the NWHI lobster fishery are owned by 12 permit holders.[16]

FIGURE 7-26: Trend in Number of NWHI Lobster Vessels



During the first years of the fishery the turnover of participants was relatively high due to the profit seeking entry-exit behavior by vessel owners who were flexible in the choice of fishing activities (Samples and Sproul 1988). The high turnover continued after 1992, the first year of the limited access program and harvest quota. The quota announced prior to the start of the fishing season weighed heavily in the participation decision as did the annual start-up costs of participating in the lobster fishery and the potential earnings in alternative fisheries (Kawamoto and Pooley 2000). In addition, during the first five years of the limited access program there were

[16]The federal regulations that established the limited access program for the NWHI lobster fishery in 1992 prohibit an individual, partnership or corporation from holding a whole or partial interest in more than one permit. However, two qualified individuals who held multiple permits at the time the limited access program was implemented were allowed to retain all of their permits.

a total of 20 permit transfers. By 1997, less than half of the permits that were issued in 1991 were still held by the original recipients.

To date, approximately 37 limited access permits to participate in the NWHI lobster fishery have been issued, but only 19 of the permits have been actually used. The turn-over rate has been fairly high, with only 4 of the 19 active permit holders participating in the fishery for more than two years (Katekaru, 2001, pers. comm.)

7.4B.6 Economic Performance

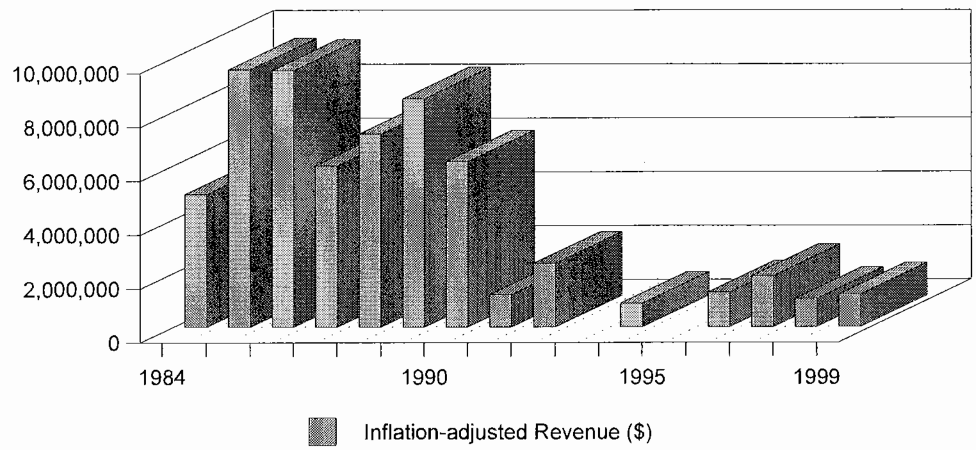
The total gross revenue of the NWHI lobster fishery has followed the trend in landings (Figure 7-27).The average gross revenue per trap has declined sharply since 1997 due to the overall decrease in CPUE and the higher catches of slipper lobsters which have a smaller average size and lower ex-vessel value in comparison to spiny lobsters (Kawamoto and Pooley 2000).

A cost-earnings study of the NWHI lobster fleet was conducted by Clarke and Pooley (1988) based on economic data collected in 1985 and 1986. The study found that despite record revenues in the fishery in 1986, fishermen as a group earned little or no economic profit. Low fleet net returns appeared to be tied to high fishing costs and diminished average catch rates. That study does not reflect current operational characteristics of the fleet, as the fishery in the mid-1980s was essentially a year-round fishery.

Since the mid-1980s, adjustments in the regulatory regime for the fishery have changed the economic conditions of the fishery (Pooley and Kawamoto 1998). Because the fishery is now seasonal rather than year-round, start-up costs have become significant determinants in yearly participation by permit holders. The brief fishing season means that fixed costs have to be amortized over a shorter time period. Similarly, travel costs have become a higher percentage of total costs due to a decrease in the number of fishing days per trip. The establishment of area-specific quotas in 1998 and the resultant successive closure of banks during the 1998 and 1999 seasons as quotas were reached caused an increase in travel times and associated vessel operating costs as vessels were forced to move from bank to bank (WPRFMC 1999b).

At least some of the permit holders have been able to adapt to these changing economic conditions. Fishery participants during the 1998 season realized a positive return on operations (gross revenues less operating costs) and were able to cover a portion of their fixed costs (WPRFMC 1999b;). In addition, the market value of the freely transferable limited access permits indicates that both economic and financial profits can still be earned in the fishery. Although the price of transferred permits is not recorded by NMFS, dockside reports in 1998 indicated that a permit was worth $40,000 to $100,000 (Pooley and Kawamoto 1998). However, the fact that generally only about half of the permits holders participated in the fishery in recent years suggests that profits from lobster fishing are low as compared to other available activities (Maine Aquaculture Innovation Center 2000).

Figure7-27: Inflation adjusted Revenue from the NWHI Lobster Fishery, 1983-1999
(Source: PIFSC 2002)



7.4B.7 Markets

As an internationally traded commodity, supply and demand circumstances for lobsters tend to be volatile, resulting in frequent price adjustments (Samples and Gates 1987). In addition, the Hawaii fishery has changed over the years in terms of target species and product form. In the early years of the fishery (1977-1984) landings consisted mainly of spiny lobsters. However, for a three-year period from 1985 to 1987 the fishery targeted a previously lightly exploited population of slipper lobsters (Polovina 1993). Between 1988 and 1997 the target was again spiny lobsters, but the catch in 1998 and 1999 consisted mainly of slipper lobsters.

The traditional way of marketing lobsters in Hawaii was selling them live in local markets (HDAR 1979). In 1978, however, a Hawai'i-based fishing company leased a modern fishing boat from the U.S. mainland equipped with on-board refrigeration for storing frozen lobster tails. Soon almost all lobsters harvested in Hawaii were sold as a frozen tail product to Hawaiiand U.S. mainland buyers (Pooley 1993). This product form dominated until 1996, when the fleet landed a significant amount of live lobsters, which were exported to Japan, Taiwan and Hong Kong or sold in up-scale restaurants in Hawaii (Pooley and Kawamoto 1998). In 1999, however, nearly all fishery participants reverted to producing frozen tails because of a drop in the price of live spiny lobsters caused by the economic downturn in Asia (Kawamoto and Pooley 2000).

Because the NWHI lobster fishery is relatively small and harvest levels have fluctuated widely, product marketing has been challenging (NMFS 2000). Typically, seafood wholesalers and retailers prefer predictable and reliable supply sources. However, NWHI lobster have established a reputation as a locally-produced quality product, and fishery participants have found buyers willing to participate on a seasonal basis.

Imports of frozen lobster tails into Hawaiifrom various Pacific Basin countries have shown an overall decline over the past decade, from 41,023 lbs in 1990 to 3,866 lbs in 1999 (NMFS Fisheries Statistics and Economics Division n.d.). A small number of live spiny lobsters are imported into Hawaii from Australia and Kiribati. The average annual amount during the past decade has been about 1,450 lbs (NMFS Fisheries Statistics and Economics Division.)

7.5C Precious Corals Fishery

Most of the information in this section pertains only to the black coral fishery occurring in Au'au Channel off Maui, as currently, it is the only fishery harvesting precious corals management unit species in the EEZ (with majority of harvest occurring in State of Hawaii waters). In 2001, American Marines Services Group received federal permits to harvest deep-water precious corals at the Makapuu Bed and in the Hawaii Exploratory Area. The company did not renew its permit, and the harvest levels from its operation can not be reported here because of NOAA's data confidentiality policy. No precious corals harvester has received a federal permit to fish in the EEZ surrounding American Samoa or Guam since the implementation of the FMP in 1980.

7.5C.1 Harvest

Between 1990 and 1997, the annual harvest of black coral in Hawaii varied from a low of 864 lb to a high of 6,017 lb, with a yearly average of 3,084 lb. As noted above, the harvest of black coral has occurred mainly in State of Hawaii waters. Table 7-25 provides historical landings and value of the black corals harvest between 1990-1997. Landings and value of the black corals recently harvested in Hawaii cannot be presented due to State of Hawaii confidentially policy.

TABLE 7-25: Volume and Value of Black Coral Landings in Hawaii (1990-97)

YEAR	HARVESTED (LB)	SOLD (LB)	VALUE ($)
1990	2349	2169	31575
1991	2305	2250	35080
1992	2398	2328	46560
1993	864	769	15380
1994	4354	4209	84180
1995	6017	5912	122765

YEAR	HARVESTED (LB)	SOLD (LB)	VALUE ($)
1996	4865	1703	41325
1997	1520	415	10394

Source: Hawaii Division of Aquatic Resources

7.5C.2 Bycatch and non-target species

The Precious Corals FMP only allows the harvest of MUS using selective gear, i.e with submersible or by hand. The use of tangle-nets and dredging is prohibited. For this reason, the precious corals fisheries in Hawaii have little to no bycatch.

7.5C.3 Economic Performance

The ex-vessel value of precious corals varies widely according to color and size. It is uncertain whether the corals harvested by the 2001 participant in the deep-water sector of the precious corals fishery were be of sufficient quality to receive the high prices required to offset the high fishing costs. The State of Hawaii's proprietary confidentiality policy restricts the public dissemination of economic reports for businesses with less than three competitors.

7.5C.4 Markets

The naming of black coral as the Hawaii state "gem" in 1987 increased consumer interest in this precious coral (Grigg 1993). However, the quantity of black coral required by jewelry manufactures in Hawaii has dropped considerably because the jewelry items produced are smaller and of higher quality and because modern cutting procedures have become much more efficient (Carleton 1987). In addition, inexpensive black coral imported from the Philippines and elsewhere fills the demand for low quality, high volume jewelry products. Maui Divers of Hawaii, Inc., the leading manufacturer and retailer of precious corals jewelry in Hawaii, buys exclusively black coral harvested in the state.

In the past, the market for colonies of black coral small enough to fit inside the typical curio display case or household aquarium was small in comparison to the market for larger trees that are processed for jewelry (Oishi 1990). According to the Hawaii Division of Aquatic Resources, however, the demand for small, immature black coral colonies has increased with the growing popularity of household marine aquaria.

The worldwide glut of Corallium produced during the boom years of the early 1980s caused the market value of pink coral to fall even below breakeven prices for Taiwanese and Japanese coral fishermen (Grigg 1993). Consequently, many fishermen dropped out of the fishery and the worldwide supply of deep-water precious corals has dwindled. For the past 20 years Hawaii businesses engaged in the manufacture of deep-water precious corals jewelry have relied on local stockpiles of gold coral and imports of pink coral from foreign suppliers. Prices for precious corals have gradually increased, and specimens of the highest quality pink coral currently sell for $5,000/lb in international auctions. However, changes in the jewelry industry during the past decade may have diminished the demand for precious corals. Products such as black pearls have captured a substantial share of the market formerly held by precious corals (C. Marsh pers. comm. 2000 Maui Divers of Hawaii, Inc., Honolulu). The precious corals jewelry industry in Hawaii has been estimated to be worth about $25 million at the retail level (Grigg 1993).

7.4D Coral Reef Ecosystems Fishery

7.4D.1 Main Hawaiian Islands

In recent decades, there has been a notable decline in nearshore fishery resources in the main Hawaiian Islands (Shomura 1987). Overfishing is considered to be one of the major causes of this decline (Grigg 1997; Harman and Katekaru 1988), but coastal construction, sedimentation, and other effects of urbanization have caused extensive damage to coral reefs and benthic habitat near the populated islands.

