3.10 FEATURES OF THE ECONOMIC ENVIRONMENT: FISHERIES MANAGED AND OPERATING UNDER THE FMP

3.10.1 Introduction

This section presents information concerning the fisheries managed and affected by the Pelagics FMP. The discussion summarizes the areas and fisheries covered, the economic contributions of the fisheries in the larger state and regional economy, and the markets for landings from the fisheries. Each fishery is described in terms of range, operations, landings, and gross revenue. Estimates of total economic contribution from the pelagic fisheries in Hawai'i are also provided. In general, 1998 is used as the base year – the latest year for which final data are available for all sectors.[2]

Several measures of the economic activity in a sector or industry can be used to estimate the impact of the sector or industry on the economy. These measures are easily confused with one another, since the differences between them is often subtle. This study uses total economic contribution and gross revenues to estimate economic activity. Additional measures include net revenues, producer and consumer surplus – including the non-market value of the resource, and net economic benefit. Each of these terms is described below.

- "Gross revenues" are the total receipts of a firm or industry from sales of its outputs. Gross revenues is thought to be a good estimate of the direct effects of a sector on the economy since it provides a straightforward estimate of the industry's activity that is relatively easy to estimate with available data. Gross revenues (unless operators are experiencing losses) also represent the total direct expenditures in the fishery including direct expenditures for input purchases, payments to labor, and profits to owners. In this EIS, gross revenues are the principle indicators of economic activity used to assess impacts of the alternatives, and are discussed extensively in Section 3.10.3-6.

- "Total economic contribution" is an estimated economic activity generated by the production of a good. The economic contribution production includes not only the activity of those generating the product, but also the activity of suppliers of inputs to the producer and activity of purchasers of the goods that use the good to produce their own outputs. Economic contributions of the fishing industry include both the manufacturers of gear that supply gear to the fishers, as well as restaurants that purchase the fish for sale to their customers. Economic contributions of pelagic fishing sectors are estimated in Section 3.10.2.2.

[2] In some cases, information for 1999 is provided when it was available in source documents. At the time of the writing of this draft much of the 1999 data were in the process of being finalized and summarized into regular annual reports.

- "Net revenue" is a measure of profits earned by a business or an industry from its sales (gross revenues) after subtracting out fixed and variable costs including payments to labor. Estimating net revenues requires substantially more information than the estimation of gross revenues, and is much more sensitive to estimation errors because of the variation in costs among firms. In addition, net revenues in an industry could be close to zero while gross revenues are very large, if the industry is very competitive and firms have little profits. In the case of this study, cost and earnings information for individual fishing sectors are discussed in Section 3.10.3. However, available cost information is relatively old and does not sufficiently reflect the current conditions in the industry preventing its use to estimate net revenue effects under the proposed alternatives.

- "Net economic benefit" is the sum of "consumer surplus" and "producer surplus". In theory, the change in net economic benefits attributable to a given action should be the basis of determine whether or not the action is desirable. Projects with positive net economic benefits will benefit society.

    - "Consumer surplus" is a measure of the benefits received by purchasers (or consumers). Generally, consumer surplus is the estimated difference between the maximum amount that consumers are willing to pay for a product and how much they actually do pay. The amount consumers are willing to pay for a good is estimated by examining how quantities of a good purchased vary with market prices over time. Wholesale and consumer markets for pelagic fish species are discussed in Section 3.10.2.3 as are qualitative discussions of market based consumer surplus.

    - To fully estimate the consumer surplus of an action one must estimate the consumer surplus realized through both goods that are sold in the market and goods that are not sold in the market. Non-market benefits are the estimated benefit that society derives from a resource that is not directly bought and sold in the market. For example, whales have considerable non-market value because society values looking at them and simply their continued existence. Neither of these values is directly traded in a market, but any estimation of the value of a program that affects whale populations would be incomplete without at least considering that these values exist. The non-market valuation of environmental goods is discussed in Section 3.10.2.3.

    - "Producer surplus" – similar to consumer surplus-is the difference between the minimum amount for which producers are willing to sell a particular amount of output and the actual amount that they receive for that output. Producer surplus is at times approximated by the total profit (or net revenue) earned by all participants in an industry. Reliable cost information for the fisheries is necessary to produce reliable estimates of net revenues.

Complex econometric techniques and substantial data are needed to accurately estimate both market and non-market contributions to consumer surplus and producer surplus. Unfortunately, reliable data for accurately estimating either aspect of consumer surplus or producer surplus are unavailable for this work. Consequently, this study examines gross revenues and total economic contribution to estimate the impact of the Pelagics FMP on the economy. It is important to note that these estimated do not include any economic contribution or economic benefit of the preservation of sea turtles, sea birds, or sharks. The measures used in this study are only estimates of the economic activity of the fishery industry. Qualitative discussions of consumer surplus and nonmarket benefits are included to clarify the scope and limitations of this study.

Section 3.10 is divided into the following subsections.

Sec. 3.10.1 Introduction

Sec. 3.10.2 Overview of Fisheries Managed – presents the region fished, the fish species managed by the plan, and protected species that have potential interactions.

Sec. 3.10.2.1 Summary of Vessels, Landings, and Gross Revenue in the Managed Fisheries – briefly describes and summarizes the fisheries, provides summary tables showing catch composition, participation, total pounds landed, and value for 1998, and figures and a table showing historical pelagic landings and gross revenues.

Sec. 3.10.2.2 Economic Contributions of Pelagic Fisheries in Hawai‘i – examines the economic impacts associated with the fisheries, including indirect and induced income and employment.

Sec. 3.10.2.3 Markets for Hawai‘i’s Pelagic Fisheries – discusses the local, national, and international markets for landings from the FMP fisheries and market channels.

Sec. 3.10.2.4 Valuation of Species and Environmental Goods – discusses potential methodologies that could be used to estimate values of environmental goods and other non-market values associated with fisheries in the western Pacific.

Sec. 3.10.3 Pelagic Fisheries in Hawai‘i – describes the four major gear fisheries covered by the Pelagics FMP. This section has four subsections as follows:

Sec. 3.10.3.1 Hawai‘i-based Longline Fishery – describes the largest pelagic fishery operating in Hawai‘i.

Sec. 3.10.3.2 Hawai'i-based Troll Fisheries – describes three pelagic fisheries that use troll gear, including the commercial troll fishery, the charter fishery, and the recreational fishery.

Sec. 3.10.3.3 Hawai'i-based Handline Fisheries – describes fisheries that use handlines. These fisheries are also known as the *ika-shibi*, *palu-ahi*, and offshore seamount fisheries.

Sec. 3.10.3.4 Hawai'i-based Pole-and-line Fisheries – describes the pole-and-line fisheries that continue to operate. The pole-and-line fishery is also known as the *aku* fishery or the baitboat fishery.

Sec. 3.10.4 Pelagic Fisheries in American Samoa – describes the domestic longline (the *alia* fleet) and troll fisheries in American Samoa that operate primarily in the EEZ.

Sec. 3.10.5 Pelagic Fisheries in the Territory of Guam – describes the domestic troll fisheries in Guam.

Sec. 3.10.6 Pelagic Fisheries in the Commonwealth of the Northern Marianas Islands – describes the domestic troll fisheries of the Commonwealth.

Much of the information in Section 3.10 has been drawn directly from publications of NMFS and the Western Pacific Regional Fishery Management Council (WPRFMC). The primary sources are listed below.

- Bartram P. 1997. *U.S. Fresh Tuna Market Study*. Prepared for the Forum Fisheries Agency, Honiara, Solomon Islands. December 1997.
- Cousins K., P. Dalzell, E. Gilman. 2000. Managing pelagic longline-albatross interactions in the North Pacific Ocean.
- Hamilton M. 1998. Cost-Earnings Study of Hawaii's Charter Fishing Industry 1996-1997. JIMAR Pelagic Fisheries Research Program. SOEST 98-08. JIMAR Contribution 98-322.
- Hamilton M. and S. Huffman. JIMAR Pelagic Fisheries Research Program. 1997. Cost Earnings Study of Hawaii's Small Boat Fishery, 1995-1996. SOEST 97-06. JIMAR Contribution 97-314.
- Hamilton M., R. Curtis, M. Travis. 1996. Cost-Earnings Study of the Hawaii Domestic Longline Fleet. JIMAR Pelagic Fisheries Research Program. SOEST 96-03. JIMAR Contribution 96-300.
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- Sharma K. and P. Leung. In press. Economic Impacts of Landings Allocation from Commercial Fishery to Recreational Fishery in Hawaii. University of Hawai'i, Aquaculture and Fisheries Economic Group, Department of Biosystems Engineering. North American Journal of Fisheries Management.
- Sharma K., A. Peterson, S. Pooley, S. Nakamoto, P. Leung. 1999b. Economic Contributions of Hawaii's Fisheries. JIMAR Pelagic Fisheries Research Program. SOEST 99-08. JIMAR 99-327.
- WPRFMC. 1995. Pelagic Fishing Methods in the Pacific.
- WPRFMC. 1999c. Measures to Reduce the Incidental Catch of Seabirds in the Hawaii Longline Fishery, A Framework Adjustment to the Western Pacific Pelagic Fisheries Management Plan Including an Environmental Assessment and Regulatory Impact Review/Regulatory Flexibility Analysis. December 13, 1999 (Revised March 2000.)
- WPRFMC. 1999d. Pelagic Fisheries of the Western Pacific Region. November 5, 1999. 1998 Annual Report (Draft).
- WPRFMC. 2000. Prohibition on fishing for pelagic management unit species within closed areas around the islands of American Samoa by vessels more than 50 feet in length. October 2000.

3.10.2 Overview of Fisheries Managed

Under the Magnuson-Stevens Act, the United States has exclusive fishery management authority over all living marine resources found within its Exclusive Economic Zones. The Council developed the Fishery Management Plan for the Pelagic Fisheries of the Western Pacific Region to manage the pelagic resources of the U.S. EEZs around Hawai'i, American Samoa, Guam, the Northern Mariana Islands, and U.S. possessions in the Western Pacific Region (Palmyra and Johnston Atolls, Kingman Reef, and Jarvis, Howland, Baker, Midway and Wake Islands) (Figure 3.10.2-1). Under the FMP, only permitted vessels may land longline-caught fish in Hawai'i. This requirement has the effect of extending the scope of the FMP far beyond the EEZ to all waters fished by Hawai'i-based longliners.[3]

[3] Vessels that hold Hawai'i longline permits but only fish on the high seas are not under the jurisdiction of the FMP if they choose to make landings outside of Hawai'i, for example in California. Longline vessels fishing in the EEZs of American Samoa, Guam and the CNMI are required to have general longline permits under the FMP, but there are currently no limits on the number of permits that may be issued.

Hawai'i fisheries managed under the FMP can be divided into three geographical areas: (1) the inhabited Main Hawaiian Islands (MHI), with surrounding reefs and offshore banks (the island of Hawai'i to Ni'ihau and Kaua'i); (2) the uninhabited Northwestern Hawaiian Islands (NWHI), a 1,200 mile string of reefs, shoals, and islets ranging northwest from the MHI; and (3) the mid-North Pacific Ocean, ranging from 40° N. to 20° S. latitude, and from 145° W. to 175° E. longitude. In addition, the Pelagics FMP has the authority to regulate pelagic fishing activities in the EEZs of American Samoa, Guam, the CNMI, and the Pacific remote island areas of Howland, Baker and Jarvis Islands, Midway, Johnston, Palmyra and Wake Atolls, and Kingman Reef..

Table 3.10.2-1 lists species managed under the FMP and termed "Pacific Pelagic Management Unit Species" (PMUS). Many or all of the pelagic species exploited under the FMP belong to highly migratory stocks that are fished throughout the Pacific. These stocks are harvested by the longline, purse seine, pole-and-line, and troll fisheries of Japan, the United States, Korea, Taiwan, and other nations. Until 1993, these stocks were also exploited by the drift gillnet fisheries of Japan, Korea, and Taiwan. These fisheries interact with and are affected by the management of protected species including turtles, seabirds, and marine mammals (Table 3.10.2-2). Note that biological issues of these species are discussed in Section 3.4. This section provides a more limited discussion to place the species in an economic context.

Figure 3.10.2-1: Exclusive Economic Zones of the Pacific Islands. Western Pacific Regional Fishery Management Council Managed Areas are Shaded. Source: WPRFMC, 1999d.

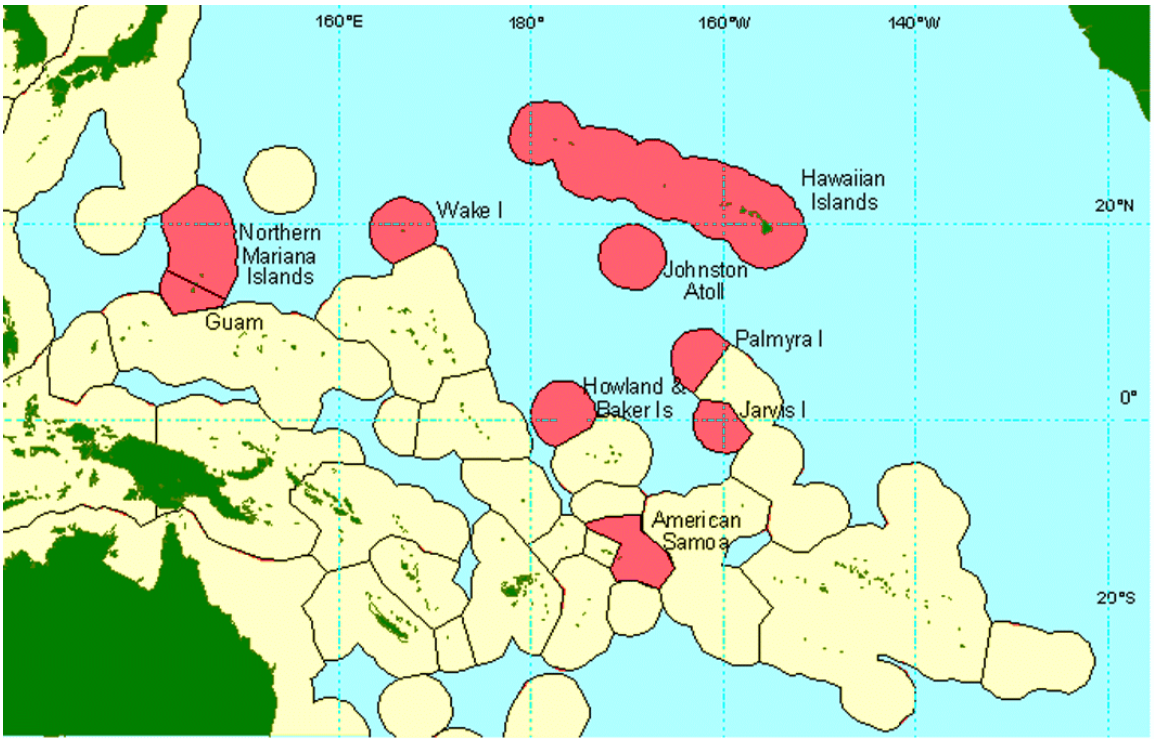


Table 3.10.2-1: Common and Scientific Names of Pelagic Management Unit Species (PMUS).

PELAGIC MANAGEMENT UNIT SPECIES		
	Common Name	Scientific Name
Billfish		
	Swordfish	*Xiphias gladius*
	Black Marlin	*Makaira indica*
	Blue Marlin	*Makaira mazara*
	Striped Marlin	*Tetrapturus audax*
	Shortbill Spearfish	*T. angustirostris*
	Sailfish	*Istiophorus platypterus*
Tunas		
	Bigeye tuna	*Thunnus obesus*
	Albacore tuna	*T. alalunga*
	Yellowfin tuna	*T. albacares*
	Northern bluefin tuna	*T. thunnus orientalis*
	Skipjack tuna	*Katsuwonus pelamis*
	Kawakawa	*Euthynnus affinis*
Sharks		
	Blue shark	*Prionace glauca*
	Thresher (big eye)	*Alopias superciliosus*
	Mako (short fin)	*Isurus oxyrinchus*
	White tip (oceanic)	*Carcharhinus longimanus*
	Tiger shark	*Galeocerdo cuvieri*
	Miscellaneous sharks	Families Carcharhinidae, Alopiidae, Sphyrnidae, and Laminidae
Miscellaneous PMUS		
	Mahimahi	*Coryphaena hippurus*
	Wahoo (*Ono*)	*Acanthocybium solandri*
	Moonfish (*Opah*)	*Lampris guttatus*
	Pomfret (*Monchong*)	Family Bramidae
	Oilfish	Family Gempylidae
Miscellaneous Pelagics		
	Lancet fish	*Alepisaurus* spp.
	Barracuda	*Sphyraena barracuda*
	Brown stingray	*Dasyatis violacea*

Table 3.10.2-2: Common and Scientific Names of Protected Species.

PROTECTED SPECIES	
Common Name	Scientific Name
Hawaiian Monk Seal	*Monachus schauinslandi*
Humpback Whale	*Megaptera novaengliae*
Dolphins	Family Delphinidae
Green Turtle	*Chelonia mydas*
Olive Ridley Turtle	*Lepidochelys olivacea*
Hawksbill Turtle	*Eretmochelys imbricata*
Leatherback Turtle	*Dermochelys coriacea*
Loggerhead Turtle	*Caretta caretta*
Laysan Albatross	*Phoebastria immutabilis*
Black-footed Albatross	*P. nigripes*
Short-tailed Albatross	*P. albatrus*
Brown Booby	*Sula leucogaster plotus*
Wedge-tailed Shearwater	*Puffinus pacificus*

3.10.2.1 Summary of Vessels, Landings, and Gross Revenue in the Managed Fisheries

The FMP manages unique and diverse fisheries. Hawai'i-based longline vessels are capable of traveling long distances to high-seas fishing grounds, with trips typically ranging from 14 to 44 days. The smaller handline, troll, charter, and pole-and-line fisheries, which may be commercial, recreational, or subsistence generally occur within 25 miles of land, with trips generally lasting only one day.