The majority of the total commercial catch of inshore fishes, invertebrates, and seaweed comes from nearshore reef areas around the MHI. The exceptions are crustaceans: over 90% of the spiny lobster landings come from the NWHI and over 50% of Kona crab landings come from Penguin Bank.

However, Holland (1985 in Friedlander 1996) noted that the Kewalo Basin charter fishing fleet uses Penguin Bank as one of its major fishing areas. Offshore and inshore fishing gear are used on Penguin Bank in about equal importance. Table 7-26 lists, in decreasing order of catch, offshore gear and inshore gear. Table 7-28 lists the most common reef/inshore fish species reported in commercial landings from Penguin Bank over the past decade, by five-year periods. Catches for most species are generally comparable for both periods with slightly less taken in the last period (1995-2000). Sharks appear to have been under-reported in the earlier period (1991-1995).

TABLE 7-26: Mean Annual Catch (lb) of Most Commonly Reported Inshore Fish Species from Penguin Bank (2-200 nm)

Species/Taxa	1991-1995	1996-2000
Bigeye scad (Selar crumenophthalums)	537	474
Goatfish (Mulloidichthys vanicolensis)	264	165
Surgeonfish (Acanthurus xanthopterus)	204	65
Scad (Decapterus spp.)	152	41
Wrasse (Bodianus bilunulatus)	149	62

Barracuda (Sphyraena helleri)	111	56
Wrasse (Xyrichthys pavo)	111	176
Sharks (misc.)	65	3605
Other goatfish (Parupeneus spp.)	37	6
Big-eye-fish (Priacanthus spp.)	28	30
Parrotfish (Scarid spp.)	22	-
Trumpetfish (Aulustoma chinensis)	14	1
Soldierfish (Myripristis spp.)	12	31
Leatherback (Scomberoides lysan)	5	6
Surgeonfish (Acanthurus dussumieri)	4	1
Surgeonfish (A. olivaceus)	4	-
Goatfish (Parupeneus porphyreus)	2	1
Unicornfish (Naso spp.)	1	1
Threadfin (Polydactylus sexfilis)	1	-
Wrasse (Coris spp.)	1	3
Flyingfish (Exocoetus spp.)	-	1

Source: Based on reported DAR commercial fisheries catch statistics from 1991-1995 (modified from Friedlander 1996) and from 1996-2000 (D. Hamm, pers. comm).

TABLE 7-27: Mean actual catch (lbs) by gear type from Penguin Bank (2-200 nm)

Gear Type	Catch (lbs/yr)
Offshore gear	
Aku pole & line	67486
Trolling	26607
Tuna handline	1295
Subtotal	95388
Inshore gear	
Deep handline	83517

Net	14191
Inshore handline	2485
Other	573
Trap	493
Diving	22
Subtotal	101281
Total	**196670**

Source: Based on reported DAR commercial fisheries catch statistics from 1991-1995 (modified from Friedlander 1996) and from 1996-2000 (D. Hamm, pers. comm).

Limited information is available on coral reef fish community structure at Penguin Bank. An investigation of deepwater artificial reefs on the bank, using manned submersibles, recorded 62 taxa (25 families), of which 32 were considered resident, 25 transient, and five incidental (Friedlander 1996). Estimates of mean biomass ranged from 3-290 mt/km^2 for resident species to 90-2,460 mt/km^2 for transient species. However, these estimates are considered high for the area, since several studies have shown that artificial reefs tend to support a higher biomass than natural reefs under similar circumstances.

An investigation of the deepwater macroalgal community, using a manned submersible, provides information on algae at Penguin Bank (Norris *et al.* 1995). The bank consists of a broad carbonate platform (~60m deep) covered with loose carbonate rubble and coarse sediments from the calcareous green alga, *Halimeda.* The algal community, comprising 54 species, is characterized by two deepwater species and many species that occur in shallow water. The deeper areas of the bank (182 m) are dominated by crustose coralline algae.

When reef-associated species that are presently managed under other Council FMPs are excluded from the analysis, almost all of the coral reef fisheries in Hawaii take place in inshore (state) waters in the MHI (Friedlander 1996). For example, in Hawaii less than 12% of the inshore fishes are caught in federal waters, based on reported commercial catch from 1991-1995. Similarly, only 18% of molluscs, 1% of seaweeds, and no echinoderms are harvested in federal waters. Of the crustaceans, less than 50% of the reported commercial catch of Kona crab—or 14,191 lbs. valued at $57,436—were taken in federal waters on Penguin Bank. Overall, only 1% of total catch, measured either by weight or value, comes from EEZ waters.

The top species by weight and value in the DAR inshore fish category were soldierfishes (*Myripristis* spp.), parrotfish (*Scarid* spp.), surgeonfishes (including *Acanthurus dussumieri, A. trostegus* and *Naso* spp.) and goatfishes (including *Mulloidichthys* spp.). Inshore fishermen target some of these species (especially the goatfishes *Parupeneus porphyreus* and *P.*

cyclostomus), since they can fetch a high price in some seasons (Friedlander 1996). *Tilapia* spp. ranked high in terms of catch, but because it sells for a low price, it does not rank very high in terms of value. In the MHI, 89% of the catch of these species came from state waters.

Crabs are also an important group for commercial, recreational, and subsistence fishermen in Hawaii, with a mean annual commercial value of $182,182 (Friedlander 1996). The dominant species in the catch is Kona crab (*Ranina ranina*) with more than 28,000 lbs. caught annually. By weight, 51% of Kona crab are caught on Penguin Bank, which has long been an important location for Kona crab net harvests of (Onizuka 1972). In contrast, almost all of the other crab species were caught less than 2 nm from shore in the MHI.

7.4D.2 NWHI

Surveys of the NWHI demonstrate that coral reefs are in good condition with high standing stocks of many reef fish. Nearshore coral reefs receive little human use because of their remoteness, exposure to harsh seasonal ocean conditions, and their protected status as part of a national wildlife refuge. Most of the shallow reefs of the NWHI lie within the boundaries of the State of Hawaii, where access and resource use are controlled by special permit .

There is a long history of fishing in the NWHI. Iverson *et al.* (1989) found ample evidence of fishing by the ancient Hawaiians as far northwest as Necker Island. Starting in the 1920s, a handful of commercial boats ventured into the NWHI to fish for shallow and deepwater bottomfish, spiny lobsters, and other reef and inshore species. Black-lipped pearl oysters at Pearl and Hermes Reef in the NWHI were overfished in the late 1920s and recent surveys show that stocks have still not recovered, due to lack of suitable oyster shell habitat (Green 1997). As discussed in the previous section, from the late 1940s to the late 1950s, there was a fishery for *akule* and reef fish around French Frigate Shoals and Nihoa Island.

Currently, there are no coral reef fisheries operating in the NWHI. Occasional visitors, including federal government personnel and contract workers at Midway Atoll, fish recreationally in the NWHI.

7.4D Bycatch and Non-target Species

All gears used to catch coral reef species are essentially artisanal in nature. Catch rates are minimal, usually only a few pounds per man-hour or other unit of effort. Large catches thus depend on fishing methods employing a lot of people, such as driven-in-net fishing or group spear fishing. Because of the characteristics of gear and methods, in most cases coral reef fishing generates very little bycatch. Bycatch is further reduced because almost all reef fish taken are eaten.

In the Pacific Islands, discards, where they occur, are usually due to cultural or practical reasons. In some cultures customary taboos may still adhere. For example, people may avoid nearshore copraphageous scavengers, such as surf perches (Theraponidae) for this reason. Taboos may also stem from the association between a species and gender, as is the case with moorish idols (Zanclidae).

Reef fish preference is also strongly influenced by urbanization: many city dwellers eat a narrower range of reef fish than their brethren in traditional villages on the same island or of the same culture. For example, in Guam triggerfish, butterflyfish, angelfish, and damselfish are typically rejected because they are considered too boney and lacking sufficient meat, while in rural areas in Micronesia these species are readily consumed. Some reef fish in Hawaii state waters are also subject to minimum size and weight restrictions for sale or for capture by spearfishing. These include species of parrotfish, goatfish, jacks, surgeonfish, mullet, milkfish, and threadfins.

In other cases, fish may be avoided due to toxicity. Puffers, toad fish, and porcupine fish (Tetraodontidae, Diodontidae) carry ichthyotoxins, while ichthyosarcotoxicity due to ciguatoxins and related toxins cause people to avoid a wide range of species, including the snapper *Lutjanus bohar*, surgeon fish *Ctenochaetus* spp., moray eels (Muraenidae), groupers (Serranidae), amberjack (*Seriola dumerilli*), and barracuda (Sphyraenidae).

Three fishing gears predominate in Pacific Island coral reefs and lagoons: hook-and-line or handline, spearguns and gillnets. The bycatch characteristics of each of these gear types is summarized below.

Hook-and-Line: Hook-and-line catches generally target carnivorous species of fish, although herbivores can be enticed to take baited hooks. Catch and selectivity of hook-and-line gear is a function of hook size, bait used, and the depth fished. Hook size and bait can select for size, with larger hooks and harder baits tending to catch larger fish. Similarly, fish size tends to increase with depth on the reef slope, although species diversity tends to decrease. Fishermen may use combinations of these factors to sharpen the focus of their fishing, particularly targeting bottomfish on the deep reef slope.

The amberjack *Seriola dumerilii*, frequently a part of deep-slope bottomfish catches in the NWHI, are discarded because they are thought to carry worms and the ciguatera toxin which makes marketing this species difficult. This is reinforced by the selectivity of fish by the fish auction at Honolulu which do not accept these fish. However, small amount of amberjack may be retained for use as bait in crab pots. The other major discard in this fishery is the thick-lipped trevally or *butaguchi* (*Pseudocaranx dentex*), which has a fairly short shelf life and commands a low price in local markets. Therefore, it is often discarded in the early days of a trip to avoid losing room for more valuable fishes, but are retained in the later days to fill fish holds if necessary.

Spearfishing: Underwater fishing with spearguns—either with scuba or snorkels—is extremely selective, since the act of capture involves a deliberate choice of target. Bycatch is likely restricted to speared fish that escape with minor wounds. Spearfishing tends to select by size, with a bias towards larger size fish and larger sizes of a given species (Dalzell 1996). Catch composition may also be different between day and night when different groups of fish are active or sedentary. Night divers can take advantage of the sleeping habits of some parrotfish to cluster in "dormitories" on the reef and therefore be especially vulnerable to spearing.

Hawaiian spearfish catches are dominated by parrotfish, surgeonfish, octopus, and squirrelfish. In areas with greater reef fish diversity, such as Guam, spearfish catches are still mainly dominated by surgeonfish, and parrotfish. Other common families—such as rabbitfish, emperors, snappers, and jacks—also contribute to catches.

Fish Traps: Fish trapping for finfish is not widely practiced in the Western Pacific Region, and is only conducted with any frequency in Hawaii. Traps, like nets, take a large random assortment of different species that probably reflects the proportions of different species groups on coral reefs. Surgeonfish dominate catches in Hawaii, making up 31% of commercial landings, and are comparable to reef fish catches in traps elsewhere in the Pacific (Dalzell 1996).

The main commercial trap fishery on Hawaii's coral reefs is in NWHI. It targets spiny lobster and slipper lobster, rather than reef fish. The fortunes of this fishery have waxed and waned over two decades, with catches in excess of a million lobsters annually in the 1980's, but with much more modest catches of between 100,000 and 300,000 lobsters in the late 1990's. The lobster traps also catch a wide range of other coral reef species, mainly reef fish and reef crustaceans. In the initial years of the fishery, many octopus were also caught and kept, but octopus catches dropped off to negligible amounts by the 1990's because of the use of escape vents. The lobster traps are two-piece plastic halves joined with pins that dissolve in seawater, preventing ghost-fishing by lost traps. They also have a series of small holes in the trap walls to allow undersized lobster and other small bycatch species to escape. Polovina (1993) reports that an estimated 2,000 traps are lost annually in the NWHI. Parrish and Kazama (1992) found that while lobsters may enter these traps, they were also able to exit and there were no observed mortalities associated with ghost fishing. These researchers concluded that lobsters utilized the traps as shelter.