Hawai'i's pelagic fisheries are small in comparison with other Pacific pelagic fisheries such as distant-water purse seine fisheries and other foreign pelagic longline fisheries (NMFS, 1991), but they comprise the largest fishery in the state of Hawai'i (Pooley, 1993). Tuna, billfish and other tropical pelagic species supply most of the fresh pelagic fish consumed by Hawai'i residents and support popular recreational fisheries (Boggs and Kikawa, 1993).

Of all Pelagics FMP fisheries, the Hawai'i-based limited access longline fishery is the largest commercial fishery. This fishery accounted for 85 percent of Hawai'i's commercial pelagic landings (28.6 million lb) in 1998 (Ito *et al.*, 1999). Other active FMP fisheries targeting pelagic species include handline, charter sport, troll, and pole-and-line fisheries. A short description of the fishing methods for each of these fishing sectors is provided in the following paragraphs.

The longline fleet operates 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 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.

Trolling 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 charter fishery is primarily a troll fishery focusing on 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 and expense fleet primarily employs troll gear to target pelagic species. Some of these fishers sell a portion of their landings to cover expenses (expense boats). While some of the fishing methods and other characteristics of the recreational and expense fleet are similar to those described for the commercial troll fleet, a survey of the recreational and expense fleet showed substantial differences in equipment, lower avidity, and lower catch rates compared to commercial fishers.

Handline fishing is an ancient technique 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 Hawai'i. Three methods of pelagic handline fishing are practiced in Hawai'i, the *ika-shibi* (nighttime) method, the *palu-ahi* (daytime) method, and seamount fishing (which uses both handline and troll methods).

The *aku* fishery is also known as the pole-and-line fishery, or the bait boat fishery because of its use of live bait. *Aku* is the Hawaiian term for skipjack tuna. The *aku* fishery is a labor-intensive, highly selective process. Live bait is broadcast to entice the primary targets of skipjack tuna and juvenile yellowfin tuna to bite on barbless hooks with feather skirts.

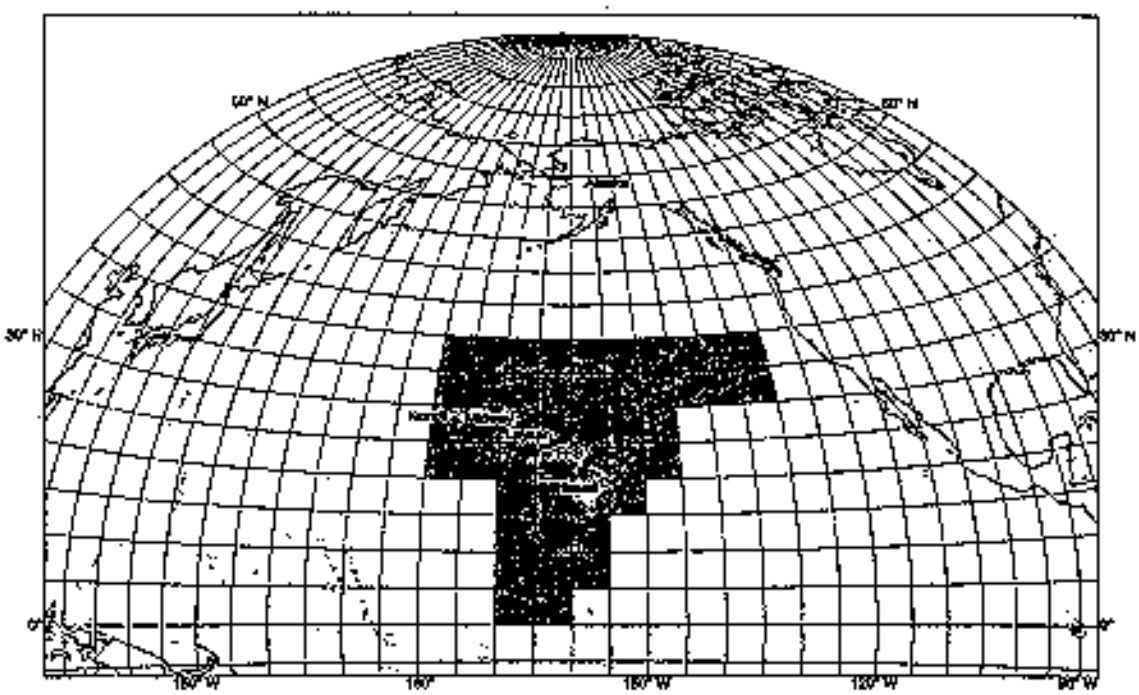
During the fast and furious catching activity, tuna are hooked on lines and in one motion swung onto the boat deck by crew members.

U.S. purse seine and albacore fleets operating outside the U.S. EEZ around Hawai'i are not managed under the Pelagics FMP are discussed in detail in Sections 3.13 and 3.14. These other U.S. and foreign fleets land more than 100 times more pelagic fish by weight than the fisheries managed under the FMP.

In most of these fisheries, including domestic fisheries under the FMP, U.S. distant-water fisheries, and foreign fisheries, incidental interactions with protected species (for example, sea turtles, seabirds, and marine mammals) occur with varying frequencies. These interactions (where information is available) are discussed in the sections focusing on the different fleet components.

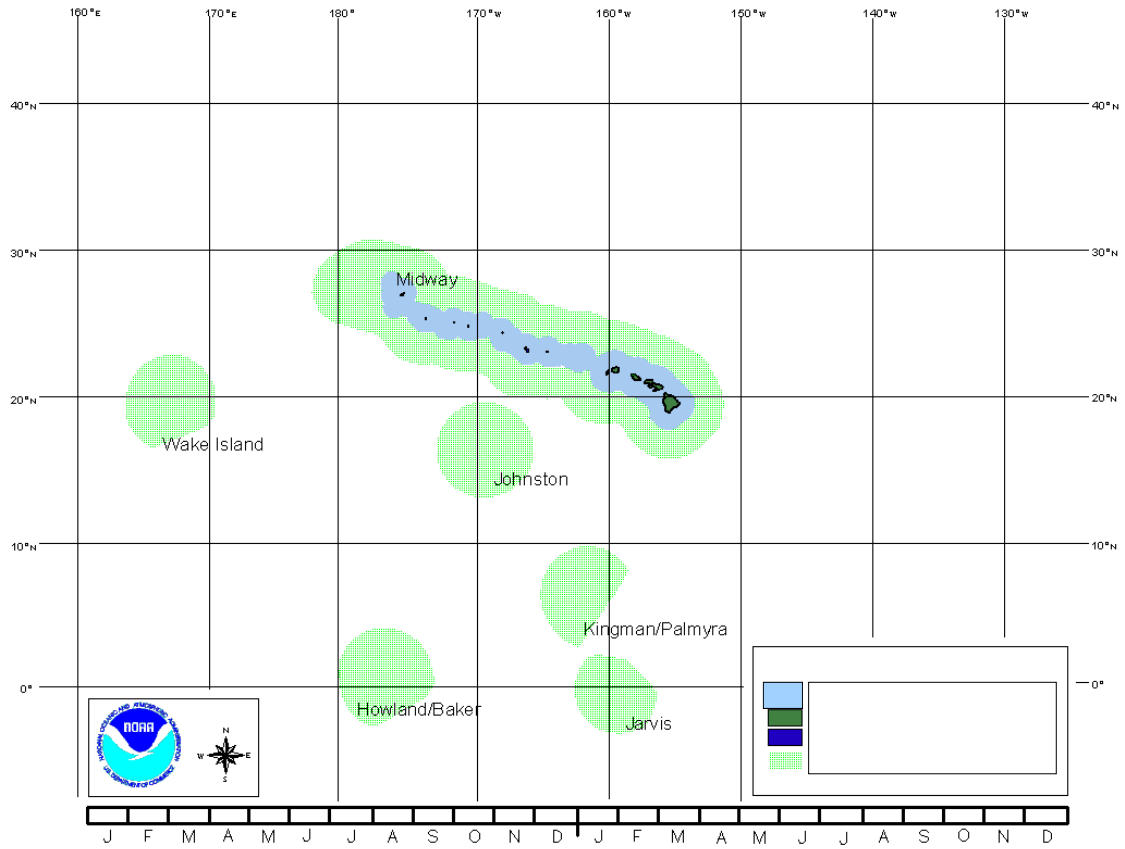
Fishing activity by handline, troll, charter, and pole-and-line fisheries tends to occur within the EEZs, with most trips occurring within 25 miles of shore due to the nature and condition of the vessels. In contrast, a large percentage of Hawai'i-based longline fishing takes place outside the EEZ around Hawai'i (Figure 3.10.2-2). When fishing on these international grounds, these longline vessels compete directly for harvests with longliners from other countries such as Japan, Korea, and Taiwan. The portion of the fishing grounds closer to the U.S. mainland is also fished by U.S. longliners delivering to California, including some Hawai'i-based vessels during midwinter.

Figure 3.10.2-2: Historical Maximum Boundaries of the Hawai'i-based Longline Fishery. Source: NMFS and WPRFMC, 2000.



In early 1991, longline fishing was prohibited in certain areas by Amendment 3 to the Pelagics FMP, in order to establish a protected species zone in the NWHI (Figure 3.10.2-3). The zone was created to protect endangered Hawaiian monk seals (*Monachus schauinslandi*), a federally protected species. A further longline exclusion zone of 50 to 75 nautical miles (nm) around the MHI was implemented through Pelagics FMP Amendment 5 to alleviate potential gear conflicts among small boat handline/troll fishers, charter boat operators, recreational fishers, and longline fishers. A Vessel Monitoring System (VMS) is used to enforce the two longline exclusion zones. The dark line outlining the islands in Figure 3.10.2-3 represents the three mile state waters. The area shaded immediately around the islands represents the area closed to large vessels. The areas shaded in a white and gray pattern represent the EEZ.

Figure 3.10.2-3: Protected Species and Near Shore Closure Zone Around the MHI and NWHI. Source: NMFS, 2000j.



Landings by Hawai'i-based fisheries in 1998 ranged from 696,000 pounds by the *aku* boats to 28.6 million pounds by the longline fleet (Table 3.10.2-3). Tunas (*Thunnus* spp.), and broadbill swordfish (*Xiphias gladius*) are the dominant target species, but a variety of other pelagic species are also landed incidentally, including blue sharks *(Prionace glauca*), *opah* (*Lampris guttatus*), marlin (Family *Tetrapturidae*, and Family *Makairadae*), and *mahimahi* (Family *Coryphaenidae*).

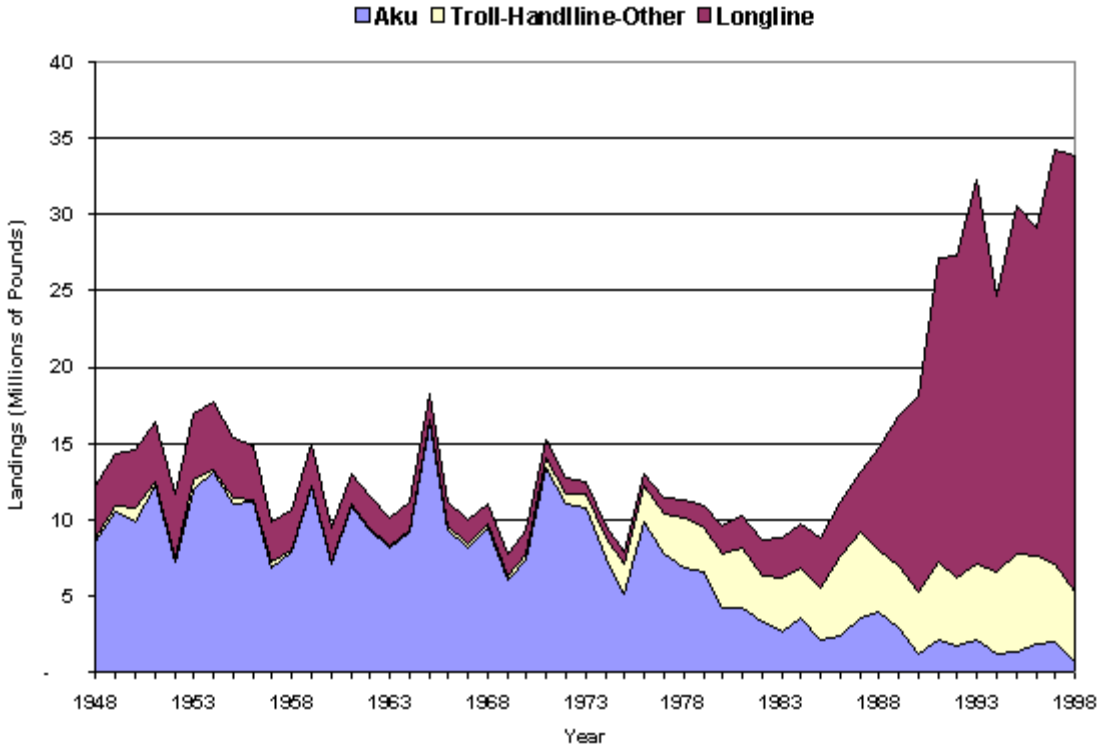
Table 3.10.2-3: Fishery Information for Hawai'i Pelagic Fisheries for 1998. Source: Adapted from WPRFMC, 1998 Annual Report; Our Living Oceans 1999 Report *in* NMFS, 2000j.

Gear/Vessel Type	Longline	Charter Fishery	Troll/Handline Fisheries	Pole-and-line Fishery (*Aku* Fishery)
Area Fished	EEZ around Hawai'i (25-200 nm) and high seas	Inshore and EEZ	Inshore and EEZ	Inshore and EEZ
Total Landings	28.6 million pounds	1.8 million pounds	4,570,000 pounds	696,000 pounds
Catch Composition	24% bigeye tuna 24% pelagic sharks 12% albacore tuna 11% swordfish 6% yellowfin tuna	billfish wahoo yellowfin tuna skipjack tuna (catch percentages are unknown)	yellowfin tuna skipjack tuna *mahimahi* Wahoo striped marlin bigeye tuna (catch percentages are unknown)	99.6% skipjack tuna
Season	All year	All year	All year	All year
Active Vessels	114	199	1,824	6
Total Permits	164 (transferable) (Limited Entry)	NA	NA	NA
Total Trips	1,140	16,700 (estimate)	26,203	223
Total Ex-vessel Value	$46.7 million	$15.3 million	$7.2 million	$0.9 million

Note: Data do not include all landings for recreational fishers. For the charter fishery, gross revenue estimates include charter fees, fish sales, and mount sales commissions for a 12-month period in 1996-1997 (See Section 3.10.3.2).

Total pelagic landings experienced a slow decline from the early 1950s through the mid-1980s. The decline was primarily due to reduced landings by the *aku* fleet although decreases in longline landings are also apparent in Figure 3.10.2-4. Landings by the troll fleet began to increase in the early 1970s but the overall decline in pelagic landings continued. The pelagic landings of the longline fleet began to slowly increase in the late 1970s but it wasn't until the mid-1980s when longline landings began to increase substantially that the decline of more than three decades was overcome. Total pelagic landings increased dramatically through the mid-1990s with substantial variability since that time.

Figure 3.10.2-4: Hawai'i-based Pelagic Landings by Major Commercial Gear Types, 1948 - 1998. Source: WPRFMC, 1999d.



Gross revenues to fishers involved in harvesting pelagic species experienced a similar decline from the early 1950s through about 1970. The decrease in gross revenue during that period appears to be shared almost equally between the *aku* and longline fisheries (Figure 3.10.2-5). Gross revenues for the *aku* fishery increased for several years in the early 1970s and *aku* boats generally maintained their gross revenues into the late 1970s when gross revenues again began to decline for this fishery. The general decline has continued through 1998. Gross revenues for the troll-handline-other gear type also began to increase in the early 1970s. This gear type experienced some stability in gross revenues from the late 1970s through the late 1980s, and since then has experienced slight decreases in gross revenues. In comparison, gross revenues for the longline fleet began to increase slowly in the 1970s and continued that growth until about 1985 when gross revenues expanded dramatically; more than tripling in a few years. Since about 1983 there has been a downward trend in longline gross revenues but the revenues are still near historically high levels. Table 3.10.2-4 presents the data portrayed in Figure 3.10.2.-4 and Figure 3.10.2-5.

Figure 3.10.2-5: Hawai'i-based Pelagic Fishing Gross Revenue, Major Commercial Gear Types, 1948-1998. Source: Ito and Machado, 1999.

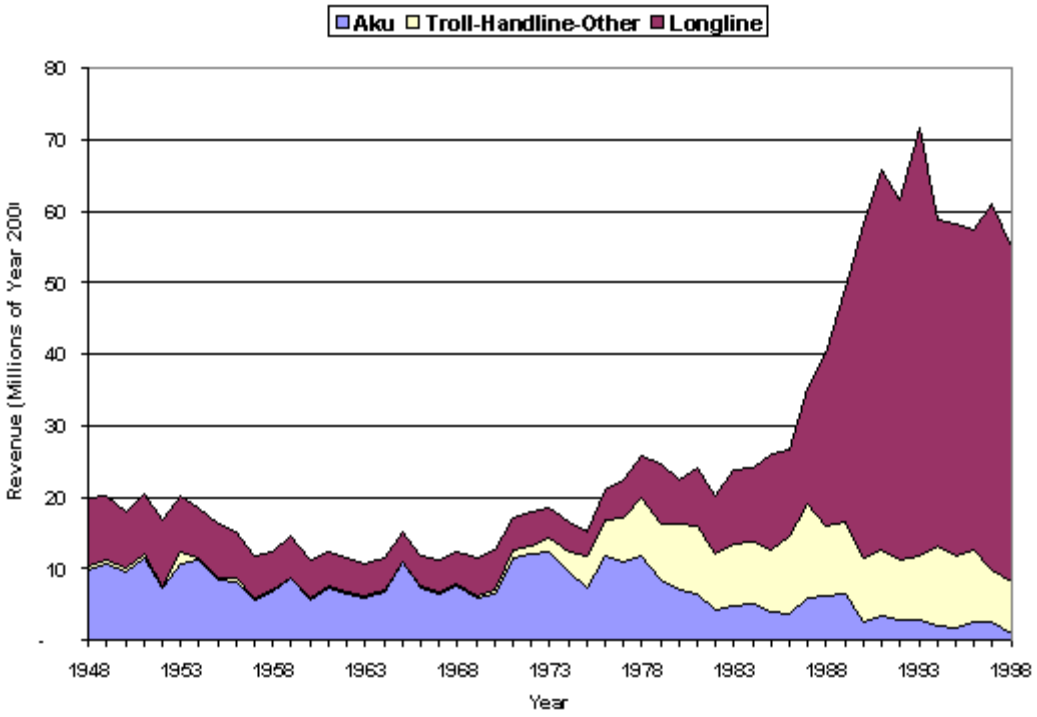


Table 3.10.2-4: Hawai'i Pelagic Landings and Gross Revenues by Major Commercial Gear Types, 1948 - 1998. Source: WPRFMC, 1999d.

Year	Landings (Millions of Pounds)			Gross Revenues (Millions of Year 2000$)		
	Aku	Longline	Troll-Handline-Other	Aku	Longline	Troll-Handline-Other
1948	8.5	3.5	0.3	9.7	9.7	0.6
1949	10.5	3.5	0.3	10.6	8.9	0.6
1950	9.8	3.9	1.0	9.7	7.9	0.4
1951	12.3	4.0	0.2	11.6	8.4	0.3
1952	7.2	4.3	0.2	7.2	9.2	0.4
1953	11.9	4.3	0.6	10.8	7.7	1.7
1954	13.1	4.4	0.2	11.2	6.9	0.2
1955	11.0	3.9	0.4	8.4	7.5	0.3
1956	11.1	3.4	0.2	8.3	6.6	0.3
1957	6.8	2.6	0.5	5.6	5.8	0.3
1958	7.9	2.6	0.2	6.7	5.5	0.2
1959	12.1	2.6	0.1	8.6	5.7	0.2

Year	Landings (Millions of Pounds)			Gross Revenues (Millions of Year 2000$)		
	Aku	Longline	Troll-Handline-Other	Aku	Longline	Troll-Handline-Other
1960	7.1	2.2	0.2	5.6	5.2	0.2
1961	10.9	2.0	0.1	7.3	4.7	0.2
1962	9.3	2.0	0.2	6.4	4.8	0.2
1963	8.1	1.8	0.2	5.9	4.4	0.2
1964	9.1	1.9	0.2	6.7	4.6	0.2
1965	16.3	1.7	0.2	10.8	4.3	0.2
1966	9.3	1.7	0.2	7.2	4.3	0.3
1967	8.2	1.6	0.2	6.4	4.4	0.3
1968	9.5	1.4	0.2	7.6	4.3	0.3
1969	6.1	1.4	0.3	5.9	5.2	0.4
1970	7.4	1.5	0.4	6.5	5.5	0.5
1971	13.4	1.2	0.7	11.6	4.6	1.0
1972	11.0	1.1	0.7	12.0	4.8	1.2
1973	10.8	0.8	0.9	12.5	4.4	1.7
1974	7.4	0.8	1.3	9.4	4.3	2.8
1975	5.1	0.7	2.1	7.4	3.6	4.3
1976	9.9	0.8	2.2	11.7	4.1	5.1
1977	7.8	1.1	2.5	10.8	5.3	6.3
1978	6.8	1.1	3.3	11.8	6.0	7.9
1979	6.5	1.4	2.9	8.4	8.5	7.8
1980	4.2	1.7	3.6	7.0	6.3	9.1
1981	4.2	2.0	3.9	6.5	8.3	9.4
1982	3.3	2.4	2.9	4.3	8.1	7.6
1983	2.7	2.7	3.4	4.7	10.4	8.6
1984	3.5	3.0	3.3	5.1	10.2	8.7
1985	2.1	3.3	3.4	3.8	13.3	8.7
1986	2.4	3.6	5.2	3.7	12.0	10.8
1987	3.5	3.9	5.7	5.9	16.4	13.0
1988	3.9	6.7	4.0	6.2	24.0	9.8
1989	3.0	9.8	4.0	6.4	32.7	10.0
1990	1.2	12.8	4.1	2.5	46.6	9.0
1991	2.1	20.0	5.1	3.3	53.1	9.4
1992	1.7	21.1	4.4	2.8	50.4	8.3
1993	2.1	25.2	4.9	2.7	59.7	9.0
1994	1.2	18.1	5.4	2.0	45.5	11.2

Year	Landings (Millions of Pounds)			Gross Revenues (Millions of Year 2000$)		
	Aku	Longline	Troll-Handline-Other	Aku	Longline	Troll-Handline-Other
1995	1.3	22.9	6.4	1.7	46.4	10.1
1996	1.8	21.5	5.8	2.5	44.8	10.1
1997	1.9	27.1	5.1	2.4	51.3	7.3
1998	0.7	28.6	4.6	0.9	46.7	7.2

American Samoa-based pelagic fisheries consist of a small fleet of *alia* longliners, a few mid-size and larger longliners, and a small fleet of trolling vessels. Guam is home to an active trolling fleet and several charter sportfishing vessels, as is the CNMI. These fleets target albacore, skipjack tuna, yellowfin tuna, and other pelagic species, and in 1998, made landings ranging from 25,000 pounds by American Samoa trollers to 884,000 pounds by American Samoa *alia* longliners (Table 3.10.2-5).

Table 3.10.2-5: Pelagic Fishery Information for American Samoa, Guam, and CNMI, 1998. Source: Adapted from WPRFMC, 1999d; Our Living Oceans 1999 Report *in* NMFS, 2000j; data provided by Hamm, 2000.

Islands	**American Samoa - 1998**		**Guam - 1998**	**CNMI - 1998**
Gear	**Longline**	**Troll/Charter**	**Troll/Charter**	**Troll/Charter**
Area Fished	Inshore and EEZ	Inshore and EEZ	Inshore and EEZ	Inshore and EEZ
Total Landings	884,154 lb	25,271 lb	817,087 lb	192,568 lb*
Catch Composition	72% albacore tuna 8% yellowfin tuna < 5% all others	74% skipjack tuna 6% barracuda 4% yellowfin tuna < 4% all others	31% mahimahi 23% skipjack tuna 19% yellowfin tuna	70% skipjack tuna 11% mahimhai 8% dogtooth tuna 6% yellowfin tuna
Season	All year	All year	All year	All year
Active Vessels	25	24	438	89
Total Permits	50 (open access)	NA	NA	NA
Total Trips	2,359	123	14,324	2,230
Total Ex-vessel Value	$968,361**	$29,949**	$711,066***	$398,086

Notes:
*Landings for CNMI are recorded commercial landings, but not all commercial landings are recorded (D. Hamm, NMFS SWSFC-HL, pers. comm., November 3, 2000).
**The ex-vessel value of landings in American Samoa was determined to be inaccurate as originally listed in NMFS 2000j. The values shown were estimated as 97 percent of total gross revenue from Table 3.10.4-6 for the longliners, and 3 percent of total gross revenue for the troll fleet (Hamm, 2000).
***Total ex-vessel value of landings in Guam are estimated from commercial landings, which are less than 50 percent of total landings.

3.10.2.2 Economic Contributions of Pelagic Fisheries in Hawai'i

This section provides estimates of the total economic contribution of Hawai'i-based pelagic fishing fleets, including direct, indirect, and induced impacts. These estimates can be used to estimate the relative importance of the fleets to Hawai'i's economy.

As indicated in Section 3.10.2.1, in 1993 the pelagic fisheries in Hawai'i combined generated more than $70 million in gross revenues from direct fish sales and sales of charter fishing trips.[4] While the total gross revenue of an industry is an important measure of economic activity, it does not capture all of the economic impacts generated by the demand for the industry's products and services. Industries rely on each other such that the total impact of an industry on an economy cannot be captured without estimating the industry's effect on other industries. To estimate the impact of an industry on the economy, not only the direct effect of that industry must be estimated, but also the indirect effects and induced effects. Indirect effects occur because an industry purchases inputs from other industries for its operations. In the fishing industry, indirect effects include purchases of boats, gear, and other fishing supplies. Induced effects occur through payments that an industry makes to its employees and through tax payments. These payments are used by the workers and the government to purchase goods and services, stimulating further economic activity.

Economists use input-output (I/O) analysis to measure the contribution of an industry to the economy. In addition, I/O analysis can be used to project economic impacts of a change in a given industry, such as the closures that have affected the longline fishery in Hawai'i.

I/O analysis begins with a full accounting of the economy. A transaction table is constructed that shows all interactions of all industries. This table shows all inputs (including labor) that each industry purchases and all payments that the industry makes (including taxes) to produce its outputs, and who purchases those outputs. From this accounting, one can determine the direct impacts of an industry: the employment, input purchases, tax payments, and gross revenues of the industry. By using the table, one can also determine the activities of all other industries that are stimulated by the industry using the interactions shown in the table. The input purchases of each of the supplying industries, in turn, stimulate further purchases and activity in the economy. These secondary transactions are the indirect effects of the model. The tax payments, payments to labor, and other gross revenues in the I/O table can be used to measure induced effects. Induced effects are generated as labor income, profits, and tax revenues generated by the inter-industry transactions are spent on goods and services in the general economy.

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[4]Gross revenues vary each year with harvests and prices. Hawai'i's fisheries have averaged approximately $60 million in gross revenues since the late 1980s. The 1993 gross revenues are cited here, as that is the base year of the model used.

By combining the direct, indirect, and induced effects, the I/O model can be used to measure the economic activity generated by the activity of the industry. Figure 3.10.2-6 lists the various effects that are estimated using I/O models.

Figure 3.10.2-6: Components of Input-Output Analysis. Source: Miller *et al.*, 1985.

Economic impacts are measured as sales, income or employment.

Direct Effects
- Purchases by the industry
  - Purchases from local suppliers
  - Imports and purchases from outside the local economy
- Direct employment (wage and salary payments)
- Proprietary income and profits
- Rents, dividends
- Tax payments and other government revenues

Indirect Effects
- Purchases by suppliers
  - Purchases by suppliers from other local suppliers
  - Imports and purchases by suppliers from outside the local economy.
- Wage and salary payments by suppliers
- Proprietary income and profits earned by suppliers
- Employment of suppliers (wage and salary payments)
- Tax payments and other government revenues paid by suppliers

Induced Effects
- Purchases using wages, salaries, proprietary income, profits, and government revenues

A 1999 study by Sharma and others (Sharma *et al.*, 1999b) estimated the economic contribution of marine fisheries in Hawai'i in an I/O model using data compiled in the fishery cost and earnings studies of Hamilton *et al.* (1996, 1997) and Hamilton (1998). The base year of the model is 1992. Much of the data used to construct the model are from that year, however, to assure accuracy the model supplemented the 1992 data with data gathered between 1992 and 1998. The research and analysis for this section of the EIS rely on that model to develop a general understanding of the economic impacts of the pelagic fishery and to estimate the potential impacts of the management alternatives on Hawai'i's economy. For reasons enumerated in the following text, the estimates should be considered relative rather than absolute measures of these impacts.

The fishery sector figures presented in Sharma *et al.* (1999) and in the EIS in this section were constructed using non-randomized survey data and potentially under-reported commercial catch data (including State tax revenue figures). In particular, the levels of activity in the recreational, expense, and charter fishing segments of the pelagic fishery are not well known and survey results may be subject to avidity bias which would inflate activity estimates. The EIS was required to make use of these figures because there is no comprehensive source of information about participation and activity levels in these pelagic fishery sectors in Hawai'i. In addition, substantial questions have been raised about the size of the commercial pelagic handline fishery as well as the other commercial small boat sectors

of the pelagic fishery. Even for the longline fishery for which there are comprehensive logbooks, estimates of landings and revenues are made by NMFS annually.

As a result, no particular conclusion should be made concerning the relative weight (value) of the various fishery sectors from the input-output analysis. However the inter-industry component of the input-output analysis – the relationship of each pelagic fishery sector with the rest of Hawai'i's economy which is the heart of the analysis – is based on survey cost data which appears broadly representative of those participants active in these fisheries. Because of this, the relative impacts of various fishery management alternatives as applied within a pelagic fishery sector, e.g., longline, should be also broadly representative. Or put another way, although the estimates of the size of the sectors are based on a set of assumptions which may not ultimately be found to be true, the input-output relationships were applied consistently across the management alternatives within a sector and thus the ranking of relative impacts of alternatives is likely to be correct. If there were to be differential effects across sectors or reallocation of fish between sectors, then these shortcomings in the underlying data could be significant. As it turns out, reallocations and differential effects between sectors (not within a sector) are not included in the set of management alternatives considered in the EIS.

Furthermore, it should be noted that input-output analysis relies on two fundamental assumptions. First, production technologies are assumed to be fixed – each industry is assumed to use the same proportions of inputs to produce its output, regardless of the quantity of outputs produced. For this condition to be true, the industries must be well established, with developed technology and adequate infrastructure. While Hawai'i's pelagic fisheries are well established industry sectors that have been active for several decades, there have been significant changes in recent years. Supporting industries, such as the auctions and fishing supply industries, also have a long history in the state. These features of the pelagic fisheries and Hawai'i's economy suggest that while I/O may be an appropriate tool to analyze the industry, the results should be viewed in representative terms rather than as absolutes.

A second assumption of I/O analysis is that prices are fixed. Increases of demands from different sectors are assumed to have no effect on the prices of goods. Prices of the outputs of the pelagic fishery, however, are known to vary seasonally. These seasonal fluctuations tend to be consistent and predictable. Some price changes in Hawai'i's fishing industry should also be considered. In 1998, for example, fish prices dropped significantly because of the decline in Asian economies. Fuel prices also fluctuated greatly in 1999 and 2000. These price variations suggest that the results of I/O analysis should be used cautiously.

A related feature of I/O analysis is that it relies on a static estimation of activity in the economy. A single year's transactions are the basis of the model. Changes in the economy or production technologies can invalidate the model if they substantially alter the flows of goods and payments. The model used in this analysis was developed using data collected from fishery operations in the early to mid-1990s. Some changes in the longline fisheries that

have occurred since that time are worth considering. Targeting of swordfish has increased. Fishers have increased the number of hooks used in each set, which may increase catch per set. Vessel and motor sizes have increased in recent years. These vessel changes affect both the areas fished and operating costs. All of these factors suggest that the results of the I/O analysis should be considered general and imprecise measures of economic impacts. These shortcomings notwithstanding, I/O is the best available means for this analysis.

The basic transaction table used in the I/O model developed by Sharma and others (1999) has been adapted and reproduced in Table 3.10.2-6. The transaction table shows estimated expenditures, sales, income and employment in each sector. Four fisheries sectors are listed: the longline fishery, other commercial fishery, charter fishery, and recreational/expense fishery.[5] Table 3.10.2-6 shows a sector labeled "All Other Hawai'i Industries" – this is an aggregation of all other sectors in the Hawai'i economy.[6]

In the table all rows represent purchases and all columns represent sales. The inter-industry transactions are included as intermediate demands in the upper left region of the table. These transactions are the sales of inputs by each industry to other industries and sum to total intermediate demand. Final demand represents sales to households and to other purchasers outside of Hawai'i's economy. These sales reflect the removal of the good from the economy, either through local household consumption or through exports. The sum of intermediate demand and final demand represent the total output of the industry.

The table shows that in 1992 the longline fishery purchased more than $15 million in inputs from other industries. Recreational fishers and the charter fishing industry purchased more than $18 million and almost $9 million of inputs from other industries, respectively. Other commercial fishers, including trollers, handline and pole-and-line fishers, purchased $6.7 million in inputs from other industries. All of these purchases stimulate indirect economic activity (outside of the primary fishing industry). The table also shows that these fishing industries combined made more than $37 million in payments to laborers and profits. These payments stimulate induced economic effects as the people receiving the payments purchased goods and services in the economy.

It should be pointed out that the industry sectors defined in the Sharma model do not exactly correspond to the pelagic fishing sectors described in this document. For example, Sharma models a single longline sector, while much of the focus in the rest of this EIS is on

[5] In the Sharma model, the recreational and expense fisheries and the charter fisheries differ from other fisheries, in that a substantial portion of these sectors' total output is from personal consumption expenditures used to catch the fish, in addition to the sale of fish. For consistency estimates of output for these sectors throughout the document include personal consumption expenditures plus revenues from the sale of harvests. Thus, the total output estimates for the the recreational and expense fisheries and the charter fisheries in this analysis, may differ from total output estimates for these sectors that are found in outside sources.