Selection effects in traps are a function of the soak time, mesh size, materials used to construct the traps, trap design, and the depth and position of the set. Traps set in relatively shallow water with little or no bait will generally maximize catches within 4-5 days. Traps baited with fish such as *aku* (skipjack tuna) or sardines and set on deep reef slopes may catch sizeable quantities of fish in a matter of hours rather than days, but the composition is very different, reflecting the generally large highly mobile carnivore complex of the deep reef slope.

Nets: In Hawaii, gillnets mostly catch the bigeye scad or *akule*. Other dominant species include surgeonfish, snappers, goatfish, and rudderfish. Goatfish, surgeonfish, parrotfish, and siganids are dominant features of gillnet catches in Guam. There are differences between night and day gillnet catches, with some nocturnally active species such as slipmouths composing part of night gillnet sets.

For smooth fusiform—or cigar-shaped—fish, gillnets tend to select a normally distributed size range, with the lower and upper size limits dependant on mesh size. Spiny fishes may be very vulnerable to gillnet catches, regardless of mesh size, because of tangling. Seasonality can also influence gillnet catches. Fish become more vulnerable during spawning season because gonad development increases their girth and spawning changes behavior (Ehrhardt and Die 1988). The selection effects of gillnets are further complicated by the type of material used, the hanging ratio or measure of meshes per unit of length, the way the net is deployed on a reef, the time of day set, and length of soak. If gillnets are not checked regularly, bycatch may increase. Entangled fish build up in the net; if they are not removed, they are either preyed on or rot and become unsaleable.

Seine nets are actively deployed around schools of fish, as opposed to gillnets, which—like fish traps—are a passive gear. Beach seines, as the name implies, are set in an arc from the beach. Both wings are drawn together on the beach and hauled to concentrate the fish in the head of the net, from where they can be bucketed ashore. Seine nets can also be used for drive-in-net, or muro-ami, fishing. A barrier net is set in the lagoon or on a reef, and fish are driven with scare lines into the apex of the net, which is then closed to catch the fish. The amount of bycatch from this type of fishing depends on whether people are largely urbanized and used to eating a narrow range of reef fish, or whether they mainly rely on fishing for subsistence and eat a broader range of fish.

Surround seines can also be set on open schools in a lagoon in the same manner as a beach seine. This fishing method is employed in Hawaii to catch schools of big-eye scad or *akule*, which are located by spotting from light aircraft. This method of fishing is extremely selective, bycatch results when not all the captured school is kept and excess fish will be released. In such cases the release of fish is commendable since they are not wasted as dead bycatch.

Lastly, cast or throw nets are also common in parts of the Pacific, where fishermen want to make modest catches, usually of small nearshore schooling reef species. These catches are taken mainly for subsistence, and fishermen will select and stalk on foot schools of fish such as surgeonfish, herrings, rabbitfish, and mullets in the hope of obtaining a catch (Dalzell *et al.* 1996). As with spearfishing, there is a high degree of selectivity in the target catch, so bycatch is negligible.

7.4E Pelagic Fishery

Hawaii's pelagic fisheries are small in comparison with other Pacific pelagic fisheries, but comprise the largest fishery sector in the State of Hawaii (Pooley 1993) (Tables 7-14, 15). Tuna, billfish and other tropical pelagic species supply most of the fresh pelagic fish consumed by Hawaii residents and support popular recreational fisheries (Boggs and Kikawa 1993).

The longline fleet has historically operated in two distinct modes based on gear deployment: deep-set longline by vessels that target primarily tuna and shallow-set longlines by those that target swordfish or have mixed target trips including albacore and yellowfin tuna. Swordfish and mixed target sets are buoyed to the surface, have few hooks between floats, and are relatively shallow. These sets use a large number of lightsticks since swordfish are primarily targeted at night. Tuna sets use a different type of float placed much further apart, have more hooks per foot between the floats and the hooks are set much deeper in the water column. These sets must be placed by use of a line shooter to provide slack in the line which allows it to sink.

The longline fishery accounted for the majority of Hawaii's commercial pelagic landings (17.3 million lb) in 2003 (Table 7-28). The fleet includes a few wood and fiberglass vessels, and many newer steel longliners that were previously engaged in fisheries off the U.S. mainland. None of the vessels are over 101 ft in length and the total number is limited to 164 vessels by a permit moratorium.

TABLE 7- 28: Hawaii-based longline fishery landings 1999-2003 (Source: NMFS, PIFSC, published and unpublished data)

Item	1999	2000	2001	2002	2003
Area Fished	EEZ and high seas	EEZ and high seas	EEZ and high seas	EEZ and high seas	EEZ and high seas
Total Landings (million lbs)	28.3	23.8	15.6	17.5	17.3
Catch Composition*					
Tuna	41%	41%	52%	52%	65%
Swordfish	9%	9%	1%	1%	2%
Miscellaneous	32%	32%	36%	37%	31%
Sharks	18%	18%	11%	10%	2%
Season	All year	All year	All year	All year	All year
Active Vessels	119	125	101	100	110
Total Permits	164	164	164	164	164
Total Trips	1137	1103	1034	1164	1216
Total Ex-vessel Value (nominal) ($millions)	$47.4	$50.2	$33.0	$37.5	$37.5

* Number of fish

The Hawaii-based skipjack tuna, or *aku* (skipjack tuna) fishery, is also known as the pole-and-line fishery or the bait boat fishery because of its use of live bait. The *aku* fishery is a labor-intensive and highly selective operation. Live bait is broadcast to entice the primary targets of skipjack and juvenile yellowfin tuna to bite on lures made from barbless hooks with feather skirts. Tuna are hooked on lines and in one motion swung onto the boat deck by crew members.

The aku fishing fleet has declined from a maximum of 32 vessels in the 1950s to only 2-3 vessels. This fleet currently lands about 700,000 lbs of fish (Table 7-29).

Pelagic handline fishing is used to catch yellowfin and bigeye tunas with simple gear and small boats. Handline gear is set below the surface to catch relatively small quantities of large, deep-swimming tuna that are suitable for *sashimi* markets. This fishery continues in isolated areas of the Pacific and is the basis of an important commercial fishery in Hawaii (Table 7-29). Three methods of pelagic handline fishing are practiced in Hawaii, the *ika-shibi* (nighttime) method, the *palu-ahi* (daytime) method and seamount fishing (which combines both handline and troll methods).

Troll fishing is conducted by towing lures or baited hooks from a moving vessel, using big-game-type rods and reels as well as hydraulic haulers, outriggers and other gear. Up to six lines rigged with artificial lures or live bait may be trolled when outrigger poles are used to keep gear from tangling. When using live bait, trollers move at slower speeds to permit the bait to swim "naturally." The majority of Hawaii-based commercial troll production (Table 7-29) is generated by part time fishermen, however, some full-time commercial trollers do exist.

The total volume of pelagic fish caught annually from the NWHI by the commercial pelagic handline and troll fishery amounts about 450,000 lbs (Reginald Kokubun, Hawaii Division of Aquatic Resources, pers comm.), comprising principally yellowfin tuna and wahoo. Total pelagic fish catches in Hawaii, from commercial and recreational fishing amount to about 33 million lbs, of which the NWHI amount to about 1.4%. Yellowfin biomass in the Central and Western Pacific is currently estimated to lie between 1.5 and 3.1 million mt (Hampton et al, 2004). The total volume of yellowfin caught annually from the NWHI by the commercial mixed handline and troll fishery amounts about 170,000 lbs (77 mt) (Reginald Kokubun, Hawaii Division of Aquatic Resources, pers comm.), or 0.003-0.005% of the biomass

Hawaii's charter fisheries primarily troll for billfish. Big game sportfishing rods and reels are used, with four to six lines trolled at any time with outriggers. Both artificial and natural baits are used. In addition to lures, trollers occasionally use freshly caught skipjack tuna and small yellowfin tuna as live bait to attract marlin, the favored landings for charter vessels, as well as yellowfin tuna.

The recreational fleet primarily employs troll gear to target pelagic species. Although their motivation for fishing is recreational, some of these vessel operators sell a portion of their landings to cover fishing expenses and have been termed "expense" fishermen (Hamilton 1999). While some of the fishing methods and other characteristics of this fleet are similar to those described for the commercial troll fleet, a survey of recreational and expense fishermen showed substantial differences in equipment, avidity and catch rates compared to commercial operations. Vessel operators engaged in subsistence fishing are included in this recreational category.

Little is known about the scale of recreational fishing activities in the NWHI. A charter vessel operation was maintained at Midway Atoll by an eco-tourism operator, but this activity terminated in 2002. Some long range charter operators may be interested in fishing in the NWHI (David Itano, University of Hawaii pers comm.) where competition for pelagic fish is several orders of magnitude lower than in the Main Hawaiian Islands.

TABLE 7-29. Fishery information for Hawaii's non-longline pelagic fisheries for 2002 (Source: WPRFMC, 2004)

Gear/Vessel Type	Troll/Handline	Pole-and-line Fishery (*Aku* Fishery)
Area Fished	Inshore and EEZ	Inshore and EEZ
Total Landings	3.4 million pounds	696,000 pounds
Catch Composition	48% yellowfin 18% mahimahi 10% wahoo 8% albacore 7% blue marlin	99.6% skipjack tuna <1% <1% <1% <1%
Season	All year	All year
Active Vessels	1455	6
Total Permits	NA	NA
Total Trips	18700	198
Total Ex-vessel Value	$8 million	$1.1 million

7.4E.1 Bycatch and non-target species

There is little byctach in Hawaii's non-longline pelagic fisheries. In the NWHI, fishers primarily are tolling for uku, mahi mahi, ono, or handlining for ahi. The gear and bait methods practiced are highly selective. For the most part, non-target species caught in these fisheries on such gears are often marketable and thus, would not be discarded.

7.5 Regional Economy and Society

The State of Hawai'i lies 2,500 miles southwest of North America, the nearest continental land mass. The eight main islands are part of a 137-island archipelago stretching 1,523 miles from Kure Atoll in the northwest to the island of Hawai'i in the southwest. The total land area of the archipelago is 6,423 square miles. The main islands include O'ahu, Maui, Kaua'i, Ni'ihau, Hawai'i, Moloka'i, Kaho'olawe and Lāna'i. Hawai'i was established as a territory of the United States in 1900 and became the 50th state in 1959.

7.5.1. Overview of the Economy

Income generation in Hawai'i is characterized by tourism, federal defense spending and, to a lesser extent, agriculture (Table 7-30). Tourism is by far the leading industry in Hawai'i in terms of generating jobs and contributing to gross state product. The World Travel and Tourism Council (1999) estimates that tourism in Hawai'i directly generated 134,300 jobs in 1999. This figure represents 22.6 percent of the total workforce.

For 2002, DBEDT estimates that direct and indirect visitor contribution to the state economy was 22.3%. A bit less than half of that (10.2%) was generated in Waikiki. Total visitor expenditures in Hawaii were $9,993,775,000. Tourism's direct and indirect contribution to Hawaii's Gross State Product in 2002 was estimated at $7,974,000,000, or 17.3% of the total. Directly and indirectly, tourism accounted for 22.3% of all civilian jobs, and 26.4% of all local and state taxes.