[6] In the original analysis by Sharma, four non-fishing business and industry sectors were listed: agriculture; construction and manufacturing; transportation, utility and trade; and finance, services, and government.

two sub-sectors of the longline fleet–tuna and swordfish. The aggregation of these two sectors into a single sector in the Input-Output model is likely to be a source of error in the estimates. Additionally, the commercial troll and handline pelagic sectors are not directly specified in Sharma's model. Therefore it is assumed that they fit the structure Sharma describes as "other commercial fisheries," which also includes the bottomfish fisheries and other non-pelagic commercial fisheries. Finally, Sharma's charter and recreational and expense fisheries also contain non-pelagic fishing activities. In spite of these potential classification errors, the analytical team believes that use of the Sharma model provides useful indicators of the broader impacts of the pelagic fisheries within the economy of Hawai'i.

Table 3.10.2-6: Input-Output Transaction Table. (Values in Millions of 1992 Dollars) Source: Adapted from Sharma *et al.*, 1999. Note: The values in this transaction table reflect the inter-industry relationships that existed from 1992.

	Longline Fishery	Other Commercial Fishery	Charter Fishery	Recreational/ Expense Fishery	All Other Hawai i Industries	Total Intermediate Demand (Sales)	Household Consumption Expenditures	Other Purchasers (Exports/U.S.)	Final Demand	Total Output
Longline Fishery	0.0	0.0	0.0	0.0	22.4	22.4	4.1	17.4	21.5	43.9
Other Commercial Fishery	0.0	0.0	0.0	0.0	6.5	6.5	5.2	2.2	7.4	13.9
Charter Fishery	0.0	0.0	0.0	0.0	0.7	0.7	4.4	11.4	15.8	16.5
Recreational/ Expense Fishery	0.0	0.0	0.0	0.0	3.1	3.1	20.6	0.2	20.8	23.9
All Other Hawai'i Industries	15.4	6.7	8.9	18.8	10298.9	10,348.7	14,164.1	22,802.9	36,967.0	47,315.7
Total Intermediate Purchases	15.4	6.7	8.9	18.8	10,331.6	10,381.4	14,198.3	22,834.1	37,032.3	47,413.7
Labor Income, Profits & Margins	23.7	6.2	7.2	0.0	30,523.8	30,560.9	0.0	0.0	0.0	30,560.9
Total Direct Imports	4.7	1.0	0.4	5.1	6,465.4	6,471.5	4,303.7	4,322.3	8,626.0	15,097.5
Total Industry Purchases	**43.9**	**13.9**	**16.5**	**23.9**	**47,320.7**	**47,413.7**	**18,501.9**	**27,156.4**	**45,658.4**	93,072.0
Total Employment	652	357	417	0.0	755,706	757,132				

The transaction table can be manipulated mathematically to generate multipliers that reflect the economic impact of changes in activity in an industry. These multipliers reflect all transactions that are stimulated by industry changes – not only purchases by the primary industry (the industry initially affected by the change) but also purchases by secondary industries (from whom the primary industry purchases inputs), and so on.[7]

Two different multipliers are generally used in these models. Type I multipliers include direct and indirect effects, and Type II multipliers include direct, indirect, and induced effects. Type I multipliers include estimates of inter-industry transactions only. Type II multipliers include not only all inter-industry transactions, but also additional activity stimulated by payments to labor made by the various industries affected by the change. Type II multipliers are generally thought to provide a more complete measure of the impact of changes on an economy and are used in this analysis.

The Type II multipliers used in this EIS are total output/industry output multipliers. A total output/industry output multiplier is an estimate of the change in total economic activity that would result from a change of $1 in output of the primary industry. The output of the primary industry is the direct output. For example, a multiplier of 2.5 means that for each dollar of output in the particular industry, a total of $2.50 of output from all industries in the economy will be produced, including the original dollar of output. Table 3.10.2-7 shows the Type II multipliers for the different industries active in the pelagic fisheries in Hawai'i. These multipliers are developed directly from the model developed by Sharma *et al.* (1999b). The Sharma model, following standard economic methods, estimated Type II total output to industry final demand multipliers which are shown in the second column of Table 3.10.2-7.

Final demand based multipliers are commonly used in I/O analysis. The multipliers used here, however, are based on output based rather than final demand based. Final demand is the amount of an industry's output that is consumed not used for other outputs. So, the difference between final demand and output is the amount of the industry's output that is used as an "intermediate input" for another industry – for example, restaurants and other retail outlets use the output of the fishing industry as an intermediate input. Multipliers developed in input-output models (including the Sharma model) should be applied to final demand rather than total industry output (Sharma, pers. comm., 2000). However, because estimates of final demand are less likely to be available, output multipliers are sometimes inappropriately applied to industry output, which results in double counting and

[7] Care should be taken in interpreting the impacts as "total impacts" as they only include "backward linkages"– those impacts that result from purchase by the industry used to produce its output. "Forward linkages" omitted by the analysis here, are those changes in economic outputs of purchasers of fish, such as restaurants and retailers. In the Hawai'i market, where a substantial portion of the local catch is sold to restaurants and retailers, these forward linked effects could be significant to the extent that the local retailers and restaurants are dependent on the local supply (see Sharma *et al.*, 1999b).

overestimates the impacts of the industry to economy.[8] In order to reduce the possibility of misuse of the output multiplier, this analysis converts the multipliers from Sharma *et al.* (1999b) to total output/industry output multipliers, making the standard I/O assumption that the ratio of final demand to industry output is constant. The ratio of final demand to industry output for each of the four fishing sectors are shown in the third column of Table 3.10.2-7. These ratios were calculated using estimates of final demand and total industry output shown in Table 3.10.2-6 above.

Table 3.10.2-7: Coefficients Used to Estimate Economic Contributions of Pelagic Fisheries in Hawai'i. Source: Adapted from Sharma *et al.* 1999b.

Fishing Industry Sector	Type II Multipliers: Total Output/Final Demand [a]	Ratio of Final Demand to Industry Output [b]	Type II Multipliers: Total Output/Industry Output [c]
Longline	2.424	0.49	1.187
Other Commercial[d]	2.549	0.53	1.357
Charter	2.687	0.96	2.573
Recreational/expense	2.581	0.87	2.246

[a] These multipliers are taken directly from Table 7 in Sharma *et al.*, 1999b.
[a] These ratios are calculated directly from Table 3.10.2-6.
[b] These multipliers are calculated by multiplying the multipliers in the second column by ratios in the third column. Multiplying the output Type II multiplier coefficient by the output of the respective fishing industry sector results in an estimate of the total direct, indirect, and induced economic output for each marine fishery sector in Hawai'i.
[b] The I/O coefficients for Other Commercial include small boat pelagic fisheries (handline, pole-and-line, and commercial troll) as well as the bottomfish, lobster, and reef fisheries. For purposes of this EIS, the coefficients generated for other commercial fisheries were used to generate economic contribution estimates for the small boat pelagic fisheries.

In an I/O model (and the economy), the total economic output created by a sector is determined by the magnitude of the multiplier and the magnitude of the output of the sector. Increases in the output of an industry will result in an increase in the total economic impact of that industry. Industry output, however, only tells part of the story. A larger multiplier reflects more economic activity generated by the activity in a sector or greater "backward linkages". "Backward linkages" are the purchases of inputs by the industry that are used to produce its output. Consequently, the more extensive the backward linkages, the larger the total intermediate purchases of the industry and the greater the impact of industry output on total economic output. It is the interaction of industry output and backward linkages (which are estimated by the multiplier) that determine the total economic impact of an industry. Backward linkages represent the stimulation of economic activity that is caused by changes in an industry's output. For example, the direct backward linkages of

[8] Overestimation would occur in this case because of the significant portion of output of the longline fishery that goes to intermediate inputs of the retail and restaurant industries rather than to final demand, and the sector's relatively low requirements for intermediate purchases compared to the other fishing sectors. The constructed multipliers used here not only preclude the incorrect practice but are also more useful for this analysis because industry output estimates are available and final demand changes are not.

the longline industry are estimated to be $0.352., meaning that for every dollar of output of that sector, $0.352 of inputs are purchased by the industry.

Estimation of Economic Contributions of Hawai'i-Based Fisheries

Using the Type II multipliers and the current output in the pelagic fishing industry sectors, it is possible to derive an estimate of the economic contribution of these sectors to total economic output. Total impact estimates of this type are not generally reliable because multipliers are only useful for measuring marginal changes in the economy, rather than large changes such as the loss of an entire industry – I/O models are based on the structure of the economy and the interactions between industries. The elimination of an entire sector (as proposed in one of the alternatives) is certain to change the structure of the economy, bringing the model's estimates into question. Notwithstanding this shortcoming, estimates of total economic contributions of Hawai'i's pelagic fishing sectors are derived and shown in Table 3.10.2-8 for representative purposes.

The economic contributions of Hawai'i's pelagic fishing sectors are shown in Table 3.10.2-7. For each sector, these contributions include industry output (or revenues generated by sales), industry labor income, industry jobs, and total economic output (or contribution). Total economic output was estimated by combining the I/O multipliers with estimates of outputs from the various fishing sectors.[9] All other numbers are direct estimates of activity entirely within the industry (without indirect or induced effects). The representative total sales (and expenditures for recreational/expense boats) from the pelagic fishing sectors were $97.57. million. The industry paid $35.09 million to labor, purchased $47.53 million in inputs, and employed 1,526 persons. Based on the I/O model, the total direct, indirect and induced economic contribution of the pelagic fisheries to output is estimated to be $159.83 million.

The longline fishing sector had the largest industry output of the six fishing sectors. The $46.65 million in industry output for the longline sector was almost 2.5 times greater than the recreational/expense sector that had the next highest output of $18.87 million. The longline sector also had the largest total output at $55.38 million, but the recreational/expense sector and the charter sector generated total output of $42.39 and $39.29 million, respectively. In fact, total output for the longline sector was only 31 percent greater than the charter sector, and 41 percent greater than the recreational sector. The relatively greater impact generated by the charter and recreational and expense sector is a reflection of high ratios of industry final demand to industry output for these two sectors

[9] Estimating total revenue for specific small-boat fishing sectors is not as straightforward as might be expected. The readily available revenue data from agency sources combine fish sales of all handline and troll vessels (including sales from recreation and charter boats), whereas the I/O model separates this group of vessels into troll/other, recreational/expense, and charter. Therefore, to provide a representative estimate of economic contributions, the sales information for each specific small boat sector as presented in Hamilton and Huffman (1997) and Hamilton (1998) is used rather than estimates from 1998. In addition, for recreational/expense vessels, the sum of total estimated expenditures and total fish sales is used rather than just total revenue. To avoid double-counting for the recreational/expense sector, the I/O model adjusts the final demand estimates.

compared to the ratio for the longline and other commercial sectors as was shown in Table 3.10.2-7.

Table 3.10.2-8: Estimated Economic Contributions by Hawai'i's Pelagic Fishing Sectors for 1998. Source: Estimated from Table 3.10.2-7 and Table 3.10.2-1.

Fishing Sector	Industry Output ($Millions)	Industry Labor Income ($Millions)	Industry Inputs ($Millions)	Industry Jobs	Total Output ($Millions)
Longline	46.65 [a]	22.53	16.36	610	55.38
Handline	9.35 [b]	3.70	4.51	188	12.69
Pole-and-Line	0.93 [c]	0.37	0.45	25	1.26
Troll	6.50 [d]	2.57	3.13	305	8.82
Recreational /Expense	18.87 [e]	NA	14.84	NA	42.39
Charter	15.27 [f]	5.92	8.24	389	39.29
Total	**97.57**	**35.09**	**47.53**	**1,526**	**159.83**

[a] Inflation-adjusted gross revenue for 1998.
[b] Representative total gross revenue as estimated in Hamilton and Huffman (1997).
[c] Inflation-adjusted gross revenue for 1998.
[d] The representative sales estimate for the commercial troll sector is from Hamilton and Huffman (1997). This estimate excludes sales by charter and recreational/expense boats that are typically included in current year gross revenue estimates from agency sources.
[e] Fish sales and expenses for recreational/expense boats as estimated in Hamilton (1998) are combined for use in the I/O model.
[f] Fish sales and charter gross revenue, as estimated in Hamilton (1998), are combined for use in the I/O model.

It is important to mention that the input-output model used here does not estimate the impacts of a fishing sectors on the sectors that purchase their outputs. For example, the impacts of these fishing sectors on the wholesale, restaurant, and retail sectors that comprise the intermediate demand for fish is not included in the above model. The primary reason that these "forward-linked" impacts are not included is because the impacts are somewhat speculative. Purchasers of Hawai'i-based fishery outputs (such as restaurants) are not singularly dependent on Hawai'i-based fishery products. If, for example, output from Hawai'i-based fisheries decline it is likely that buyers of Hawai'i-based fishery products will turn to imported fish and other substitute products (such as beef, pork, or chicken) rather than close their businesses. The decline in the availability of Hawai'i-based fishery products on these industries is particularly difficult to estimate. Certain changes may not be substituted for, which would be included in the final results if they could be accurately estimated. For example, Hawai'i's wholesale distributors expend some efforts to fillet round fish in preparation for marketing. This value added process will be lost to the local economy, if filleted imported fish is substituted for reductions in fish from the Hawai'i-based fishery.

Notwithstanding the estimation difficulties mentioned in the previous paragraph, Sharma *et al.* (1999b) calculated the sources of intermediate demand for Hawai'i-based fishery products. These sources of intermediate demand are collectively defined as the "fishery trade and distribution" sectors and are shown in Table 3.10.2-8.

Table 3.10.2-9: Sources and Magnitude of Intermediate Demand for Hawai'i's Fishing Sectors. Source: Adapted from Sharma *et al.*, 1999b.

	Other food & tobacco products	Eating & drinking	Hotels & lodging places	Total Intermediate Sales	Total Final Demand	Total Industry Output
Longline	3.15	12.85	6.42	22.41	21.47	43.88
Other Commercial	3.10	2.27	1.14	6.51	7.41	13.92
Charter	0.32	0.35	0.00	0.68	15.78	16.46
Recreational/expense	1.79	0.85	0.42	3.06	20.83	23.89
Total	**8.36**	**16.32**	**7.98**	**32.66**	**65.49**	**98.15**

Note: Table includes all commercial fisheries in Hawai'i, including pelagic, bottomfish and other fisheries.

Sharma also calculates the fisheries-related economic impact of fishery trade and distribution sectors within Hawai'i's economy. This calculation is made by estimating the "margin" – the total sales of fishery related products less the cost of producing those products – that the fishery trade and distribution sectors earn when they sell their final fisheries products. These margins are an estimate of the contribution of these sectors to the economy. Sharma estimates the total value of these margins derived from the intermediate purchases of Hawai'i-based fishery trade and distribution sectors to be $4.9 million. Indirect effects of these margins of the fishery trade and distribution sectors add an additional $1.6 million to Hawai'i's economy.[10]

It is possible to decompose the fishery trade and distribution margins to more precisely estimate the contributions of the longline fishery. In Table 3.10.2-10 it is shown that approximately 69 percent of the total intermediate sales from all Hawai'i-based commercial and recreational fisheries is derived from the longline fishery. Multiplying the margins by the percentage derived from the longline sector yields estimates of the direct ($3.4 million) and indirect ($1.1 million) contributions of the longline fishery to the trade and distribution sectors. The total contribution of the longline fishery to the trade and distribution sectors is therefore estimate to be $4.5 million.[11] The additional contributions calculated here augment the estimated total contribution of the longline fishery to the state economy by approximately eight percent. In later sections of this EIS this additional contribution due to forward linkages is not explicitly added, because as indicated above, it is likely that the fishery trade and distribution sectors will find substitute products and activities, if there are significant disruptions to the longline fishery.

[10] Estimates of fishery related margins earned by the fishery distribution and trade sectors and subsequent indirect and induced effects include bottomfish as well as the pelagic fisheries. Information contained in Sharma *et al.* (1999) does not provide details necessary to isolate the effects of the pelagic fisheries alone, although clearly the pelagic fisheries contribute the biggest share of impacts.

[11] This estimate assumes that margins accrue equally across sectors and assuming that each of the fishery trade and distribution sectors have approximately equal multipliers. Induced effects are not estimated.

A Comparision of Input-Output Models and Methods

Several input output models other than the one used here are available to study economic impacts. The IMPLAN model is perhaps the most popular, however, that model aggregates all fishing activity into a single sector. As a result, the different responses of the different fishing sectors are lost when analyzing economic impacts with IMPLAN. A second alternative model is the Fisheries Economic Assessment Model (the FEAM model), which uses IMPLAN data for all sectors other than fishing sectors. Use of the FEAM model requires very detailed data concerning local fishing sectors. For each sector, data must be available for not only the sector's input purchases but also for the amount of inputs that are purchased from local suppliers as opposed to suppliers outside of the local economy. Because accurate and reliable data concerning supply purchases was not available, the FEAM model was not used by the study team.

The model developed by Sharma *et al*. (1999) used for input output analysis is based on data collected over a series of years. The model was developed by economists who have studied the Hawai'i fisheries for several years and relies on several sources to develop the best model possible with existing data. Although the model may not be flawless, the analysts believe the Sharma model is the best available input-output model for analyzing Hawai'i's fisheries.

In addition to a variety of models from which to choose, the use of models may differ among practitioners. For example, the model relied on in this analysis has been applied differently by Dr. Ping Sun Leung and Dr. Samuel Pooley, co-authors of the model, to estimate the changes in impacts of the longline fleet on the economy under the Alternative 7 scenario with effort switching (see Section 4.8.8). Leung and Pooley arrived at substantially higher estimates of economic impact than the study team by multiplying the Sharma model's final demand-based multiplier by the total output of the longline sector. A comparison of Leung and Pooley's results with those reached in this analysis appear in Table 3.10.2.9.

Table 3.10.2.10: Comparison of Effects between Multiplier Application Methods.

	Alternative 7a (effort switching)	
	DEIS Table 4.8-22	**Leung** **(as calculated by Pooley)**
Direct Effect	-$8.6 million	-$8.6 million
Direct Income Effect	-$4.1 million	not estimated
Total Income Effect	not estimated	-$9.3 million
Total Effect	-$10.2 million	-$20.85 million

3.10.2.3 Markets for Hawai'i's Pelagic Fishery

Pelagic fisheries, the largest fisheries in Hawai'i, make important contributions to Hawai'i's cultural heritage and economy. This section provides an overview of markets for the harvest from Hawai'i's pelagic fisheries. The section includes discussions of the following topics:

- The fish trade in Hawai'i in general
- Fish auctions and alternative manners by which Hawai'i's fish are bought and sold in Hawai'i
- Price determinants and markets for pelagic species harvested in Hawai'i's waters
- Ultimate destinations and uses of the different species
- Availability of substitutes and alternative supplies for each species in the market
- Benefits to Hawai'i consumers from the harvest of pelagic species by Hawai'i fishers

The marketing and distribution system for fresh pelagic fish landed in Hawai'i is part of a larger network of interconnected local and worldwide components that supplies a variety of fresh and frozen products to consumers in Hawai'i and elsewhere (Pooley, 1986). Hawai'i's fishers supply a variety of pelagic fish in a range of qualities and quantities.

Local fishers using a variety of fishing methods are the dominant source of fresh pelagic fish for the Hawai'i market. Hawai'i's large pelagic longline fleet targets bigeye, yellowfin, and albacore tunas as well as swordfish. Longliners also supply marlin to the market, primarily as incidental catch. The handline fishing fleet targets yellowfin, bigeye, and skipjack tunas. Commercial trollers provide a variety of pelagic fish, especially *mahimahi*, wahoo, marlin, and yellowfin tuna, depending on the season (DBEDT, 2000; Bartram, 1997). Table 3.10.2-10 shows 1998 landings of major pelagic species in Hawai'i.

Table 3.10.2-11: Hawai'i Reported Landings for Pelagic Species, 1998. Source: WPacFin, 1998d.

	Landing Volume (Pounds)	Volume Sold (Pounds)
Bigeye Tuna	5,135,926	5,101,883
Yellowfin Tuna	3,743,428	3,596,942
Albacore Tuna	3,336,715	3,315,419
Skipjack Tuna	1,834,361	1,724,225
Blue Marlin	1,080,165	978,227
Striped Marlin	848,401	829,791
Swordfish	4,335,945	4,325,696
Mahimahi	1,164,088	1,089,400
Ono	896,700	816,177
Moonfish	1,000,844	1,000,665
Pomfret	288,435	287,449
Sharks [a]	256,666	166,188
Total	**23,986,263**	**23,304,100**

[a] This figure for sharks does not include data on sharks that were harvested for fins only with the carcass discarded. The U.S. Congress prohibited the finning of sharks in December 2000.

Export markets are important for tuna and swordfish, which are produced and traded extensively on an international scale. However, much of the highest-quality tuna never finds it way out of the Hawai'i market, where consumers are among the most discriminating in the world.

Historically, swordfish did not have a strong demand in Hawai'i, and the bulk of landed swordfish is exported to larger, established markets on the U.S. mainland and in Japan. Subsequently, a market niche developed. Other pelagic species harvested in Hawaiian waters, such as blue marlin, striped marlin, *mahimahi* (also known as dolphinfish) and *ono* (also known as wahoo), are consumed largely in the local market. Marlin, prized in some markets, is considered an affordable alternative to the more expensive tuna. *Mahimahi* and *ono* have an established niche in the local market, which consumes the entire local supply, supplemented by imports of these species from other fisheries (Bartram, 1997).

Per capita seafood consumption by residents and visitors to Hawai'i is twice the U.S. average. Therefore, it is not surprising that the local supply falls short of local demand. For certain grades and species of fish, such as *aku* (skipjack tuna), demand is greater than landings in Hawai'i's waters. To meet the excess demand, much fresh and frozen fish is imported to Hawai'i. Although the imported volume may be as high as two-thirds of local production, substantial portions of the imports are re-exported to other markets. Hawai'i's central Pacific location is convenient for consolidating fish shipments from other Pacific islands for shipping on to the U.S. mainland (Bartram, 1997).

Markets for pelagic species fluctuate throughout the year. Prices for a given species may vary seasonally with fluctuations in quality, quantity, demand, and quantities of substitutes. Quality is a function of several factors. Gear and fishing method affect the condition of the fish and the quality of the meat. Fish quality is also thought to change seasonally with water temperature fluctuations.

Hawai'i's Fish Markets and Fish Distribution

Hawai'i commercial fishers sell all of their fish fresh (with the exception of shark fins) and enjoy the benefit of a well developed seafood industry in Hawai'i. The fishing and seafood industries function efficiently to produce fresh fish, which is marketed and distributed to the consumer quickly, maintaining product quality. A portion of local landings, primarily the lower-quality fish, is frozen by the buyers for resale outside of Hawai'i (Bartram, 1997).

Each level of the marketing network plays a significant, specialized role, and each works interdependently with the other segments. The result is an integrated system that is capable of quickly unloading, processing, marketing, and distributing fresh fish. The marketing sector in Hawai'i is highly evolved and able to find markets for the wide variety of pelagic fish species, sizes, and qualities.

Market dynamics are facilitated by the presence of two fish auctions that facilitate sales in a manner that is different from practices in most other U.S. markets. Auction sales are complemented by a more typical system in which fishers consign their landings to wholesalers and export brokers, who ship to both the continental United States and foreign markets. In addition, minor amounts of some species are sold directly to retailers and restaurants (Pooley, 1986; Bartram, 1997). The discussion of marketing channels focuses primarily on auctions and bilateral agreements that fishers make with wholesalers and exporters. Because bilateral agreements are similar in the wholesale and export markets, the discussion of these markets is consolidated.

Hawai'i's two fish auctions, the United Fishing Agency auction in Honolulu and the Suisan Fish Auction in Hilo, are major components of the Hawai'i market. Approximately 40 percent of the total local harvest and well over half of the local longline harvest are sold through these auctions. The Honolulu auction is the larger of the two and serves the most developed market in the state. (O'ahu is the most developed of Hawai'i's islands and the state's largest international airport is in Honolulu.) The Suisan Fish Auction primarily serves the smaller local market on the Island of Hawai'i.

The auctions play a critical role in local markets by handling a large quantity of the high-quality fish. Many species, including all tuna species, swordfish, striped and blue marlin, *mahimahi*, and *ono*, are sold at the auctions, and all fish are sold fresh. The auctions are conducted with open bids with the highest bidder winning. Fishers pay a commission of approximately ten percent of the sale price to the auction. From the viewpoint of

economics, the auctions are close to being "perfectly competitive" markets.[12] The auctions are also important for the price information that they provide to those active in other forms of transactions (Pooley, 1987; DBEDT, 2000).

The auctions provide buyers with an opportunity to inspect fish closely prior to purchase. Fish are sold individually (rather than in lots), and the vessel is identified. Purchasers are allowed to grade the fish for quality by examining size, core temperature, body condition, and muscle quality. Buyers may examine a sample of muscle (drawn from the core of the fish, its tail, or a notch in the tail). The sample provides limited information about muscle quality, and damage is minimal. Although this multidimensional process is subjective, skilled buyers have the opportunity to make purchasing decisions with far more information than is available in more traditional transactions. The grading process is especially critical in the tuna market, in which quality is closely monitored at each stage in the downstream distribution chain (Bartram and Kaneko, 1996).

The bilateral markets, in which fishers contract directly with wholesalers and exporters, are an alternative to the open atmosphere of the auctions. These transactions dominate sales of fish to processors of frozen fish, who are less sensitive to quality concerns and time constraints on delivery. These markets also provide a more private environment in which transaction terms are not revealed to competitors (Pooley, 1986).

Risk is greater for smaller buying enterprises than for larger buying enterprises, in both bilateral agreements and auctions. Choosing whether to rely on one market or a combination of two depends on whether the firm is more sensitive to changes in prices or to changes in quantities. A small wholesaler who needs a reliable supply may face substantial risk in terms of quantity if its supply depends on the success of one or a few fishers, as it would if the firm depended on bilateral contracts. Since many different fishers participate in the auction market, the supply is more reliable. Price fluctuations, however, are likely to be far greater in the auction market, where prices respond more quickly to changes in supply. Large wholesalers, on the other hand, are able to contract with several suppliers to reduce both forms of risk incumbent in bilateral agreements. Transaction costs are higher for bilateral agreements than for an auction, which allows free inspections of fish and uses a bidding structure rather than negotiations (Pooley, 1986).

Wholesale purchases can be separated into three categories: restaurant supply, retail supply, and exports. The different needs of these markets have caused wholesalers to adopt various strategies for purchasing supplies. Restaurants tend to have steady demand, so wholesalers supplying them attempt to maintain a relatively constant inventory. The composition of the inventory may change with seasonal fishery changes, but the objective is to maintain a steady

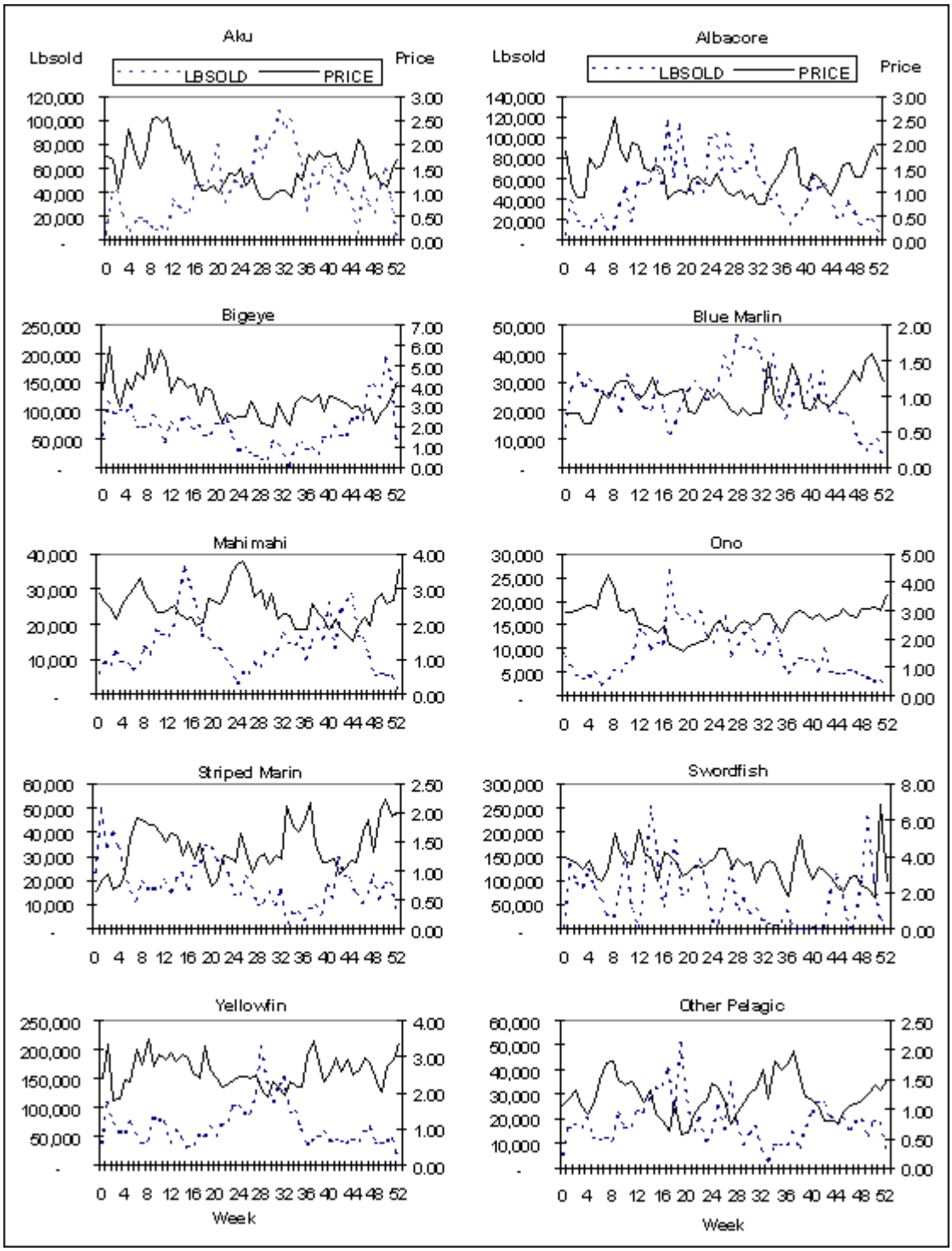
[12] In competitive markets all suppliers and purchasers compete in a market where the prices, quantities and qualities of the products are fully revealed and sales go to the highest bidder. The only imperfection in the auctions (which is very minor in comparison to other markets for fish) is that fishers are known to time deliveries to the auction to avoid saturating the market with fish.

flow of fish to known consumers. Retailers tend to sell large quantities of fish through specials. The goal of wholesalers that supply retailers is to minimize inventories, yet maintain a supply to satisfy demand for a mix of sale items. Exporters attempt to maintain a broad array of products, all with steady flows to satisfy a steady demand from known customers (Bartram, 1997). The market is rounded out by fish peddlers, who purchase fish for immediate retail sale in their stands and small shops. Peddlers often emphasize freshness over grade, but the lowest grades of tuna are suitable only for canning, drying, and smoking (Bartram and Kaneko, 1996).

Pelagic Species in the Hawai‘i Market

This section examines markets for each pelagic species in the Hawai‘i-based fisheries. Species are categorized into three groups, tuna, billfish, and other pelagic fish, based on the different markets that they serve. Local, continental United States, and foreign markets are all discussed. Competitive supplies of the species and substitutes are both discussed. Figure 3.10.2-7 shows prices and pounds landed in 1996 by week for the major pelagic species by week that are sold through the Hawai‘i wholesale market. These prices and all prices stated below are wholesale prices.

Figure 3.10.2-7: Weekly Prices and Pounds Sold in the Hawai'i Wholesale Market, 1996. Source: Pan and Pooley,2000.



Tuna

Tuna forms the largest segment of Hawai'i's fish production and is an expanding market. Variation in uses of different species is apparent, as Hawai'i has both significant imports and exports of tuna (Bartram, 1997). The high-quality tuna that is exported from Hawai'i is sold mostly to Japanese buyers. Hawai'i exporters and fishers target the Japanese tuna market because of its renowned high prices for fish. Tuna is also sold to mainland U.S. markets. These markets rely on sources other than Hawai'i for high-quality fish. However, they import some lesser grades of tuna from Hawai'i to serve the demand for lower-quality fish (Bartram and Kaneko, 1996).

Although significant exports are made, annual local consumption of fresh tuna alone is approximately 6,349,000 pounds. Several niches within Hawai'i's tuna market have developed, each with its own quality standards. The market for tuna served raw as *sashimi* is generally known as the most demanding. Other markets include cooking (highly variable in quality demanded), *poke* (raw cubes served with spices and condiments), and smoking or drying (with the lowest quality requirements) (Bartram, 1996).

As much as 40 percent of local tuna consumption is raw, in the form of *sashimi* and *poke*, a local favorite. Bigeye and yellowfin are commonly used for *sashimi*, but bigeye is the species of choice because of its brighter muscle color, higher fat content, and longer shelf life (Bartram, 1996).

Use of a tuna entering the market is determined by species and grading. Grading is assessment of the quality of the fish by examining species, weight, core temperature, muscle coloration, transparency, texture, and fat content. Grading is based on a 4-number system, with No. 1 indicating the highest quality and No. 4 indicating the lowest quality. Different tuna species are preferred for different uses. Supply, grading, and species all play important roles in determining the price of tuna (Bartram, 1996).

Although grade is a primary price determinant, another factor that affects price is the gear with which the fish was caught. Tuna (particularly yellowfin) caught by trollers are highly susceptible to burning, a condition that causes the muscle to soften and be slightly watery.[13] While burning is considered in grading, the frequency of the problem in troll-caught fish has caused the fish auctions to allow more intrusive inspection of troll-caught fish, which can damage some of the meat and reduce the sale price. Other gear-related price influences include lower prices for No. 2 bigeye caught by handlines due to shelf life concerns, and high prices for No. 3 and No. 4 yellowfin caught by trollers due to their freshness (DBEDT, 2000; Bartram, 1996).

[13] Burning occurs when the core temperature of the fish is high when it dies. The cause of the condition is not certain, but is thought to result from high activity of the fish during capture.

Bigeye and Yellowfin Tuna

Both bigeye and yellowfin tuna are commonly used for *sashimi* in Hawai'i. Although bigeye is the preferred species for *sashimi*, the two species are generally interchangeable in the market and therefore are discussed in a single section. Differences in the two markets are discussed where pertinent.

Most bigeye and yellowfin are caught by longline and sold fresh at the Honolulu fish auction. Smaller quantities of both species, mostly handline landings, are sold at the Hilo fish auction or directly to wholesalers. (DBEDT, 2000).