Department of Defense expenditures in Hawaii in 2002 were $4,293,459,000. Defense expenditures in Hawaii are expected to increase significantly in the near future. These expenditures fall into two broad categories: monies for the pending arrival of the Stryker force, which requires changes in facilities and additional facilities; and the renovation of old military housing as well as the construction of new military housing. As of late July 2004, Hawaii is expected to receive $496.7 million in defense-related spending. When combined with funds earmarked for construction that are contained in a measure before the Senate, Hawaii stands to receive more than $865 million in defense dollars, which do not include funds for day to day operations or payroll (Inouye 2004).

Agricultural products include sugarcane, pineapples (which together brought in $269.2 million in 1997), nursery stock, livestock, and macadamia nuts. In 2002, agriculture generated a total of $510,672,000 in sales. Agricultural employment decreased from 7,850 workers in 2000 to 6,850 in 2003. This change may be due to the increasing use of lots zoned for agriculture for construction of high-end homes, a trend which is evident throughout the state.

TABLE 7-30: Statistical Summary of Hawai'i's Economy, 1995-1999, 2002

CATEGORY	UNITS	1995	1996	1997	1998	1999	2002
Civilian Labor Force	Number	576400	590200	592000	595000	594800	582200
Unemployment	Percent	5.9	6.4	6.4	6.2	5.6	4.2
Gross state product in 1996 dollars	$ Millions	37963	37517	37996	38015	38047	38,839 (2001)
Manufacturing Sales	$ Millions	2045	1724.1	1468.8	NA	NA	NA
Agriculture (all crops and livestock)	$ Millions	492.7	494.6	486.5	492.6	512992	510672
Construction completed	$ Millions	3153.3	3196.4	2864.9	NA	NA	NA
Retail sales	$ Millions	15693	16565	16426	NA	NA	NA
Defense expenditures	$ Millions	3782.5	3883.5	4074.9	4103.7	4174.2	4293459

Source: DBEDT 1999, 2002; BOH 1999a

Median household income in Hawai'i was calculated to be $40,827 in 1990, rising to $49,820 in 1999. Statewide per capita income in 1989 was calculated to be $15,770, rising to $25,684 in 1995 and $27,544 in 1999. The figure for 2002 is $30,040, or 97% of the national average. Hawaii per capital income as a percentage of the national average figure has fallen steadily since 1970 (DBEDT 2003). The poverty rate in Hawai'i grew more over the 1990s than in the nation as a whole. Despite this growth, Hawai'i's poverty rate, which increased from 11.2 percent in 1988-89 to 12.4 percent in 1997-98, remained lower than the national rate (13.0 percent in 1997-98). In 1999, 8% of Hawaii's families were below poverty level, compared to 9% nationally according to the 2000 Census. Hawai'i employment growth was virtually nil for most of the 1990s, continuing through to the end of 1998. Civilian employment has decreased from 411,250 in 1991 to 396,050 in 2002, which is a decrease from 98% of all civilian labor force having employment, to 96%.

For several decades Hawai'i benefitted from the strength of regional economies around the Pacific that supported the state's dominant economic sector and principal source of external receipts – tourism (BOH 1999a). In addition, industries of long-standing importance in Hawai'i, such as the federal military sector and plantation agriculture, also experienced significant growth. However, Hawai'i's economic situation changed dramatically in the 1990s. The state's main tourist market, Japan, entered a long period of economic malaise that caused the tourism industry in Hawai'i to stagnate. The post-Cold War era brought military downsizing. Tens of thousands of acres of plantation lands, along with downstream processing facilities, were idled by the end of the decade due to high production costs. Employment in Hawai'i sugar production fell by 20% between 1990 and 1993 and by an additional 50% from 1994 to 1995 (Yuen et al. 1997). Net out-migration became the norm in Hawai'i, notwithstanding the state's appeal as a place to live. In 1998, the state-wide unemployment rate was 6.2%, and unemployment on the island of Moloka'i reached 15% (DBEDT 1999).

By 2002, an improving economy showed a statewide unemployment rate of 4.4%, with Molokai down to 8.6% (DBEDT 2003). Despite downswings in tourism in the last few years due to the events of 9/11, the SARS scare, Japanese economic issues, and world political conditions, tourism in Hawaii is improving to the point that there are fears that there will not be enough hotel rooms to accommodate all the Japanese tourists who want to come for O Bon season in August 2004 (Schafers 2004).

As a consequence of the economic upheaval of the 1990s and the extensive bankruptcies, foreclosures and unemployment, Hawai'i never entered the period of economic prosperity that many U.S. mainland states experienced. Between 1998 and 2000, Hawai'i's tourism industry recovered substantially, mainly because the strength of the national economy promoted growth in visitor arrivals from the continental U.S. (Brewbaker 2000). However, efforts to diversify the economy and thereby make it less vulnerable to future economic downturns have met with little success. The events of September 11, 2001 and their negative effects on travel and tourism have halted Hawai'i's short-lived economic recovery. To date, economic development initiatives such as promoting Hawai'i as a center for high-tech industry have attracted few investors. It is unlikely that any new major industry will develop in Hawai'i in the near future to significantly increase employment opportunities and broaden the state's economy beyond tourism, the military, and construction.

7.5.2 Fishing Related Economic Activities

The harvest and processing of fishery resources play a minor role in Hawai'i's economy. The most recent estimate of the contribution of the commercial, charter and recreational fishing sectors to the state economy indicated that in 1992, these sectors contributed $118.79 million of output (production) and $34.29 million of household income and employed 1,469 people (Sharma et al. 1999). These contributions accounted for only 0.25% of total state output ($47.4 billion), 0.17% of household income ($20.2 billion) and 0.19% of employment (757,132 jobs). However, in contrast to the sharp decline in some traditional mainstays of Hawai'i's economy such as large-scale agriculture the fishing industry has been fairly stable during the past decade. Total revenues in Hawai'i's pelagic, bottomfish and lobster fisheries in 1998 were about 10% higher than 1988 revenues (adjusted for inflation) in those fisheries.

Hawai'i's commercial fishing sector includes a wide array of fisheries. The Hawai'i longline fishery is by far the most important economically, accounting for 73 percent of the estimated ex-vessel value of the total commercial fish landings in the state in 1999 (Table 7-31). As shown inthat table, the NWHI and MHI bottomfish fisheries account for a relatively small share of the landings and value of the state's commercial fisheries.

TABLE 7-31: Volume and Value of Commercial Fish Landings in Hawai'i by Fishery, 1999

FISHERY	POUNDS LANDED (1,000s)	PERCENT OF TOTAL POUNDS LANDED	EX-VESSEL VALUE ($1,000s)	PERCENT OF TOTAL EX-VESSEL VALUE
Pelagic longline	28300	75%	47400	73%
Troll	2960	8%	4550	7%
Pelagic handline	2340	6%	3950	6%
Aku pole and line	1450	4%	1850	3%
MHI bottomfish handline	420	1%	1300	2%
NWHI bottomfish handline	370	1%	1210	2%
NWHI lobster trap	260	1%	1040	2%
All other fisheries	1650	4%	3330	5%
Total	37750	100%	64630	100%

Source: Data compiled by PIFSC.

Another perspective on the role of bottomfish in Hawaii is to compare landings with pelagic, reef fish, and other fish. Table 7-32 shows the changing patterns from 2000 to 2003 (National Marine Fisheries Service 2004).

TABLE 7-32: Annual Estimated Commercial Landings in Hawaii (1000lbs), 2000-2003

YEAR	PELAGIC FISH	BOTTOMFISH	REEF FISH	OTHER FISH
2000	26763	718	199	957
2001	22011	660	250	591

YEAR	PELAGIC FISH	BOTTOMFISH	REEF FISH	OTHER FISH
2002	22330	621	345	662
2003	21993	602	315	661

Estimates of the economic activity in the various sectors (commercial, charter and recreational) of Hawaiʻi's bottomfish fishery can be obtained from various published data. According to the WPRFMC (1999a), for the period 1994-1998, the ex-vessel value of annual commercial landings in the NWHI and MHI bottomfish fisheries averaged about $1,096,200 and $1,625,800, respectively. Based on data collected in a recent cost-earnings study of Hawaiʻi's charter fishing industry (Hamilton 1998), it is estimated that the charter boat fleet earns about $342,675 per year from taking patrons on bottomfish fishing trips. Finally, based on information gathered in a recent cost-earnings study of Hawaiʻi's small boat fishery (Hamilton and Huffman 1997), it is estimated that annual personal consumption expenditures for recreational vessels engaged in bottomfish fishing total about $2,827,096. Recreational vessels are fishing boats that do not sell any portion of their catch.

However, the above values reflect only the direct revenues and expenditures in the various sectors of the bottomfish fishery. They do not take into account that employment and income are also generated indirectly within the state by commercial, recreational and charter fishing for bottomfish. The fishery has an economic impact on businesses whose goods and services are used as inputs in the fishery such as fuel suppliers, chandlers, gear manufacturers, boatyards, tackle shops, ice plants, bait shops and insurance brokers. In addition, the fishery has an impact on businesses that use fishery products as inputs for their own production of goods and services. Firms that buy, process or distribute fishery products include seafood wholesale and retail dealers, restaurants, hotels and retail markets. Both the restaurant and hotel trade and the charter fishing industry are closely linked to the tourism base that is so important to Hawaiʻi's economy. Finally, people earning incomes directly or indirectly from the fishery make expenditures within the economy as well, generating additional jobs and income.

A more accurate assessment of current contributions of the bottomfish fishery to the economy can be obtained using the Type II output, income and employment multipliers calculated by Sharma et al. (1999) for Hawaiʻi's (non-longline) commercial, charter and recreational fishing sectors. Applying these multipliers to an approximation of the final demand in each of the sectors involved in bottomfish fishing, it is estimated that this fishing activity contributes $10.78 million of output (production) and $2.51 million of household income to the state economy and creates the equivalent of 113 full-time jobs (Table 7-33).[17]

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[17]Several input-output models other than the one used here are available to study economic impacts. The model developed by Sharma et al. (1999) is based on data collected in Hawaiʻi over a number of years, and is believed to be the best available for analyzing Hawaiʻi's fisheries. It should be noted, however, that different practitioners may apply a model in different ways.

TABLE 7-33: Estimated Output, Household Income and Employment Generated by Bottomfish Fishing Activity in Hawai'i

FISHERY	SALES ($)	FINAL DEMAND ($)	OUTPUT ($)	HOUSEHOLD INCOME ($)	EMPLOYMENT (JOBS)[1]
NWHI bottomfish fishery					
Commercial vessels[2]	1096200	580,986	1,382,747	482,218	25
MHI bottomfish fishery					
Commercial vessels[2]	1625800	861,674	2,050,784	715,189	36
Charter vessels[3]	305664	293,437	760,002	269,962	14
Recreational vessels[4]		2827096	6587134	1046026	38
Total			10780667	2513431	113

[1] Calculated as full-time jobs. The input-output model assumes that fishing accounts for 20% of the employment time of part-time commercial fishermen (Sharma et al. 1999).
[2] Average annual sales estimate for 1994-1998 from WPRFMC (1999a).
[3] Sales estimate based on the following assumptions: 199 active vessels; average annual sales of $76,800 per vessel from charter fees and mount commissions; and 2% of total sales attributed to bottomfish fishing trips (Hamilton 1998).
[4] Expenditure estimates based on the following assumptions (Hamilton and Huffman 1997; Pan et al. 1999):

Number of recreational boats	2490
Annual number of bottomfish fishing trips	3.81
Average trip costs	84.75
Average fixed costs: apportioned according to ratio of bottomfish fishing trips to total number of trips	213

7.5.3 Hawaii's Population Size and Ethnicity

The 1990 census listed the population of Hawai'i as 1,108,229. This figure rose to 1,179,198 in 1995 and to 1,211,537 in 2000. The population increased by a rate of 6.9 percent between 1990 and 1999.

The state of Hawai'i is divided into five counties. The county of Maui includes the islands of Kaho'olawe, Lāna'i, Maui and Moloka'i. The county of Honolulu encompasses the island of O'ahu and the Northwestern Hawaiian Islands excluding Midway Atoll. Kaua'i County consists of the islands of Kaua'i and Ni'ihau. The population of each county is provided in Table 7-34.

TABLE 7-34: Hawai'i Population by County

AREA	1990 CENSUS	2000 CENSUS
Hawai'i State	1108229	1211537
Honolulu County, HI	836231	874154
Hawai'i County, HI	120317	148677
Kaua'i County, HI	51177	58463
Maui County, HI	100374	128094

Source: U.S. Census Bureau

The 2000 Census redefined the way race is measured in a number of ways, allowing individuals to identify themselves as one race or a combination of races, as well as having a separate classification system for Hispanic or Latino and race. As a result, describing the makeup of Hawaii's population is more complex. Perhaps the most accurate way to describe Hawaii's population is to report the proportions of race alone or in combination with one or more other races. In 2000, 39.3 percent of Hawaii residents described themselves as white, 2.8 percent as black or African American, 2.1 percent as American Indian or Alaska native, 58 percent as Asian, 23.3 percent as Native Hawaiian and other Pacific Islander, and 3.9 percent as some other race. These proportions add up to more than 100 percent because many individuals reported more than one race. Of the 78.6 percent of residents who reported just one race, 24.5 percent listed white, 1.8 percent black or African American, 41.6 percent Asian (including 4.7 percent Chinese, 14.1 percent Filipino, 16.7 percent Japanese, 1.9 percent Korean, and .6 percent Vietnamese), and 9.4 percent Native Hawaiian and or other Pacific islander.

In 1995-1996, Hamilton and Huffman (1997) conducted a survey of small-boat owners who engage in Hawai'i's commercial and recreational fisheries, including the troll, pelagic handline and bottomfish handline fisheries. The survey found that the three largest ethnic groups represented in the sample were Japanese (33 percent), mixed with part-Hawaiian (16 percent) and Caucasian (12 percent). Hamilton and Huffman speculated that the high proportion of Japanese and part-Hawaiians in the sample reflects the traditional connections that these two ethnic groups have with the sea. These sociocultural connections are discussed further in the following section.

With specific regard to the NWHI bottomfish fishery, a 1993 survey of 15 owner-operators and hired captains who participate in the fishery found that 87 percent were Caucasian and 13 percent were part-Hawaiian (Hamilton 1994). However, it is likely that the ethnic composition of the deckhands aboard these vessels is much more mixed and reflects the highly diverse ethnic character of the state's total population

7.5.4 Sociocultural Setting

Blue sampans ride in the harbor at Kewalo
under the copper brilliance of the sun;
blue sampans reel and tilt into the trade wind
on sea-paths traced by the Hawaiian moon;
blue sampans stagger and rise gallantly out of chasms of sea
in storms blowing out of the sultry south,
in hurricanes howling over the barren isles
far to the north, in a world of wind and foam.
Clifford Gessler/ Tropic Landfall: The Port of Honolulu, 1942, p.267

Over the past 125 years the sociocultural context of fishing in Hawaiʻi has been shaped by the multi-ethnicity of local fisheries. Although certain ethnic groups have predominated in Hawaiʻi's fisheries in the past and ethnic enclaves continue to exist within certain fisheries, the fishing tradition in Hawaiʻi is generally characterized by a partial amalgamation of multi-cultural attributes. An examination of the way in which the people of Hawaiʻi harvest, distribute and consume seafood reveals remnants of the varied technology, customs and values of Native Hawaiians and immigrant groups from Japan, China, Europe, America, the Philippines and elsewhere.

7.5.5 Social Aspects of Fish Harvest

Commercial fishing first became important in the Hawaiian Islands with the arrival of the British and American whaling fleets during the early nineteenth century. The whalers made the islands their provisioning and trading headquarters because of their central location in the Pacific (Nakayama 1987). This trade reached its zenith in the 1850s when more than 400 whaling vessels arrived in Honolulu annually (Shoemaker 1948). European- and American-owned trading concerns, called "factors," were established to service the whalers and gradually became the dominant enterprises in Honolulu. The significance of whaling to Hawaiʻi's economy waned considerably during the late-nineteenth century by which time plantation agriculture centered on sugar and pineapple production had grown in importance. A number of the trading companies that supported the whaling industry, however, adjusted to these economic changes and remained at the heart of Hawaiʻi's industrial and financial structure (Shoemaker 1948).

The introduction of a cash economy into Hawaiʻi and the establishment of communities of foreigners in the islands also led to the development of a local commercial fishery. As early as 1832, it was the custom for fish and other commodities to be sold in a large square near the waterfront in Honolulu (Reynolds 1835). In 1851, the first regular market house for the sale of fishery products was erected (Cobb 1902). The territorial government replaced this market in 1890 with an elaborate structure that Cobb (1902:435) referred to as "one of the best [market houses] in the United States." Other fish markets were established on the islands of Maui and Hawai'i. Locally caught bottomfish were in high demand at these markets. In Bryan's (1915) list of seafood preferences by the various "nationalities" in Hawai'i, all of the bottomfish species listed (i.e., *hāpu'upu'u*, *kāhala*, *'ōpakapaka* and *uku*) were among the types of fish purchased by all social groups. Bryan (p.371) noted that some of the "snappers" "...may be procured almost every day, there being more than a hundred thousand pounds sold annually in the Hawaiian markets." Jordan and Evermann (1903:240) wrote of *uku*: "This fish is common about Honolulu, being brought into the market almost every day. It is one of the best of food-fishes." *Gindai* is also referred to as "one of our best food fishes" by Brigham (1908:17). Cobb (1902) reported that *'ula'ula*, *uku* and *ulua* were among the five species of fish taken commercially on all the islands. Titcomb (1972) writes that *'ōpakapaka* was one of the most common fish on restaurant menus prior to World War II.

Initially, commercial fishing in Hawai'i was monopolized by Native Hawaiians, who supplied the local market with fish using canoes, nets, traps, spears and other traditional fishing devices (Jordan and Evermann 1902; Cobb 1902; Konishi 1930). However, the role that Native Hawaiians played in Hawai'i's fishing industry gradually diminished through the latter half of the nineteenth century. During this period successive waves of immigrants of various races and nationalities arrived in Hawai'i increasing the non-indigenous population from 5,366 in 1872 to 114,345 in 1900 (OHA 1998). The new arrivals included Americans, Chinese, Portuguese and Filipinos, but particularly significant in terms of having a long-term impact on the fishing industry was the arrival of a large number of Japanese. The Japanese, like the majority of the early immigrants, were contracted to work on Hawai'i's sugar cane plantations. When contract terms expired on the plantations many of the Japanese immigrants who had been skilled commercial fishermen from the coastal areas of Wakayama, Shizuoka and Yamaguchi Prefectures in Japan turned to the sea for a living (Okahata 1971). Later, experienced fishermen came from Japan to Hawai'i for the specific purpose of engaging in commercial fishing. The bottomfish fishing gear and techniques employed by the Japanese immigrants were slight modifications of those traditionally used by Native Hawaiians.

During much of the twentieth century Japanese immigrants to Hawai'i and their descendants were preeminent in Hawai'i's commercial fishing industry. The tightly knit communities that the first Japanese immigrants formed both helped ease the transition to American society and retarded the process of acculturation (Tamura, 1994). The Japanese were able to maintain their separate communities in Hawai'i more effectively than any other immigrant group. Among those Japanese communities of particular significance were the settlements of commercial fishermen and their families in the Palama, River Street and Kākā'āko areas of Honolulu adjacent to the harbor (Lind 1980).

The adherence of Japanese immigrants to traditional cultural practices included Japanese religious observances, and many of the religious activities of communities such as Kākā'āko were centered on fishing (Miyasaki 1973). Various traditional Japanese taboos and rituals directed how a new fishing boat was to be launched, when a vessel could leave or return to port, what items could be brought on board a boat and many other aspects of fishing behavior

(Hamamoto 1928; Katamoto 1984). Over the years, succeeding generations of fishermen of Japanese ancestry in Hawai'i became more "Americanized," but many Japanese fishing traditions persisted. For example, Japanese immigrant fishermen brought from Japan the Shinto practice of building a *jinsha* (shrine) dedicated to a deity such as *Konpira-sama* or *Ebisu-sama* (Kubota 1984; Miyasaki 1973). Today, an *Ebisu jinsha* constructed at Ma'alaea on the island of Maui during the early 1900s still stands, and fishermen of Japanese ancestry as well as others who share a common bond in fishing continue each year to ceremonially bless individual fishing vessels (Kubota 1984; T. Arine, pers. comm. 2000. Maui *Jinsha*).[18]

In addition to ethnic and community ties, the physical danger of fishing as an occupation also engendered a sense of commonality among fishermen. Describing the captains and crews of the early sampan fleet in Hawai'i, Okahata (1971:208) wrote: "It is said that the fishermen were in a clan by themselves and were imbued with a typical seaman's reckless daring spirit of 'death lies only a floor board away.'" The extreme isolation of the NWHI and the limited shelter they offered during rough weather made fishing trips to these islands particularly hazardous. The perils of fishing in the NWHI for bottomfish and other species captured the attention of the public media (e.g., Inouye 1931; Lau 1936), and inspired one individual to compose the poem included in the preface to this section.

As late as the 1970s, the full-time professional fishermen in Hawai'i were predominately of Japanese descent (Garrod and Chong 1978). However, by that period hundreds of local residents of various ethnicities were also participating in Hawai'i's offshore fisheries as part-time commercial and recreational fishermen. In addition, a growing number of fishermen from the continental U.S. began relocating to Hawai'i. Many of the new arrivals came to the islands because declining catch rates in some mainland fisheries had led to increasingly restrictive management regimes.

Today, the people who participate in Hawai'i's bottomfish fishery and other fisheries comprise an ethnically mixed and spatially dispersed group numbering several hundred individuals, although actual numbers are difficult to ascertain. Most are year-round residents of Hawai'i, but some choose to maintain principal residences elsewhere. Participants in the bottomfish fishery do not reside together in a specific location and do not constitute a recognizable "fishing community" in the geographical sense of the term. There are a few rural villages in the state where most residents are at least partially economically dependent on fishing for pelagic species (Glazier 1999). In general, however, those who are dependent on or engaged in the harvest of fishery resources to meet social and economic needs do not include entire cities and towns, but subpopulations of metropolitan areas and towns. These subpopulations comprise fishing communities in the sense of social groups whose members share similar lifestyles associated with fishing.