Quantities of both fish vary with season. The handline landings, particularly in summer, are notably higher for yellowfin than for bigeye. Yellowfin harvests peak from April to September. Unlike other species, bigeye harvests are at their highest levels in winter months, from October to April (DBEDT, 2000).

Hawai'i landings of bigeye tuna grew substantially in 1997 and 1998. In the earlier 1990s, annual bigeye landings had ranged between approximately 3.3 million and 4.7 million pounds, before growing to approximately 5.4 million pounds in 1997 and 7.1 million pounds in 1998. Over the same period, yellowfin harvests remained relatively constant, ranging between a high of approximately 2.5 million pounds and a low of 1.3 million pounds (with the exception of 1992, when less than one million pounds were harvested (WPRFMC,1999d).

The majority of the highest-grade bigeye and yellowfin are retained for local consumption. A portion of the No. 1 bigeye and yellowfin is shipped to Japan. A study of 1994 sales of bigeye and yellowfin in Japan found that Hawai'i bigeye and yellowfin brought the highest price of any bigeye and yellowfin in that market (Bartram, 1996). In recent years, demand for high-quality bigeye and yellowfin on the West coast of the United States has grown to become a significant market for Hawai'i's production (Bartram, 1997).

Yellowfin sold from Hawai'i to the West coast market, however, tends to be of lower quality, having a shorter remaining shelf life and poorer texture than yellowfin in the Hawai'i market. Most of the West coast high-quality supply is from the Gulf of Mexico, where 50 percent of a typical boatload is given a No.1 grade. In the Hawai'i market, only about 25 percent of the average boatload is graded No.1. However, the West coast has become more discriminating in recent years, and more No.1 bigeye is purchased there than in the past. The West coast has proven to be a huge market for No. 1 yellowfin from Gulf of Mexico and other Southeast U.S. ports. West coast prices for No.1 yellowfin, which until recently were approximately $0.50 to $0.75 lower per pound than Hawai'i prices, are now approximately the same as Hawai'i prices. Increased prices generally have resulted from the development of a wider West coast market for high-grade fish. This market has been stimulated by imports of bigeye and yellowfin from Central and South America. The West coast has proven desirable to these suppliers since the market is much closer than Japan,

where long travel distances increase costs and consume shelf life, increasing price risks. While West coast demand for high-quality bigeye and yellowfin from Hawai'i suppliers has increased, supply has been dampened because of the high price commanded for high-quality fish in the Hawai'i market. The Hawai'i market, however, has placed little demand for top-quality tuna on the Central and South American markets because much of the landings from those fisheries is by handline, a harvest method that is thought to yield a grainy muscle texture (Bartram, 1997).

While the West coast is playing a more active role in the market for high-quality bigeye and yellowfin from Hawai'i in recent years, the East coast of the United States has not participated in this market. The segment of the East coast market that demands high-quality fish has easier access to Atlantic tuna, which includes both yellowfin and bluefin, the species considered to have the highest quality for *sashimi* in the demanding Japanese markets.

Between 1992 and 1996, No.1 bigeye sold for an annual average Hawai'i price of $7 to $8 per pound.[14] During seasons of highest demand and quality, prices peak in the range of $9 to $10 per pound. Lows of $5.90 to $6.35 per pound have been observed in seasons of low demand and quality. The great variation in price throughout the year is attributable to seasonal changes in quality and changes in demand with tourist seasons. Similarly, No.1 yellowfin prices average $6.60 to $6.80 per pound, with highs of $7.25 to $7.75 per pound and lows of $5.50 to $5.90 per pound. Prices for both species are high from December to April. Japanese year-end traditions stimulate prices in January. High prices carry over after the New Year because of the relatively low supply of high-quality fish and high tourist demand in the early months of the year. Additionally, the local social and cultural event calendar, including Lent, school graduations and holidays are thought to influence local demand. Low prices in June and July in both markets are caused by high supply of good-quality tuna in these months. The yellowfin season generally peaks in these summer months. The price rises slightly in the fall and remains stable through November, the period during which the supply of bigeye peaks, until the year-end rise in demand from the Japanese market (Bartram, 1997).

Hawai'i's consumers have traditionally placed a high demand on the Hawai'i market for high-quality tuna. The Hawai'i market has historically supplemented its local supply by importing substantial quantities of bigeye and yellowfin, mostly from the Indo-Pacific region. Imports have declined in recent years as consumers have sought to satisfy more of their demand from the local supply. The reasons for the decline in imports are somewhat undear. One contributing cause is the decline of the tuna fleet in the Marshall Islands in the mid 1990s and changes in fleet operations in the Pacific. In addition, the Hawai'i market has seemed more willing to substitute local, high-quality albacore at times when top-quality bigeye and yellow fin are in short supply (Bartram, 1997).

[14] All prices in this section are ex-vessel values of headed and gutted fish.

Hawai'i fishers also supply substantial amounts of No. 2 bigeye and yellowfin to the market. This good, but lower-grade fish, is typically used for *sashimi*, *poke*, and cooking. From 1992 to 1996, the annual average Hawai'i prices for No. 2 bigeye ranged from $4.50 to $5.50 per pound. This price is much higher than the price on the West coast for No. 2 bigeye from Central and South America, limiting the ability of Hawai'i's suppliers to play a significant role in that market. No. 2 yellowfin typically sells for $3.85 to $4.30 per pound. Unlike the Hawai'i market, the West coast market seems to prefer the firmness of the No. 2 yellowfin muscle over the darkness of the No. 2 bigeye. Consequently, the price of No. 2 yellowfin is typically between $0.65 and $0.75 higher in California than in Hawai'i. This has enabled Hawai'i's sellers of No. 2 yellowfin to make substantial sales in the West coast market. Seasonal price variations of No. 2 bigeye and No. 2 yellowfin are similar to those of their higher-grade counterparts (Bartram, 1997).

Historically, imports, primarily from the Republic of the Philippines and the Federated States of Micronesia, have supplemented local harvests in meeting the demand for No. 2 bigeye and No. 2 yellowfin. These shipments have declined in the last decade with increases in local landings. Inconsistencies in the quality of these imports have also curtailed shipments to the demanding Hawai'i market. These imports have also declined because of a practice used to enhance or preserve the quality of the fish known as "smoking," which is not favored in the Hawai'i market. By this process the fish is exposed to carbon monoxide, which darkens the meat and extends the shelf life, and then is frozen for shipment. The actual effects of the process are disputed. Although the process itself is thought to be harmless, ,any experts believe that it may simply hide quality defects rather than improve the fish or extend shelf life. Experts can visually distinguish tuna treated by this process. Most consumers, however, do not have the expertise to identify treated product (Bartram, 1997; WPRFMC, 2000d; Seafood Market Analyst, 2000).

The market for lower-quality bigeye and yellowfin is limited. Low-quality No. 2 and No. 3 bigeye and yellowfin are characterized by paler, softer muscle that limits their value. The Hawai'i market has used some of these lower-quality tuna for *poke*.[15] The market for these fish has been in decline because of some change in preference away from low-grade bigeye and yellowfin to other species such as marlin and albacore (Bartram, 1997).

The increasingly selective West coast market, where there is no market for *poke*, will accept these lower-quality fish only when stocks of higher quality are down. These fish typically sell for $1 to $1.50 per pound, a price at which they are too costly for importing. Much of this lower-quality tuna that is sent to the West coast is thought to be shipped on to the East

[15] Skipjack, however, is the preferred species for *poke* and has been well supplied in recent years, limiting the market for lower-quality yellowfin and bigeye.

coast, where it satisfies some of the demand of the low end of that market (Bartram, 1997).[16]

Albacore

Albacore tuna has long been considered a second-quality species because of the light color of its muscle. In recent years, use of albacore has grown substantially both in and outside of Hawai'i. Albacore is substituted in *poke* when other tuna is in short supply. Albacore with red muscle, which is somewhat unusual, may also be substituted in *sashimi* for bigeye tuna, the preferred species. In addition, a substantial market for albacore has developed with retailers who sell it for grilling. Lower-quality fish may be used for smoking or drying or may be exported to the U.S. mainland for canning (DBEDT, 2000; Bartram, 1997).

Longline fishers land most of the albacore tuna in Hawai'i. Handliners also contribute a small share to the local supply. The majority of the fish is sold at the Honolulu fish auction. However, small quantities are also sold by handliners at the fish market in Hilo and directly to wholesalers. The albacore season peaks between May and September. Off-season landings tend to be limited. (DBEDT, 2000)

Albacore harvests grew substantially in the late 1990s. Prior to 1994, annual albacore landings never exceeded one million pounds. In 1996, 1997, and 1998, annual landings exceeded 2.4 million pounds (WPRFMC, 1999d). The growth in market share took place despite the fact that its muscle is paler and softer than that of bigeye and yellowfin. Part of this growth is due to shipments to the continental United States, where albacore's relatively longer shelf life is an advantage. U.S. distant-water boats are also known to offload albacore in Hawai'i for shipment to the continental United States.

Between 1992 and 1996, the average annual price of albacore ranged from approximately $1.35 to $1.60 per pound. The rare albacore with red muscle typically brought a premium of $0.15 to $0.40 per pound, and higher when bigeye and yellowfin were in low supply. High demand for albacore in the continental United States is shown by slightly higher West coast prices, which were approximately $1.80 to $2.25 per pound (Bartram, 1997).

Seasonal price variations for albacore generally follow the same pattern as price variations for No. 1 bigeye and No. 1 yellowfin, but tend to be more dramatic than for these other

[16] Some evidence suggests that some lower-quality fish likely reach the Japanese market. This evidence, however, is inconsistent with all other data sources and is therefore questionable. U.S. export data indicate that in 1999 Hawai'i exported more than 40 percent of the country's yellowfin exports, with an average price of approximately $0.60 per pound. Japan received slightly less than 50 percent of the country's yellowfin exports and paid an average price of slightly more than $0.65 per pound. While these figures leave substantial room for other areas to have exported yellowfin to Japan, it is likely that there is some overlap. The average price, in both cases, is substantially below the price typically demanded for high-quality yellowfin, suggesting that a portion of Hawai'i's exports to Japan are lower-quality fish (Seafood Market Analyst, 2000). This conclusion, however, is inconsistent with all other sources, suggesting that these data are erroneous.

tuna species. This trend is likely due to the extreme scarcity of albacore in the off-season. Unlike the other species, albacore have reached their peak prices in recent years, spiking drastically in September. The extreme rise may be caused by late onset of the bigeye season, which typically dominates the market for fresh tuna in the fall (Bartram, 1997).

Skipjack Tuna

Skipjack tuna has a long tradition in Hawai'i's fishery. Although landings were lower in the 1990s than in previous decades, skipjack is an important part of Hawai'i's pelagic fisheries. Today, skipjack is commonly used for *sashimi* and is the preferred species for *poke*. Lower-quality skipjack may also be smoked or dried (DBEDT, 2000; Bartram, 1997). Prior to the closure of the tuna cannery in 1984, as much as 75 percent of skipjack production was canned (S. Pooley, pers. comm., February 2001).

Trollers, longliners, and pole-and-line fishers harvest skipjack. Peak harvests occur in summer months from April through September. Skipjack is sold at the Honolulu and Hilo auctions, to wholesalers, and by some peddlers in roadside shops and stands (DBEDT, 2000).

Harvests of skipjack declined significantly after 1980. Between 1987 and 1989, skipjack landings in Hawai'i averaged more than 3,500 pounds. Between 1990 and 1998, skipjack harvests averaged less than 2,000 pounds per year (WPRFMC, 1999d). This decline coincided with the decline of the pole-and-line fleet, which is now almost nonexistent. Consequently, substantial imports of skipjack have entered the Hawai'i market to satisfy the local demand for drying and for use in *poke* (Bartram, 1997).

Billfish

Hawai'i fishers produce significant quantities of billfish in addition to the extremely popular tuna. Swordfish are targeted by the longline fleet. Blue marlin and striped marlin are the targeted by the recreational and expense fishers. Swordfish have limited local popularity and usually are exported to take advantage of their high demand in the U.S. East coast market. Both marlin species are popular in the local market. As with tuna, these pelagic species are generally graded based on muscle transparency and muscle color. Generally, grading is less critical in these markets than in the high-quality market for *sashimi* tuna.

Swordfish

Swordfish is the second largest fishery in Hawai'i after bigeye tuna. The majority of swordfish is exported to the continental United States. Although swordfish is used locally for *sashimi* at times, grilling is the most popular method of preparation.

Most swordfish are caught by the longline fleet using nighttime shallow fishing techniques with luminescent attractants. Swordfish are also occasionally caught by tuna longline fishers

as incidental catch. Trollers and handliners also participate in this fishery, but to a minor degree.

The peak season for swordfish is the early summer months from April to July. Most of the fish are sold at the Honolulu fish auction. A portion, however, is sold directly to wholesalers and exporters. Most of the fish are shipped to the U.S. East coast, where Hawai'i swordfish brings a premium price. East coast purchasers commonly purchase swordfish in airline container quantities to realize economies of scale in shipping.

Harvest levels grew substantially during the early 1990s due to the adoption of the nighttime surface fishing techniques. In 1987 and 1988, swordfish landings averaged 50,000 pounds. By 1991 landings had grown to more than ten million pounds. Swordfish landings peaked in 1993 at slightly more than 13 million pounds and have since ranged between 5.5 million and slightly more than seven million pounds a year (WPRFMC, 1999d).

Hawai'i generally is one of many suppliers of swordfish to a major U.S. market served by a worldwide supply. In 1998 (when Hawai'i landings were slightly more than seven million pounds), approximately 34.6 million pounds of swordfish were imported into the continental U.S. market. Imports of fresh swordfish in excess of two million pounds were received in the United States from Brazil, Chile, and Australia. Singapore alone exported more than eight million pounds of swordfish to the U.S. market (WPRFMC, 1999d; Seafood Market Analyst, 2000). In addition, other areas of the continental United States recorded significant harvests. In 1998, the U.S. Pacific fleet (excluding Hawai'i) caught three million pounds of swordfish, and the Atlantic and Gulf fleets caught an additional 4.8 million pounds (Hamm, Chan and Quach, 1999).[17] Assuming that most of this domestic landings are used in the U.S. East coast market, Hawai'i's landings comprise less than 15 percent of the U.S. East coast swordfish market.

Hawai'i's swordfish sell for a premium price. Between 1992 and 1996, prices generally averaging between $3 and $3.25 per pound. In 1994 prices were relatively high, averaging $3.50 per pound. As with prices for other species, prices of swordfish fluctuated throughout the year. High prices reached $3.50 to $4.10 per pound, while lows ranged from $2 to $2.75 per pound.

Prices are generally above average in January and February, when the U.S. market is under-supplied because of low U.S. East coast harvests. Prices also tend to be high in June and July, when Hawai'i's swordfish landings are at their lowest. From September to December, prices tend to be at their lowest.

[17] Data for the 1999 U.S. catch are unavailable. In the last 4 years for which data are available, catch was relatively stable, between 7.5 million and 8 million pounds.

Moon phases are influential in the swordfish fishery. Harvests peak each month just before the full moon. Prices are expected to be lowest then as fishers deliver fresh fish to the markets. Prices jump to monthly highs shortly after the full moon, when harvests are at their lowest levels (Bartram, 1997).

Blue Marlin and Striped Marlin

Marlin is used as *sashimi* and *poke* in Hawai'i. Large group caterers often prefer marlin because it discolors more slowly than tuna. Premium *sashimi*-quality striped marlin, which has orange-red meat and higher fat content, is thought to be of higher quality than blue marlin, although blue marlin with acceptable fat content is used as *sashimi*. Both are cooked by Hawai'i restaurants. Blue marlin is popular with lower-income and fixed-income groups and often is smoked (Bartram, 1997; DBEDT, 2000).

Neither marlin species is targeted by commercial fishers in Hawai'i. The majority of the landings are caught incidentally by the longline tuna fleet. Trollers also contribute to Hawai'i marlin harvests. Sport fishers, however, target blue marlin and often sell their landings in the commercial market. A large share of the shortish market is composed of charters, from which the landings typically are sold, with proceeds going to the boat and crew. Most commercial marlin landings are sold in the Honolulu auction. Sport fishers and trollers, however, may sell their landings directly to wholesalers, retailers, or restaurants (DBEDT, 2000).

The blue marlin and striped marlin harvests are a significant but secondary part of the Hawai'i market. The combined annual landings of both species in the past ten years typically have been about two million tons. Historically, striped marlin harvests have exceeded blue marlin harvests, but in two of the last four years, blue marlin exceeded striped marlin by more than 100,000 lb (WPRFMC, 1999d).

The commercial market for Hawai'i-caught marlin is limited because California has declared both marlin species protected gamefish, prohibiting their legal sale in California. Between 1992 and 1996, the average Hawai'i price for blue marlin ranged from $1.25 to $1.45 per pound. As with swordfish, the average price for blue marlin reached a high in 1994-$1.80 per pound. Yearly highs for blue marlin prices ranged from $2.15 to $2.65 per pound in 1992-1996, while lows ranged from $0.60 to $1.25 per pound. Striped marlin had slightly higher average annual prices in the same period, because of its greater suitability for use in *sashimi*. Average prices ranged from $1.40 to $1.65 per pound, with a high average price of $2.25 in 1994. Annual high prices ranged from $2.35 to $3 per pound during the same period, while annual lows ranged from $0.75 to $1 per pound (Bartram, 1997).