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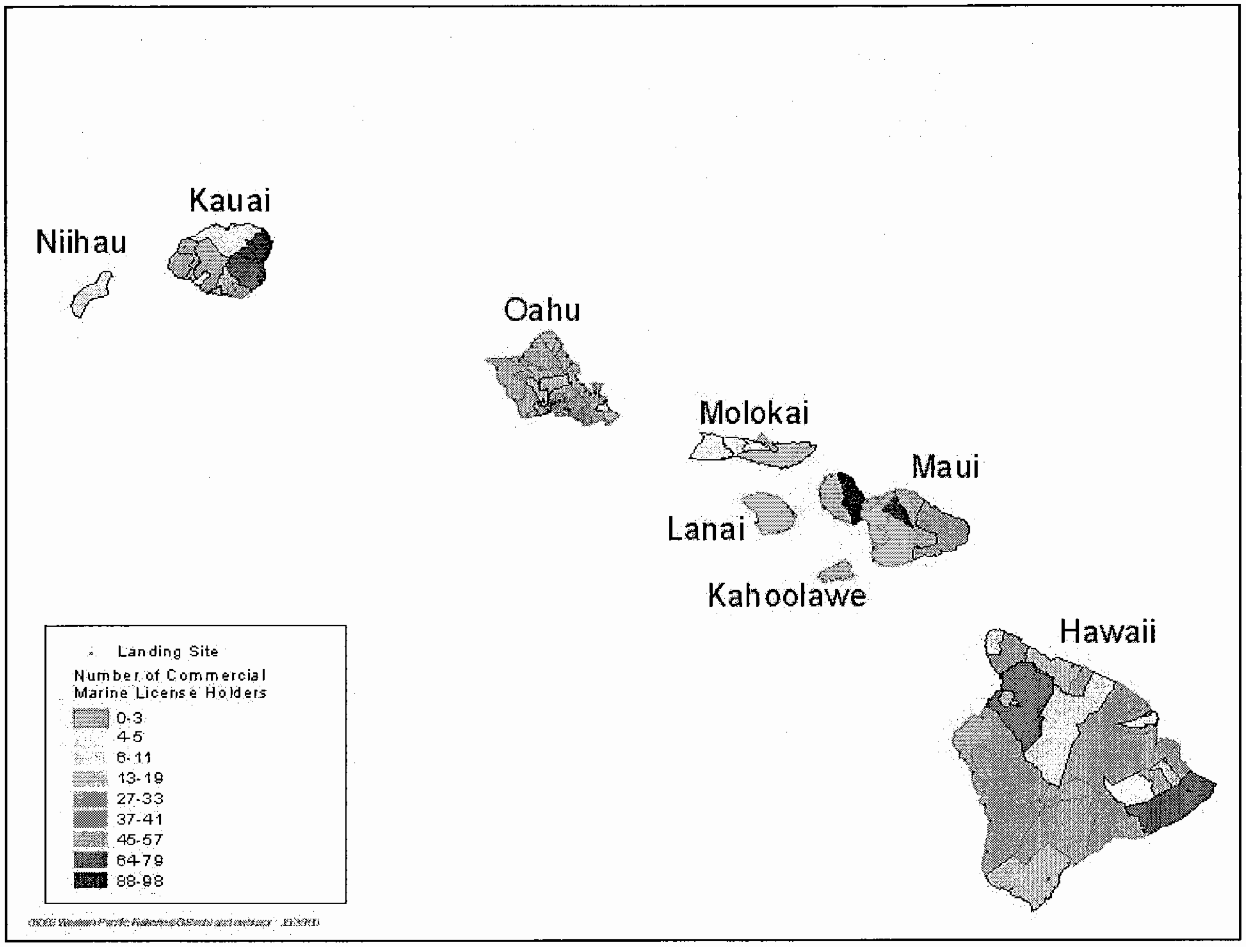
[18] In some communities in Japan *Ebisu* is regarded specifically as the god of fishing, farming and commerce (Tokihiko 1983). He is depicted holding a fishing rod in his right hand and a sea bream under his left arm.

The dispersal of bottomfish fishery participants can be examined by mapping residence information from relevant fishery license or permit holders. The Hawai'i Division of Aquatic Resources (HDAR) administers a register of State of Hawai'i commercial marine license holders. State regulations require any person who "takes marine life for commercial purposes," whether within or outside of the state, to first obtain a commercial marine license from HDAR. For a particular vessel this regulation applies to each person aboard (captain or deckhand) who catches or attempts to catch a fish for commercial purposes. Figure 7-28 shows the distribution of the business or home mailing address zip codes of commercial marine license holders who indicate that their primary fishing gear is bottomfish handline gear. Each of the five larger main islands has significant concentrations of participants.

Another potential source of information on the distribution of participants in the MHI bottomfish fishery is the HDAR list of registered bottomfish fishing vessels. Hawaii Administrative Rule Chap. 13-94 requires any vessel owner who fishes for certain bottomfish species to register their vessels for bottomfish fishing. As of 2002, approximately 2,960 vessels have been registered (W. Ikehara, pers. comm. 2002. HDAR). The residences of the owners of these boats were not mapped, however, as the list contains many individuals who do not actually harvest bottomfish but who registered their vessels in anticipation of a future limited entry program for the MHI bottomfish fishery. There are currently no fees to register a vessel for bottomfish fishing, and many individuals may have registered, not because they intended to enter the bottomfish fishery at this time, but because they wanted to be ensured access to the fishery in the future.

Information on the residences of Mau Zone and Ho'omalu Zone limited entry program permit holders is available from the register of permit holders administered by NMFS. The register indicates that eight permit holders reside in various communities on Oahu, three reside in two different communities on Kaua'i, one resides on Maui, one resides on the island of Hawai'i and three have mailing addresses at separate locations on the U.S. mainland.

FIGURE 7-28: Distribution of Mailing Address Zip Codes of HDAR Commercial Maine License Permit Holders Who Participated in the Hawaii Bottomfish Fishery, 1998 (n=1,133)



Most of the vessels that comprise the NWHI bottomfish fishing fleet utilize harbor facilities at Kewalo Basin, a harbor located in the metropolitan Honolulu area. Three vessels operate from Port Allen Harbor on Kauai. Nearly all of the participants in the NWHI bottomfish fishery reprovision in Honolulu and offload their catch at Kewalo Basin because it is close to the fish auction. In addition, most of the large-volume, restaurant-oriented wholesalers that buy, process and distribute fishery products are located in the greater Honolulu area. Businesses whose goods and services are used as inputs in Hawai'i's offshore commercial fisheries, such as ice plants, marine rail ways, marine suppliers, welders and repair operations, are similarly concentrated in Honolulu. However, the contribution of the harvesting and processing of fishery resources to the total economic fabric of Honolulu is negligible in comparison to other economic activities in the metropolitan area, such as tourism. In other words, Honolulu is the center of a major portion of commercial fishing-related activities in the state but is not a community substantially dependent upon or substantially engaged in fisheries in comparison to its dependence upon and engagement in other economic sectors.

The bottomfish fishing fleet that concentrates its effort in the waters around the MHI consists mainly of trailered vessels operating from numerous launching facilities scattered throughout the state (Hamilton 1997). Glazier (1999) identified 55 ramps and harbors used by commercial and recreational fishing boats. This number does not include several private boat mooring and launching facilities. Many of these harbors and ramps offer minimal shore-side support services, and even some of the large, well-developed harbors are remote from any central business district or residential area. However, the extensive network of launching sites provides fishermen living anywhere on a given island ready access to multiple fishing grounds (Glazier, 1999).

The motivations for fishing among contemporary Hawaiʻi fishermen tend to be mixed even for a given individual (Glazier 1999). In the small boat fishery around the MHI the distinction between "recreational" and "commercial" fishermen is extremely tenuous (Pooley 1993a). Hawaiʻi's seafood market is not as centralized and industrialized as U.S. mainland fisheries, so that it has always been feasible for small-scale fishermen to sell any or all of their catch for a respectable price. Money earned from part-time commercial fishing is an important supplement to the basic incomes of many Hawaiʻi families.

It is also important to note that many people in Hawaiʻi who might be considered "commercial" fishermen hold non-fishing jobs that contribute more to their household income than does fishing (Pooley 1993a). For some fishermen non-fishing jobs are not a choice, but a necessity due to the inability to earn an adequate return from fishing. Many participants in Hawaiʻi's offshore fisheries often catch insufficient fish to cover even fuel, bait and ice expenses, but they continue fishing simply for the pleasure of it. Some go so far as to pursue non-fishing occupations that allow them to maximize the time they can spend fishing regardless if it is profitable or not (Glazier 1999).

Fulfillment of social obligations may also at times be an important reason for fishing. Fish are an important food item among many of the ethnic groups represented in Hawaiʻi, especially during various social events. Fishermen are expected to provide fish during these occasions and may make a fishing trip especially for that purpose (Glazier 1999).

Finally, some Hawaiʻi fishermen feel a sense of continuity with previous generations of fishermen and want to perpetuate the fishing life style. The aforementioned 1993 survey of participants in the NWHI bottomfish fishery found that half of the respondents who fish in the Hoʻomalu Zone were motivated to fish by a long term family tradition. This sense of continuity is also reflected in the importance placed on the process of learning about fishing from "old timers" and transmitting that knowledge to the next generation. A recent sociocultural survey of small trolling vessel captains in Hawaiʻi found that many of those interviewed either descend from long time fishing families or have worked in fishing or fishing-related work since they were in their teens (Glazier 1999). The average captain had almost 18 years of offshore fishing experience. The survey found that 35% of boat captains were taught how to fish by their fathers, grandfathers or uncles, while 32% reported being taught by friends (Glazier 1999). Only 14% indicated that they taught themselves. Most Hawai'i' fishermen consider knowledge and experience to be more important factors in determining fishing success than "high-tech" gear. An example of the value placed on information passed down from previous generations of fishermen is the monument that one town on O'ahu has recently proposed to commemorate the *kūpuna* (elders) of that area who are recognized for their fishing skills and knowledge (Ramirez 2000).

Whatever the motivations for fishing, the contributions of friends and family members to these efforts are often substantial. Small boat fishing in Hawai'i is almost always a cooperative venture involving friends or relatives as crew members (Glazier 1999). In addition, wives, in particular, often play an essential role in shore-side activities such as the transport of fish to markets, purchase of ice, vessel maintenance, bookkeeping and so forth (Glazier 1999).

In Hawai'i during the past several years there have been a number of highly publicized clashes between the owners of large and small fishing boats and between fishermen who are newcomers and those who are established residents (Glazier 1999). The reasons for these conflicts are complex, but the perception that the state's marine resources are being damaged and depleted by certain groups of fishermen is a central factor. Fish landing statistics support the notion that catch rates in some fisheries are on the decline. Many fishermen have found that fishing is no longer a profitable enterprise and have dropped out of the industry (Glazier 1999). The situation is aggravated by a depressed state economy that has made it more difficult for many fishermen to find the financial resources to support marginal fishing operations.

In some cases, government regulations have helped alleviate competition among fishermen. In 1991, for example, a longline vessel exclusion zone ranging from 50 to 75 nm was established around the MHI to prevent gear conflicts between large longline vessels and small troll and handline boats. However, government regulations have also added to the level of tension and feelings of frustration among fishermen. For instance, many fishermen in Hawai'i have adjusted to natural variations in the availability of various types of fish by adopting a multi-species, multi-gear, highly flexible fishing strategy. However, this strategy is increasingly constrained by the implementation of limited access programs in Hawai'i's major commercial fisheries (Pooley 1993a).

Despite this highly competitive and divisive environment fishermen have been able to develop and maintain networks of social relations that foster collaboration and mutual support. For example, fishermen's attempts at organizing to promote their shared interests, whether in the market or lobbying government for changes in policy, have generally been fragmented. Nevertheless, some fishermen in Hawai'i are represented by a *hui* or organization, and these voluntary associations often facilitate coordination and cooperation for the mutual benefit of their members. A case in point is the Maui Cooperative Fishermen's Association, which is comprised of bottomfish fishermen many of whom are part-timers. The Association negotiates product prices with one or more seafood distributors who, in turn, supply local hotels and restaurants with fresh fish.

Glazier (1999) observed that membership in a Hawaiʻi fishing *hui* can instill a strong feeling of camaraderie and solidarity among fishermen. The cohesion within these organizations constitutes available social capital for both their members and the broader community. For example, fishing clubs often organize or participate in community service projects (Glazier 1999). Examples of more ad hoc forms of cooperation among fishermen are also common. For instance, fishermen may take turns trucking each other's fish from distant landing sites to the central fish auction in Honolulu, thereby reducing transportation costs (Glazier 1999).

Close social relationships also continue to be maintained between some fishermen and fish buyers. For example, small boat fishermen on Kauaʻi and the Kona side of the island of Hawaiʻi tend to sell their catch directly to local buyers who, in turn, sell it to restaurants or retail markets (Glazier 1999). By sending their fish directly to dealers fishermen not only avoid the commission charged by the auction but also enjoy the price stability over the long-term that comes with an established reciprocal relationship. As Peterson (1973) noted, "A fisherman feels that if he is 'good to the dealer' in supplying him with fish that he needs to fill his order, 'the dealer will be good to him' and give him a consistently fair price for his fish."

7.5.6 Social Aspects of Fish Distribution and Consumption

Archaeological evidence indicates that seafood was part of the customary diet of the earliest human inhabitants of the Hawaiian Islands (Goto 1986). An early European visitor to Hawaiʻi observed that, "There is no animal food which a Sandwich Islander esteems so much as fish" (Bennett 1840:214). Nineteenth century immigrants to Hawaiʻi from Asia also possessed a culture in which fish was an integral part of the diet. Despite the "exorbitant" fish prices that Hawaiʻi residents have often encountered in the markets, the level of consumption of seafood in the islands has historically been very high. One early commentator noted:

> *In the Honolulu market 2,000,000 pounds of fresh salt water fish valued at $5,000,000 are sold annually. These figures represent a high price for a food that abounds in the waters all around the Islands, yet the people of this community, who are great lovers of the products of the sea, will gratify their tastes even at this expense* (Anon. 1907:17).

Today, per capita seafood consumption in Hawaiʻi is still at least twice as high as the national average (Shomura 1987).

Because seafood was such a significant item in the diets of local residents, the fish markets themselves became important institutions in Hawaiʻi society. Dole (1920:20) noted that the fish market located in the busiest section of Honolulu was more than a commercial establishment, it was also "...Honolulu's political center where impromptu mass meetings were held ...; it was, in a way, a social center also, especially on Saturdays for then business was at its height." Much of the retailing of fish now occurs through self-service supermarkets, but Honolulu's fish markets have endured and continue to be centers of social interaction for some island residents.

The fish markets are comprised of retail units the majority of which are single proprietorship-family type operations. Close social connections have developed between retailers and consumers, as the success of the dealers is largely a function of their ability to maintain good relations with their customers and maintain a stable clientele (Garrod and Chong 1978). One journalist wrote of the Oʻahu Market, where fresh fish and produce have been sold for nearly a century: "In the hustle and bustle of daily life in downtown Honolulu, many people are drawn to Oʻahu Market because of its informal charm and the feeling of family one gets while shopping there" (Chinen 1984).

Early in the last century Bryan (1915) developed a list of the various fish purchased in the Honolulu market by each of Hawaii's principal "nationalities." The ethnic identification of Hawaiʻi's *kama ʻāina* (long-time residents) with particular species has continued to the present day. The large variety of fish typically offered in Hawaiʻi's seafood markets reflects the diversity of ethnic groups in Hawaiʻi and their individual preferences, traditions, holidays and celebrations.

Many of the immigrant groups that came to Hawaiʻi brought with them cultures in which fish are not only an integral part of the diet but given symbolic and even transformative connotations. Certain fish communicate messages of solidarity, favor, opulence and the like, or are believed to impart specific desirable traits to the diners (Anderson 1988; Baer-Stein 1999). For example, some types of bottomfish that are red in color have found acceptance within the Japanese community in Hawaiʻi as a substitute for red *tai* (sea bream, *Pagrus major*) – a traditional Japanese symbol of good luck and, therefore, an auspicious fish to be served on festive occasions (HDAR 1979; Shoji 1983). The red color of these fish also symbolizes prosperity and happiness.[19] The December peak in landings of *ʻōpakapaka*, *onaga*, *kalekale* and *ehu* reflect the demand for them as an important dish in feasts celebrating *Oshogatsu* (Japanese New Year's), considered the most important cultural celebration for people of Japanese ancestry in Hawaiʻi. Serving these fish is also important during non-seasonal events such as wedding and birthday banquets. For Hawaiʻi residents of Chinese descent fish or "*yu*" is an important item during feasts celebrating *Tin nien* (Chinese lunar New Year) and other ritual observances, as it is a homophone for abundance (Choy 1989). Fish also symbolize regeneration and freedom because of their rapid ability to propagate as well as their speed and unconfined lifestyle (Baer-Stein 1999). Fish with white, delicately-flavored flesh are in particularly high demand by the Chinese community during New Year celebrations and other festive occasions (Peterson 1973).

An insistence on quality, as well as quantity and variety, has also long been a hallmark of Hawaiʻi's seafood markets. For example, the Japanese immigrants to Hawaiʻi came from a society in which fishermen, fish dealers and even cooks typically handle prized fish with considerable care (Joya 1985). Hawaiʻi seafood consumers continue to demand fresh fish. Both the discriminating tastes of local residents and the symbolic meaning with which some fish are imbued are linked to the importance of fish as gifts from one person or family to another. In

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[19]The reason *tai* is regarded as a celebratory fish among Japanese is thought to be due not only to its beauty of form and color but also because "*tai*" suggests the word "*medetai*," meaning auspicious (Shoji 1983)

Hawaiʻi various types of high-priced fish such as red snapper are highly regarded as gifts (Peterson 1973). Such sharing and gift giving may play an important role in maintaining social relations, as exemplified by the traditional Japanese obligation to engage in reciprocal exchanges of gifts according to an intricate pattern of established norms and procedures (Ogawa 1973). Those who neglect the obligation to reciprocate risk losing the trust of others and eventually their support.

The sharing of fish among members of the extended family and community is also an early tradition of the indigenous people of Hawaiʻi. The social responsibility to distribute fish and other resources among relatives and friends remains a salient feature of the lives of many Native Hawaiians that is enacted on both a regular basis and during special occasions (Glazier 1999). Among Native Hawaiians fish is considered a customary food item for social events such as a wedding, communion, school graduation, funeral or child's first birthday (baby *lūʻau*) (Glazier 1999).

7.5.7 Social Significance of Fishing to the Broader Community

Commercial fishing has been part of Hawaiʻi's economy for nearly two centuries. Long-established fishing-related infrastructure in Honolulu such as the fish markets and Kewalo Basin mooring area has helped define the character of the city. Moreover, for some major ethnic groups in Hawaiʻi such as the Japanese and Native Hawaiians the role that their forebears played in the development of commercial fisheries in the islands remains an important part of their collective memory. In 1999, for example, the Japanese Cultural Center of Honolulu organized an exhibition commemorating the past involvement of Japanese in Hawaiʻi's commercial fishing industry.

Given the historical significance of commercial fishing in Hawaiʻi, it likely that some local residents consider the fishing industry to be important in the cultural identity and heritage of the islands. Individuals who have never fished and do not intend to may nonetheless value the knowledge that others are fishing and that this activity is continuing to contribute to Hawaiʻi's social, cultural and economic diversity. This existence value may be expressed in various ways. For example, some individuals may engage in vicarious fishing through the consumption of books, magazines and television programs describing the fishing activities that others are pursuing in the waters around Hawaiʻi.

Just as Hawaiʻi's fishing tradition is an integral part of the islands' heritage and character, the image of Hawaiʻi has become linked with some types of locally caught seafood. Among the fish species that have become closely identified with Hawaiʻi are bottomfish such as *ōpakapaka* and *onaga*. The continued availability of these seafoods in Hawaiʻi has important implications for the mainstay of the state economy - tourism.[20] Many Japanese tourists visiting Hawaiʻi want to enjoy

[20]Suryanata (2000) notes that many attributes of Hawaiʻi have been constructed in the marketing of Hawaiʻi by the tourist industry, and unusual or exotic food complements the marketed image. In describing the current initiative to revive Hawaiʻi's agricultural sector by diversifying into high-value non-traditional export crops, such as tropical flowers, gourmet coffee and tropical speciality fruits, she writes "None of these products is unique to

the traditional foods and symbols of prosperity of Japan while they vacation in Hawai'i, including various types of high quality fresh fish (Peterson, 1973). Hawai'i tourists from the U.S. mainland and other areas where fish is not an integral part of the customary diet typically want to eat seafood because it is perceived as part of the unique experience of a Hawai'i vacation. For both Japanese and U.S. mainland tourists, the experience of consuming fish in Hawai'i may be enriched if the fish eaten is actually caught in the waters around Hawai'i. Suryanata (2000) observes that markets within the state for "grown in Hawai'i" products have expanded in the past decade through the proliferation of gourmet restaurants that feature "Pacific Rim" and "Hawai'i Regional Cuisine." This marketing strategy eschews traditional symbols constructed by the tourism industry in favor of inciting an appreciation of the social relationships and physical environment that make Hawai'i an unique place.

Suryanata (2000) also notes that place-based speciality food can retain its appeal to buyers beyond a vacation period or even attract buyers who have never been to the place in question. Just as a consumption of organic food may signify a commitment to a certain environmental and social value, a consumption of products from Hawai'i can symbolize a partial fulfillment of a desire to experience or relive a Hawai'i vacation. According to a national seafood marketing publication, the power of this constructed value to influence prospective buyers has not been lost on Hawai'i's seafood dealers:

> *When it comes to selling seafood the Hawaiians have a distinct advantage. Their product comes with built-in aloha mystique, and while they've emphasized the high quality of the fish taken from their waters, they've also taken full advantage of the aura of exotic Hawaii itself in promotion on the mainland and, now, in Europe* (Marris, 1995).

Local production of food as opposed to a reliance on imports also creates opportunities to foster social connections between consumers and their food producers. As noted above, much of the retailing of fish in Hawai'i now occurs through supermarkets, and a large quantity of the seafood sold is imported. However, there still exists in Hawai'i personal connections between consumers and the individuals who harvest and retail fish. Such connections may have broad public value. For example, a recent article by agricultural researchers identified proximity as one of the key attributes of a sustainable food system:

> *A sustainable food system is one in which "food is grown, harvested, processed, marketed, sold, [and] consumed as close to home as possible." An emphasis on locally grown food, regional trading associations, locally owned processing, local currency, and local control over politics and regulation is found within a proximate system. A proximate food system will have "grocery stores close to*

Hawai'i in a true sense to merit a higher price, but marketing strategies seek to define a strong place-association of these products with Hawai'i, to capitalize on Hawai'i's exotic image and to develop niche markets for speciality products from paradise." This statement is equally true for locally-produced seafood sold in Hawai'i.

home which carry local items with little or no corporately owned products to compete," and would provide "specialty items that characterize the bioregion" (Kloppenburg et al. 2000:182).

7.6 Native Hawaiian Community

7.6.1 *Mai Kīnohi Mai* (From the Very Beginnings)

The foundation of a people's culture is often revealed in the stories told about their origins. Native Hawaiians define their relationship to the *ʻāina* (land) as the relationship between younger sibling (*poʻe Hawaiʻi* - Native Hawaiians) and elder sibling (*ʻāina*) both of whom were descended from *Papa* (Earth mother) and *Wākea* (Sky father) (Kameʻeleihiwa 1992). The relationship of *poʻe Hawaiʻi* with the ocean was one defined in sacred terms as manifested by the embodiment of the ocean as the realm of *Kanaloa*, one of four primary *Akua* (Divine Beings) in the pantheon of Native Hawaiian *Akua.* The customary and traditional relationship of *poʻe Hawaiʻi* to the fauna and flora of this oceanic realm was one of *ʻohana* (family) in which many of the naturally occurring plants and animals (including fish) were regarded as ancestors embodied in temporal form who acted as divine family guardians (Kamakau 1976; Malo 1951).