Seasonal variability in price is greater for both blue marlin and striped marlin than for tuna. The Hawai'i blue marlin season peaks between June and October. The peak of the striped marlin season is opposite, beginning in November and continuing until June. The seasonal price changes are similar for the two fish, suggesting that the prices are driven by changes

in tuna supply and total demand for fish rather than by the volume of marlin harvests. Marlin prices reach annual highs from February to April and again in September and December. The high prices early in the year coincide with a period of low tuna supplies. The transition from summer yellowfin to winter bigeye is the likely explanation for the high price for marlin in September. Marlin is also likely substituted for tuna in December when demand is high. The low prices in June and July occur during the period when tuna supply is at its highest and overall demand is at a low. Low prices occur in October, when marlin and bigeye are in high supply (DBEDT, 2000).

The markets for billfish in particular have been affected by limits on mercury in imported fish. The U.S. Food and Drug Administration has a limit of 1.0 parts per million for methyl mercury in fish imports. Every lot imported is tested before release for sale. The procedures allow an importer to obtain a "green card" limiting testing requirements if the importer's first five shipments all test below the limit. The procedure is costly for minor importers and is believed to limit the inflow of swordfish into the United States. The sampling procedure is also costly and can damage fish, further deterring imports of swordfish into U.S. markets (Bartram, 1997).

Other Pelagic Species: *Mahimahi*, *Ono*, Moonfish, and Pomfret

Most Hawai'i restaurants have diversified menus that include *mahimahi* and several other species, such as marlin, *ono* (wahoo), *opah* (moonfish), and large-scale black pomfret. Demand for these pelagic species has led to substantial landings by Hawai'i fishers, who sell to the Hawai'i market. Harvests of *mahimahi* and *ono*, the most commonly targeted species, fluctuate seasonally. Significant quantities of *opah* and pomfret are caught incidentally. Quantities of these two species fluctuate significantly, but follow no seasonal trend. All of these species are sold fresh, because almost no market exists for frozen local landings (Bartram, 1997; DBEDT, 2000).

Most *mahimahi* and *ono* are caught by trollers, although portions of the harvest are taken by longline and pole-and-line fishers. These species are sold through the Honolulu and Hilo fish auctions and directly to wholesalers and restaurants. *Mahimahi* is a favorite in many local restaurants. *Ono* is generally substituted when *mahimahi* is in short supply. Annual average Hawai'i prices of *mahimahi* ranged from approximately $2.40 to $3.15 per pound between 1992 and 1996. In the same period, the annual average *ono* prices ranged from $2.25 to $3.15 per pound. The limited local supply of *mahimahi* has led to import of substantial quantities to Hawai'i from Taiwan, Japan, and Latin America. Since imported fish tend to be slightly cheaper than fresh local fish, imported fish tend to be directed toward less expensive restaurants. Little of either of these species is exported, because local consumers consume most of the local supply.

Pomfret and moonfish are also frequently sold in local restaurants. These species complement the supply of *mahimahi* and *ono* in the local fresh market. Both species are

primarily incidental catch of the longline fleet and are sold almost exclusively through auctions (Bartram, 1997, DBEDT, 2000).

Sharks

Prior to its prohibition of by the Hawaii Legislature and the U.S. Congress in 2000, shark finning had been a source of significant revenue for crewmembers in the Hawai'i-based longline fishery. Most of these revenues are generated by sales of blue shark fins sold to satisfy the demand for fins in the Asian market. A small market has also developed recently for thresher and mako sharks. The landings of these two species is small and does not contribute substantially to the overall revenue in the fleet.

The prohibitions on finning of sharks are likely to substantially limit the activity of Hawai'i-based longline vessels in the Asian market for shark fins. No market exists for the carcass of blue sharks, which is the dominant incidental catch species in Hawai'i longline fisheries (WPRFMC, 1999c), and until such a market develops, the landing of these sharks is unlikely.

Consumer Benefits from Local Harvests

Hawai'i consumers benefit from the harvest of fish by local fishers. While these benefits are not well documented, the local market suggests that these benefits may be substantial and should not be overlooked. Economists frequently rely on a measure known as "consumer surplus" to measure the gain to consumers that is realized through the price of a good in a market. The difference between the maximum price a consumer would be willing to pay for an item and the actual market price is called the "consumer surplus." The consumer surplus is the realized benefit from the market price of an item being less than the maximum the consumer would pay for it. Seasonal variation in fish prices in the local market provides evidence of substantial consumer surplus in the Hawai'i market resulting from the local supply of fresh fish.

The prices for the different grades and species of tuna frequently fluctuate by as much as 40 percent, with high prices occurring during periods of low local supply and low prices occurring during seasons when harvests peak. Seasonal price fluctuations are similar in the markets for the two marlin species and for *mahimahi* and *ono*. These wide price changes suggest that consumers realize large surpluses during seasons when local supplies are at their maximum. The quantity of imports brought into the Hawai'i market when local harvests are at their seasonal lows support this conclusion. During these seasons of low local landings, consumer surplus is reduced. Consumers pay significantly higher prices for both fresh and frozen fish. The willingness of Hawai'i's consumers to pay substantially higher prices for imported fish in the off-peak seasons suggests that regulations of fishers and limitations that reduce landings will reduce consumer surplus significantly. The consumer surplus lost by Hawai'i's consumers is transferred to importers, who are able to obtain these substantially higher prices for their fish. While some of this price increase may be a profit for

imports, a substantial portion also pays the cost of transporting the fish to the Hawai'i market.

Consumer surplus to Hawai'i's local consumers is an important benefit of the Hawai'i fishing industry. These benefits should not be overlooked in setting policies or adopting regulations that are likely to affect the supply of local fish to the Hawai'i market.

3.10.2.4 Valuation of Environmental Goods

This section summarizes the important issues involved with estimating the economic value of turtles, albatross, and other species and resources that may be affected by fisheries managed under the Pelagics FMP. The section includes a brief overview of techniques that could be used to estimate such values, and a short discussion of why estimating such values is beyond the scope and budget of this EIS.

This discussion is provided in anticipation of questions about the benefits of management alternatives. A more detailed discussion on these issues is in Appendix O.

While the topic of species value is discussed in detail in existing literature, new research would be needed to determine the value of the sea turtles and seabirds affected by the Western Pacific pelagic fishery. For example, numerous studies have been conducted on the value of endangered species (Loomis and White, 1996). In addition, several studies provide estimates of the value of protected species in Hawai'i, including the Hawaiian monk seal (WPRFMC, 2000e). However, no valuation studies have been conducted for sea turtles or seabirds in Hawai'i, or for other species of interest in the pelagic fishery. As a result, new research would be needed to understand the value of these species. Such research has not been undertaken for this EIS because reasonable estimates cannot be generated within the available budget or time frame of the EIS.

This discussion is a very brief summary of the state of the art and explains the research that would be needed to estimate the value of sea turtles, seabirds, and other species of interest. The discussion outlines the theory of non-market valuation[18], identifies methodologies or approaches to non-market valuation, and provides an overview of issues specific to the pelagic fishery. No attempt is made to refine or elaborate on the estimates of the cost of proposed changes to the FMP. Nevertheless, using a simple, commonsense assumption that reductions in protected species interactions have positive benefits, the relative merits of the various alternatives with respect to protected species can be evaluated. Those that reduce interactions the most will have the greatest benefit in terms of preserving protected species.

[18] Non-market valuation is the economic assessment of the value of goods and services for which market data (for example, sales receipts or some other measure of what an individual is willing to pay for a particular item) are not available.

3.10.2.4.1 Overview

The assignment of value to environmental goods is a method used to present a more complete assessment of the benefits and costs of proposed actions, such as fishery management decisions. Unfortunately, environmental goods are typically not traded in a market and unlike normal goods, such fish and automobiles, there are no prices or transactions that can be recorded and monitored. Therefore non-market methods of valuation are employed.

Preserving environmental assets such as sea turtles and seabirds may generate a range of benefits for humans. For analytical and discussion purposes, these values can be divided into a variety of categories, including use and non-use, direct use and passive use, and so on. Table 3.10.2-10 offers one summary of value types and their definitions. Different publications use different taxonomies and definitions (Arrow *et al.,* 1993).

Table 3.10.2-12: Types of Value.

Type of Value	Description
Bequest	Value of preserving a resource for future generations
Discovery	Potential medicinal, scientific, or other value of a resource that might be discovered in the future
Direct Use	Use value associated with a resource, such as fish or timber
Existence	Value associated with the existence of a resource
Indirect Use	Value a resource provides in the production of a marketable commodity
Option	Value today of preserving the ability to use a resource at a later date

Note: Other values discussed in other contexts, such as the preservation of salmon, include cultural (heritage) and religious (ceremonial) value. It is not clear whether these types of value are subsumed by one of the value types listed or should be considered distinct.

Most, if not all, of the types of value shown in Table 3.10.2-11 are subject to debate. For example, option value is sometimes defined as a risk premium arising from uncertainty as to the future value of a commodity. Alternative definitions focus on the concept of irreversibility. (See, for example, the different discussions about option value in Chapman (1999) and WPRFMC (2000e). Other uncertainties related to value types include discussions about whether specific values are knowable or measurable at all, and if they are, whether they are additive or what their relationship to one another might be.

Concerns about how to describe and combine values notwithstanding, the greatest challenge in valuing resources such as sea turtles and seabirds is in determining a means of estimating those values in the absence of observable data. The fact that people volunteer to watch sea turtles on beaches and to help ensure that as many hatchlings as possible make it to the ocean provides evidence that people assign value to sea turtles. Similarly, the fact that people travel great distances to see in person specific species of seabirds is evidence that people assign value to seabirds. Unfortunately, the magnitude of these values is difficult

to gauge because not all of the actions require monetary expenditures, and the money that a person spends to see or to help a particular resource may or may not reflect the total value that the person might assign to that resource.

With this caveat in view, different techniques can be used to estimate the values a person assigns to a particular resource based on the expenditures they make to travel to see the resource, or based on other related expenditures. When no expenditures are made, it is possible to ask people directly how much they would be willing to pay for the protection of the resource. Unfortunately, these techniques are subject to a wide variety of criticisms and may be applicable only in certain settings. Notwithstanding a lack of means to estimate the value of the protected species, alternatives that reduce interactions the most will have the greatest benefits in terms of preserving protected species.

3.10.2.4.2 Methodologies for Estimating Non-Market Values

Methods used to estimate the values that people place on environmental assets, and the other (non-anthropocentric) value those assets may have, can be placed in two broad categories: direct and indirect approaches. Pearce and Moran (1994) note that the direct approach includes "techniques which attempt to elicit preferences directly by the use of survey and experimental techniques. In contrast, indirect approaches are those techniques which seek to elicit preferences from actual, observed market-based information."

Direct Approaches

Direct approaches include experiments and questionnaires, with questionnaires more common in the recent past. Questionnaires commonly used to determine values of environmental assets include those designed to elicit the relative ranking of an asset relative to other goods – at least one of which has a known or observed value – and those designed to elicit actual values (examples of survey questions can be found in Pearce and Moran, 1994). The primary method by which preferences and values are measured directly is commonly referred to as the contingent valuation method (CVM). CVM is popular because it allows individuals to state their preferences regarding non-use values. (A CVM study could be conducted to determine people's willingness to pay to ensure protection or increase the probability of survival of a particular species.) In addition, most economists agree that CVM yields reliable estimates of value when used in the proper context, so long as proper guidelines are followed and care is taken in the design of the experiment.

A "blue ribbon" panel of economists prepared a report for the National Oceanic and Atmospheric Administration (NOAA) on the merits, limits, and proper use of CVM (Arrow, *et al.*, 1993). The NOAA committee concluded that the best prospects for use of CVM are in attempting to find values for environmental gain in circumstances where those offering value estimates are familiar with the resource(s) in question, such as local recreation amenities. CVM may not be as useful when estimating the value of an environmental asset that has been lost, or in circumstances where there is a great deal of uncertainty.

Despite favorable comments by the NOAA committee and others on the use of CVM under certain circumstances, it should be noted that CVM is not universally accepted as a valid means of estimating the value of environmental assets (Freeman, 1993). Criticisms range from concerns about specific biases and information problems to concerns about the psychological and cognitive processes by which people formulate responses to CVM questionnaires (Pearce and Moran, 1994).

Indirect Approaches

Indirect methods for estimating the value of an asset include the travel cost method, hedonic analysis, and consideration of replacement costs. Each of these approaches uses actual expenditure data related directly or indirectly to the asset or resource in question.

The travel cost method uses observed expenditures, such as the cost of traveling to a recreation area, as a starting point for estimating the value of the asset. This approach reveals a minimum value for specific use values. It does not reveal information about non-use values such as bequest value or option value (because such values need not be related to a trip). In addition, uncertainties about this approach include valuing the time involved in traveling to a particular site and how to partition travel costs when a trip includes more than one activity. For example, it is not clear exactly how to value the time of different individuals who travel to a particular recreation area and what portion of their travel costs should be attributed to one area if they visit multiple sites in one trip (Bockstael *et al.*, 1987).

With respect to the western Pacific pelagic fisheries, the travel cost approach (or some variant) could be used to estimate the value people place on observing sea turtles and seabirds, and the value of sport and recreational fishing that could be affected by changes to the Pelagics FMP. Jones and Stokes (1987) and Crandall *et al.* (1992) provide examples of how the travel cost method has been used to estimate the value of recreational fishing at a particular location and, separately, the value of a resource used for viewing (or other passive activities).

Other indirect methods (including their strengths and weaknesses) are discussed in Appendix O.

3.10.2.4.3 Issues Specific to the Western Pacific Pelagic Fisheries

The Hawaiian archipelago provides habitat to a variety of threatened or endangered species, including the black-footed and Laysan albatrosses, five species of sea turtles, and the Hawaiian monk seal. In addition, the health and vitality of other environmental resources are of interest in the context of pelagic fishery management strategies (WPRFMC, 2000e). Efforts to protect species will impose costs on western Pacific pelagic fisheries participants, but presumably will be of benefit to the species themselves and to the citizens of the United States in terms of the value these people put on the conservation of these species and other resources.

Sea Turtles

Estimates of values for leatherback turtles, hawksbill turtles, green turtles, and loggerhead turtles would need to include consideration of numerous value types and, as a result, would require several different estimation procedures. While sea turtles are protected under the ESA, the International Union for the Conservation of Nature and Natural Resources, and the Convention on International Trade in Endangered Species (CITES), sea turtles and sea turtle eggs are still harvested by indigenous people in various countries. For example, a legal egg harvest exists in Costa Rica (Eckert, 2000). Such subsistence and/or cultural activities imply a direct use value for sea turtles. At the same time, the large number of volunteer organizations dedicated to sea turtle conservation shows the presence of existence, bequest, and other non-use values. In addition, expenditures related to ecotourism (to visit beaches with turtles, to dive in areas where turtles are present, and so on) show a passive value of some form – be it use or non-use. Unfortunately, such values have not been estimated for Pacific sea turtles and are, therefore, unavailable for this EIS.

Seabirds

It is theoretically possible to estimate the value of black-footed and Laysan albatrosses, as well as other sea birds affected by pelagic fisheries. As with sea turtles, however, a number of different approaches would need to be followed to prepare an estimate. Historical data from the sale of albatross feathers and eggs in the early 1900s could be used to estimate potential use values if the populations were restored. Expenditures by bird watchers to view the different albatrosses and other seabirds of the western Pacific reveal a willingness to pay – a measure of benefit – to observe the birds in their natural habitat. As with sea turtles, this enjoyment of the species could be described as existence value, bequest value, or some other type of value. Estimates of value could be determined through a well-constructed contingent valuation study. Other values that could be considered include scientific or discovery value.

3.10.2.4.4 Conclusions

The value of sea turtles, sea birds, and other species of concern in the pelagic fisheries of the Western Pacific could, at least theoretically, be estimated. The resulting values could be used in a benefit-cost analysis to assess the net value of species preservation. However, none of these values has been estimated in other studies, and to prepare new efforts would require more time and money than is available for this EIS. (Estimating values for the sea turtles and seabirds in question would require that many challenging issues be resolved regarding the different types of value that should be considered and the estimation procedures to be used. Due to controversy surrounding many of the different types of value that could be considered and methodologies that could be used, a quantitative analysis of the value of the sea turtles, seabirds, and other species of concern would have to be conducted with care. The time needed to collect the necessary data and to perform the analyses exceeds the time allowed for this EIS.)

3.10.3 Pelagic Fisheries of Hawai'i

This section provides in-depth examination of the pelagic fisheries of Hawai'i. These fisheries involve a number of different gear types and cover fishing grounds that extend from shore well out into international waters. Four subsections are provided describing the longline, troll, handline, and pole-and-line fisheries. Most of the data used in this section are for 1991 through 1998. Some preliminary 1999 data are available, and they are used for comparison where possible. In some instances, data dating back to the 1970s or earlier are presented for comparison.

3.10.3.1 Hawai'i-based Longline Fishery

The Hawai'i-based longline fishery is a limited access fishery of 164 vessels (114 active in 1998 and 1999), all less than 101 feet in length. These vessels compete in an international fishery for tuna, swordfish, and billfish on fishing grounds which extend beyond the U.S. EEZs. The fleet can be separated into three trip types, based on target species, fishing grounds, and operational characteristics. In this discussion, the trip targets are tuna, swordfish, and mixed species target. The fishery lasts all year, with the third calendar quarter having the lowest landings. In 1998 the overall fishery involved 1,140 fishing trips, with landings of 26.6 million pounds, and an ex-vessel value of $46.7 million. The most complete recent description of the fishery is by Ito and Machado (1999) which provides much of the material presented in this section. Data are available for 1999, but were not available in published format at the time of preparation of this EIS. Where possible, information for 1999 is included in the less detailed tables.