This spiritual connection was the foundation of the Hawaiian commitment to care for the land and sea and protect them for use by future generations. The understanding of Native Hawaiians in the interdependence of people and the natural resources that sustain them was preserved in the wisdom of *kūpuna* (ancestors) and articulated in *ʻōlelo noʻeau* (sayings of wisdom). The following sample of proverbs compiled by Pukuʻi (1983) illustrate the conservation ethic of Native Hawaiians.

E ʻai i kekahi, e kāpi kekahi.
Eat some now and save some for another time. (#252)

He pono ka pākiko ma mua o ka hoʻokelakela wale aku.
Better to be economical than too liberal. (#912)

Lilo akula ka nui a koe ka unahi.
Most [of the fish] are taken and only the scales are left.
Said after one has taken the "lion's share" for himself. (#2004)

The Hawaiian sense of stewardship was essential given the dense human population in Hawaiʻi and the islands' limited natural resources. Estimates of the population of Hawaiʻi prior to European contact vary. A recent analysis of the Hawaiian population by Stannard (1989) suggests that the population may have approached one million people prior to foreign penetration into the Pacific. Such a large population could also explain how it was that the Native Hawaiian people came to use the area now known as the Northwestern Hawaiian Islands. A population approaching the population that inhabits these islands today would have likely sought to expand its fishing territory as far as possible in order to survive and prosper.

It is part of the historic record that voyages between the MHI and the southern reaches of the NWHI were undertaken on a regular basis. There is also ample evidence that Native Hawaiians were skilled and prolific fishermen both in inshore waters, including the banks near the main islands and extending into the open ocean (e.g., Beckley 1883; Goto 1986; Kahaulelio 1902; Murakami and Freitas 1987; Scobie 1949). It is likely, therefore, that Native Hawaiians frequented the NWHI for ritual and food gathering. Physical evidence found on both Nihoa and Necker islands indicates that Native Hawaiians frequented these islands long enough to build a series of religious temples and agricultural terraces (Emory, 1928).

Evidence of Hawaiian habitation of the NWHI can also be found in the oral traditions of Native Hawaiians. Moses Keale, a recently deceased native of Niʻihau, related a tradition of Niʻihauans voyaging to Nihoa for extended periods of time in conjunction with changing weather patterns. These stays were long enough to plant sweet potatoes and harvest those that had been planted on the previous visits. Fish were also caught and preserved for transport back to the MHI (pers. comm. 1980). More recently, in answer to a question regarding extent of the aforementioned voyages, a *kūpuna* (elder) from Niʻihau stated that these voyages went beyond Nihoa (and possibly Necker) to "*mokupuni palahalaha*" (small flat islands) where one could see from one side of the island to the other (Malaki Kanahele, pers. comm. 2000).

Another example of Hawaiian familiarity with the Northwestern Hawaiian Islands found in the oral record is a section of the story of *Pele* and *Hiʻiaka* published in the Hawaiian language newspaper *Kūʻokoʻa Home Rula* (1911) in which *Pele* recites the wind names of Nihoa.

Na Makani o Nihoa
He Honouli ka makani o Nihoa
He Waialoha ka makani noho ana o Nihoa
He Lupekiikai ka makani kaapuni o Nihoa

Rauzon (2001) suggests that other *mele* (chants) and legends as well as accounts of the navigational assistance that Hawaiians provided to early European explorers indicate that Hawaiians were familiar with many of the NWHI.

7.6.2 *Komo Ka Poʻe Haole* (Penetration of Foreigners)

By the time Captain James Cook came upon the Hawaiian Islands in 1778, the sovereign line of Hawaiʻi had persisted for more than 23 generations - or more than 500 years - of a sustained, stable system of governance. In 1810, Kamehameha succeeded in establishing political control over all of the major islands. In order to cope with increasing foreign contacts, the Hawaiian Kingdom began adopting western legal systems such as a parliament, a constitution and treaties with other nations, including several with the United States. However, during the remainder of the century the succession of Hawaiian monarchs that followed Kamehameha were unsuccessful in warding off the increasing encroachment by various colonial powers. In 1883, the Kingdom of Hawaiʻi was overthrown by a group of mostly American businessmen backed by U.S. soldiers (Kuykendall, 1953). The provisional government sought annexation by the United States, and after passage of the "Newlands Resolution" in 1898, Hawaiʻi was considered a territory of the United States.

Today, a fundamental question for many Native Hawaiians and others is the legality of the methods used by the United States to acquire the Hawaiian Islands in the 19th century. In 1993, the U.S. Congress passed the Apology Bill which states that "...the indigenous Hawaiian people never directly relinquished their claims to their inherent sovereignty as a people over their national lands to the United States, either through their monarchy or through a plebiscite or referendum."

In the absence of any treaty or voluntary relinquishment, the lingering sovereign claim by Native Hawaiians may dictate that a higher right to the living marine resources within the U.S. EEZ surrounding the Hawaiian Islands might still be justified. Murakami and Freitas (1987) argue that legal claims of Native Hawaiians to the fishery have not been extinguished by the U.S. government. He notes that, "...Congressional enactments and the 1983 Presidential Proclamation to extend U.S. jurisdiction over mineral resources of the EEZ and the fisheries of the FCZ [200-mile Fishery Conservation Zone] would not affect the viability of this claim in the absence of any treaty or settlement act resolving the potential Hawaiian claim to the fishery, mineral and other natural resources of the FCZ and EEZ around the Hawaiian and Northwest Hawaiian Islands."

Murakami and Freitas (1987:27) summarize the legal aspects of U.S. participation in the conservation of fisheries around the Hawaiian Archipelago in regard to Native Hawaiian claims:

> *The U.S. government has the power to affect the Hawaiian claim to portions of the Hawaiian and Northwestern Hawaiian Island FCZ and EEZ by either: 1) condemning the fisheries granted to Hawaiian commoners and their successors in the FCZ, which will require it to compensate the Hawaiian people for the taking of their fishing grounds; or 2) exercising its public trust duties to protect the aboriginal claims to the resources of the EEZ and FCZ, which will require it to determine what allocation of the revenues it will allow to Hawaiians and what form and extent of participation it will grant to protect the marine environment in which the communal right to fish and gather may take place. The resolution of these issues may have to involve a resolution of the Hawaiian claim for reparations or restitution linked to the 1893 overthrow.*
>
> *The legal uncertainty is rooted in the failure of the U.S. to resolve the potential aboriginal or other claims of Hawaiians for restitution or reparations as a domestic, dependent nation of people, as those of native Americans and Alaska natives have been, or are being resolved. There is ample precedent to support such a claim in Congress. So long as that claim is outstanding, Hawaiians will*

continue to have a defensible claim to the fishery resources of the FCZ and mineral and other resources of the EEZ.

The aforementioned Apology Bill stated that

> *The Congress ... (4) expresses its commitment to acknowledge the ramifications of the overthrow of the Kingdom of Hawai'i, in order to provide a proper foundation for reconciliation between the United States and the Native Hawaiian people; and (5) urges the President of the United States to also acknowledge the ramifications of the overthrow of the Kingdom of Hawai'i and to support reconciliation efforts between the United States and the Native Hawaiian people.*

Some progress has been made in resolving the Hawaiian claim for reparations or restitution linked to the 1893 overthrow. In December 1999, a series of reconciliation hearings attended by federal representatives, Native Hawaiians and the general public was conducted in Hawai'i. In addition, in July 2000, Hawai'i's congressional delegation introduced a bill to express the policy of the United States regarding the United States' relationship with Native Hawaiians, to provide a process for the reorganization of a Native Hawaiian government and the recognition by the United States of the Native Hawaiian government.

As these reconciliation efforts proceed, it is also likely that clarification of rights will be an outgrowth of litigation in the courts. The Hawai'i Supreme Court, for example, has addressed the nature of certain Hawaiian traditions and customs in a number of cases where it had been asked to address the protection of traditional and customary practices under state law. Most recently, in *Public Access Shoreline Hawai'i v. Hawai'i County Planning Commission* , 79 Hawai'i 425, 903 P.2d 1246 (1995), the court emphasized the obligation of a state agency to preserve and protect Native Hawaiian rights. In its consideration of an action by the Hawai'i Planning Commission arising under the Coastal Zone Management Act, the court concluded that the legitimate customary and traditional practices must be protected to the extent feasible in accordance with Article XII, Section 7 of the state constitution and that the state does not have the unfettered discretion to regulate the rights of ahupua'a tenants out of existence.[21] The court reiterated that the Native Hawaiian rights protected by the state constitution may extend beyond the *ahupua'a* in which a Native Hawaiian resides. Moreover, the rights remain intact "...notwithstanding arguable abandonment of a particular site, although this right is potentially subject to regulation in the public interest." Finally, the court went one step further in supporting traditional practices. It said that ancient practices can revive themselves and still have legal authority. In the words of the court, "...continuous exercise is not absolutely required to maintain the validity of a custom."

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[21] Article XII, Section 7 of the Hawai'i Constitution states: "The State reaffirms and shall protect all rights, customarily and traditionally exercised for subsistence, cultural and religious purposes and possessed by *'ahupua'a* tenants who are descendants of native Hawaiians who inhabited the Hawaiian Islands prior to 1778, subject to the right of the State to regulate such rights."

7.6.3 Socio-economic Conditions of Native Hawaiians

At present, people of Native Hawaiian ancestry comprise about 21% of Hawai'i's population (DBEDT 1999). By most statistical measures, they have the lowest incomes and poorest health of any ethnic group in the state. Native Hawaiians have long been among the most economically disadvantaged ethnic or racial group in Hawai'i in terms of standard of living, degree of unemployment, dependence on transfer payments and limited alternative employment opportunities. In recent years, Native Hawaiians have had the highest proportion of individuals living below the poverty line. In 1989, 6% of all the families in the state had incomes classified below the federal poverty level (OHA 1998). During the same period, 14% of Native Hawaiians were below the poverty line. Nearly 15% of Native Hawaiian households receive public assistance income, compared to 6.8% of households in the State (OHA 1998). In several residential areas over a third of Native Hawaiian households receive public assistance.

For centuries Native Hawaiians relied on seafood as their principle source of protein. However, the availability of many traditional seafoods has been significantly diminished. Overfishing and ecological degradation of inshore areas by pollution has had a pronounced negative impact on Native Hawaiian marine subsistence practices. Shomura (1987), for instance, notes that between 1900 and 1986, the harvest of coastal fish species in Hawai'i declined by 80 percent, and catches of neritic-pelagic species declined by 40 percent. The changes in diet that resulted from loss of access to sea resources have contributed to the poor health of Native Hawaiians. Of all racial groups living in Hawai'i, Native Hawaiians are the group with the highest proportion of multiple risk factors leading to illness, disability and premature death (Look and Braun 1995).

As noted earlier, there is abundant historical and archaeological evidence of the social importance of fishing in traditional Hawaiian culture. With specific regard to bottomfish, this significance was of both an economic and ritual nature (Iversen et al. 1990). Bottomfish such as *kāhala*, *ulua* and *'ula'ula* (*onaga*) are specifically mentioned in traditional prayers used by fishermen, and fishing for these species was associated with religious rites. The cultural significance of bottomfish species to Hawaiian society is also indicated by the growth stage names for *'ōpakapaka*, white *ulua*, *kāhala* and the varietal names for *'ula'ula* and *uku*.

There may continue to be a strong cultural and religious connection between contemporary Native Hawaiians and certain species of bottomfish (Iversen et al. 1990). Some present day Native Hawaiian consumers of these bottomfish may still associate these fish with traditional beliefs and with their dependence upon the fish for food. Because of the high cost of some bottomfish, they may be frustrated in maintaining such a traditional connection. Industry sources report that Native Hawaiians purchase proportionally less bottomfish than other ethnic groups, possibly because other types of fish cost less, and if Native Hawaiians have less disposable income to spend on fish, they would likely opt to purchase less costly species (Iversen et al. 1990).