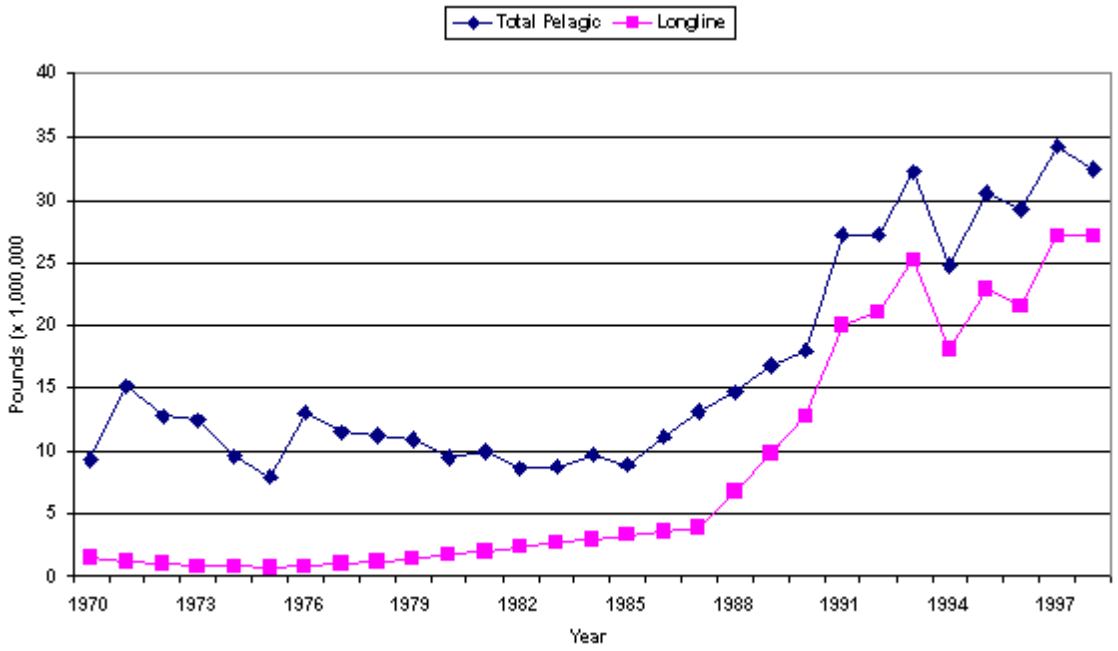
A detailed history of the Hawai'i-based longline fishery is in Boggs and Ito (1993, *in* NMFS and WPRFMC, 2000). In summary, longline fishing in Hawai'i had been conducted for many decades before the expansion of the fishery in the late 1980s. The first modern Hawai'i-based longline vessels were wooden pole-and-line tuna sampans (*aku* boats), which fished mainly within 2-20 nm of the coast. By the 1930s the longline fishery was second only to the pole-and-line fishery (*aku* fishery) in landed volume of fish and accounted for most of the yellowfin tuna, bigeye tuna, and albacore tuna landed in Hawai'i. The early longline fishery peaked in the mid-1950s, with landings exceeding 2,000 mt (4.5 million pounds), and then declined steadily into the late 1980s with decreasing investments in boats and gear.

In the late 1980s, the longline fishery began to revitalize (Figure 3.10.3-1). This change was due to the development of local and export markets for fresh tuna (mainly the *sashimi* market) on the continental United States and in Japan, the beginning of large-scale local exploitation of swordfish stocks around Hawai'i (although longlining was much revitalized before swordfish longlining started in Hawai'i), and favorable yen/dollar exchange rates.

Participation in the longline fishery grew from 37 vessels in 1987 to 88 in 1989 and further increased to 141 in 1991. Following this rapid expansion, entry to the longline fishery was curtailed through a 1991 moratorium on permit issuance under Amendment 4 to the

Pelagics FMP. In 1994, a limited entry program was implemented for the Hawai'i-based longline fishery through another amendment to the FMP. The amendment established a ceiling of 164 transferable permits, and further limited fishing capacity by restricting maximum vessel length to 101 ft.

Figure 3.10.3-1: Hawai'i Commercial Pelagic and Longline Landings, 1970-1998. Source: WPRFMC, 1999d.



The longline fleet is required by Federal law to fish beyond 25-50 nm from the Hawaiian islands with fishing grounds extending out more than 1,000 nm in international waters (Table 3.10.3-1). Target species include swordfish and albacore, bigeye, and yellowfin tuna. There are a total of 164 limited entry longline permits in the Hawai'i-based longline fishery, however, only 119 vessels were active in 1999. In 1998, the fleet made 1,140 fishing trips and landed 28.6 million pounds valued at $46.7 million (ex-vessel gross revenue).

Table 3.10.3-1: Fishery Information for Hawai'i-based Longline Fishery for 1998. Source: WPRFMC and Our Living Oceans 1999 Report from NMFS, 2000j.

Area Fished	EEZ around Hawai'i (25 to 200 nm) and high seas
Total Landings	28.6 million pounds
Species Composition	25 percent bigeye tuna 22 percent pelagic sharks 9 percent albacore tuna 25 percent swordfish
Season	All year
Active Vessels	114
Total Permits	164 (transferable, limited entry)
Total Trips	1,140
Total Ex-vessel Value	$46.7 million

General Summary

The longline fleet operates in two distinct modes based on gear deployment: deep-set longline by vessels that target primarily tuna and shallow-set longline by those that target swordfish or have mixed target trips. The differences between these two modes include equipment for setting gear, longline gear preparation, and fishing depths and grounds. The fleets also show some differences in vessel size, and in fishing background and ethnicity of participants. This section provides an overview of data for the longline fleet as a whole.

For statistical purposes, NMFS categorizes longline trips into three trip types according to species targeted: swordfish, tuna, or mixed (targeting both swordfish and tuna). Later sections examine data in which the differences among swordfish, mixed, and tuna modes are more distinct. Also in later sections, the directed tuna fishery is described separately for ease of presentation.

The Hawai'i-based longline fleet includes many newer steel longliners that were previously engaged in fisheries off the U.S. mainland, and a few wood and fiberglass vessels (WPRFMC, 1995). Around 1980 the Hawai'i Department of Business and Economic Development provided funds for the construction of three steel longliners, the beginning of the re-emerging fleet. Entrants in the early 1990s were mostly steel-hulled vessels up to 101 feet in length, and their operators were former participants in the U.S. Gulf of Mexico and East coast tuna and swordfish fisheries. These newer entrants are also characterized by a greater reliance on sophisticated electronic gear for navigating, marking deployed longline gear, and locating fish. The revitalized fleet also adopted more modern longline gear, using continuous nylon monofilament main lines stored on large spools, and snap-on monofilament branch lines. In the mid- to late 1980s a local longliner successfully experimented with catching

swordfish to the north of the Hawaiian islands with lightsticks and monofilament line. Compared with traditional, tarred-rope longlines, monofilament gear is easier to change configuration and can be used to modify fishing depth more easily.

In early 1991, longline fishing was prohibited in certain areas by Amendment 3 to the FMP; this amendment established a protected species zone around the NWHI. The zone was created to protect endangered Hawaiian monk seals, an endangered species. A further longline exclusion zone of 50 to 75 nm around the MHI was implemented through FMP Amendment 5 to alleviate gear conflicts among longline fishers and small boat fishers (i.e., handline and troll, charter boat operators, recreational fishers) (Figure 3.10.3-2). A Vessel Monitoring System (VMS) was and is being used to enforce the two longline exclusion zones with a high degree of succ.

Hawai'i-based longline vessels vary their fishing grounds by season and by target. Fishing grounds for 1994 to 1998 are shown in 5°-by-5° squares in Figure 3.10.3-2. Most effort is to the north and south of the Hawaiian Islands between latitudes 5° and 40° N. and longitudes 140° W. and 180°. Fishing effort is not uniform throughout the year: there is a seasonal lull in the third quarter due to low catch rates of the target species. This pattern is discussed in greater detail by target fishery, later in this section. The grounds cover a wide area and most are well beyond the 200 mile EEZ. Some of the more productive grounds are more than 1,000 km from port. These are the same grounds used by the international fleet of pelagic longliners. The area fished far east of Hawaii is also fished by longliners operating out of California.

Figure 3.10.3-3 compares swordfish (shallow) sets and tuna (deep) longline sets in representative drawings. (The actual number of hooks and their placement will vary.) Swordfish sets are buoyed to the surface, have few hooks between floats, and are relatively shallow. This same type of gear arrangement is used for mixed target sets. Tuna sets use a different type of float placed much further apart. Compared with swordfish sets, tuna sets have more hooks between the floats with hooks achieving greater depths in the water column. The hooks themselves are different for each target type. The sag in the mainline of a tuna set is much greater than shown in the figure ranging from 300 to 1,200 feet.

The number of hooks that Hawai'i-based longline vessels set by area for 1991 through 1999 is shown in Figure 3.10.3-4. The number of hooks set outside the U.S. EEZs almost doubled during the past decade. More hooks are set outside the EEZs, and in recent years the number set within the NWHI EEZ has decreased.

As a result of increased participation and technology, landings in the Hawai'i-based longline fishery increased rapidly after 1987 (Figure 3.10.3-1). The 1993 fishery landings reached 25.0 million pounds, approximately half of which was swordfish. Landings peaked in 1998 at 28.6 million pounds and were 28.3 million pounds in 1999 (Table 3.10.3-2). Swordfish landings decreased from its peak in 1993 while tuna landings have increased during the same period.

The increase in landings in the nine-year period shown is not related to an increase in the number of trips (Table 3.10.3-2). During this period the active number of vessels decreased, from 141 in 1991 to 119 in 1999 (16 percent), while the number of trips dedined, from 1,670 to 1,137 in 1999 (32 percent). However, in that same period the number of hooks fished rose by 55 percent (12.3 million hooks in 1991 to 19.1 million in 1999), while total landings were variable, between 18.4 million pounds in 1994 and 28.6 million pounds in 1998. The number of vessels operating in 1991 was an all-time high of 141, compared with 37 in 1987. Effort in number of trips increased accordingly. While 1991 was an anomalous year for numbers of vessels and trips, the figures demonstrate the level of effort (in terms of number of vessels participating) that is possible under the current limited access system.

The NMFS SWFSC-Honolulu Laboratory Fishery Monitoring and Economics Program (FMEP) relied exclusively on shoreside sampling to determine longline vessel activity and landings estimates from 1987 to 1991. The Hawai'i Division of Fish and Game had a monthly longline reporting program as early as the 1960s. Subsequently, a federal logbook system for domestic longliners operating in the Western Pacific Region was implemented in November 1990. Some longliners (originally from the East coast and Gulf of Mexico) left Hawai'i during 1994. In that year, six swordfish vessels headed east to the Atlantic Ocean, while about seven Gulf of Mexico vessels went west to the South Pacific (primarily Fiji). The cause of this exodus is not known, but reasons mentioned by fishers and vessel owners included poor swordfish landings in the central Pacific area, the high cost of operating and maintaining vessels in Hawai'i, the time and money spent on traveling between Hawai'i and the U.S. mainland, the need to keep permits active in fisheries elsewhere in the United States (such as the Atlantic longline fishery), or new fishing opportunities elsewhere (South Pacific Area) (NMFS, 2000f).

The average species composition of the Hawai'i-based longline fishery based on NMFS logbook data for 1991-1998 is depicted in Figure 3.10.3-5. Species are reported in numbers of fish, and may be converted to a weight measurement by using species averages derived from market sampling. The two most economically important components, swordfish and bigeye tuna, made approximately equal contributions in numbers of fish caught. Usual longline incidental catch (other than tuna and billfish) includes *mahimahi*, barracuda, moonfish, and *ono*, nearly all of which are kept and used. There is a large shark incidental catch and bycatch, primarily blue sharks. Their carcasses are not usually retained. (When harvested, blue sharks emit noxious fumes that make them unpalatable, the pungency of their uric acid infused blood can contaminate the flesh of other fish and spoil them. Therefore blue shark carcasses when kept are stored in a separate part of the fish-hold.) Typically the only part kept is the fins, which are dried for shark fin soup. Usually only mako and thresher shark carcasses are landed whole for meat. In June 2000 a state law was passed in Hawai'i prohibiting both harvesting shark fins for fins only from state waters and landing shark for fins only, regardless of where the sharks were caught. In December 2000, the U.S. Congress also prohibited shark finning by U.S. fishing vessels. If shark fins are landed, the rest of the carcass must be utilized.

Figure 3.10.3-2: Longline Fishing Grounds and Hooks Set by Area for the Hawai'i-based Longline Fishery, 1994-1998. Source: Ito and Machado, 1999.

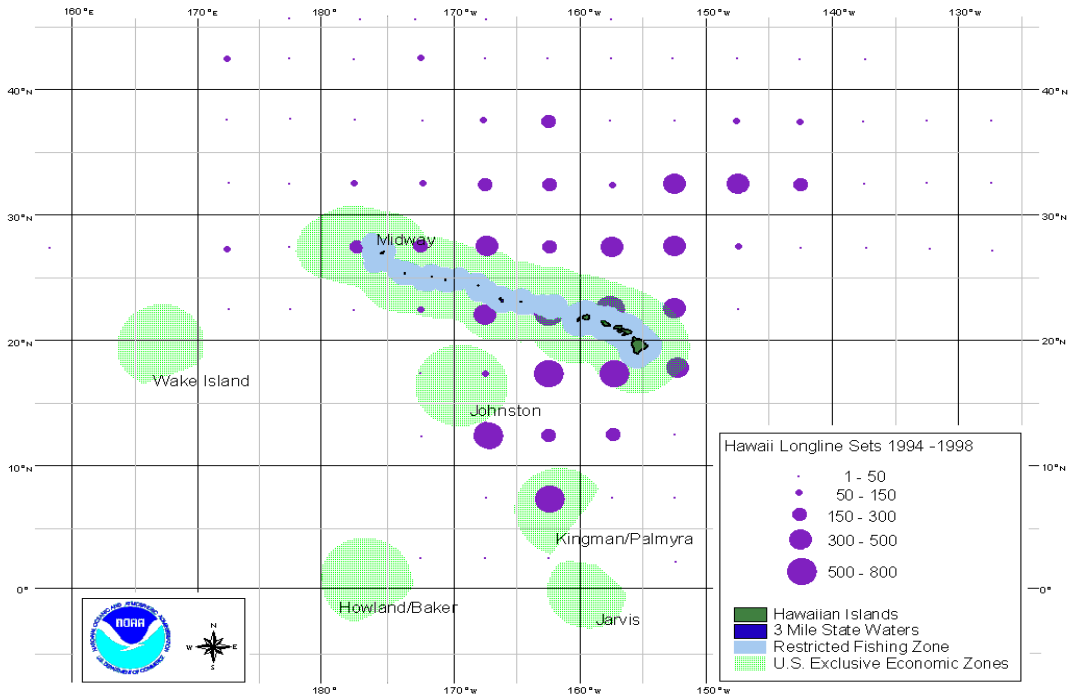


Figure 3.10.3-3. Pacific Longline with Gangions (Depth Varies Based on Target Species). Source: WPRFMC, 1995.

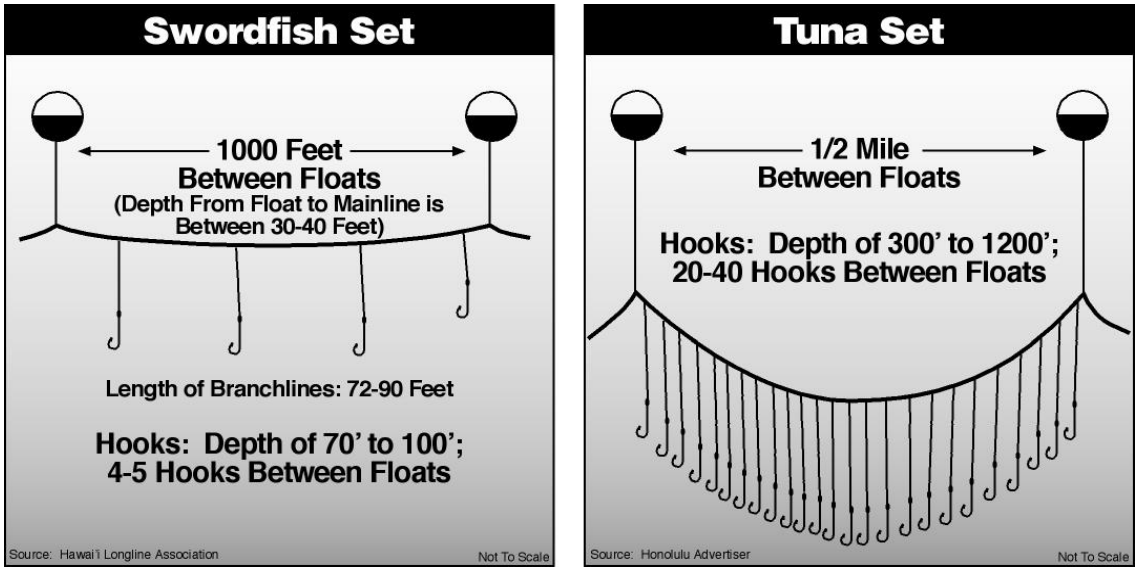


Figure 3.10.3-4: Trends in Annual Hooks Set by Area for the Hawai'i-based Longline Fishery, 1991-1999. Source: Ito and Machado, 1999.

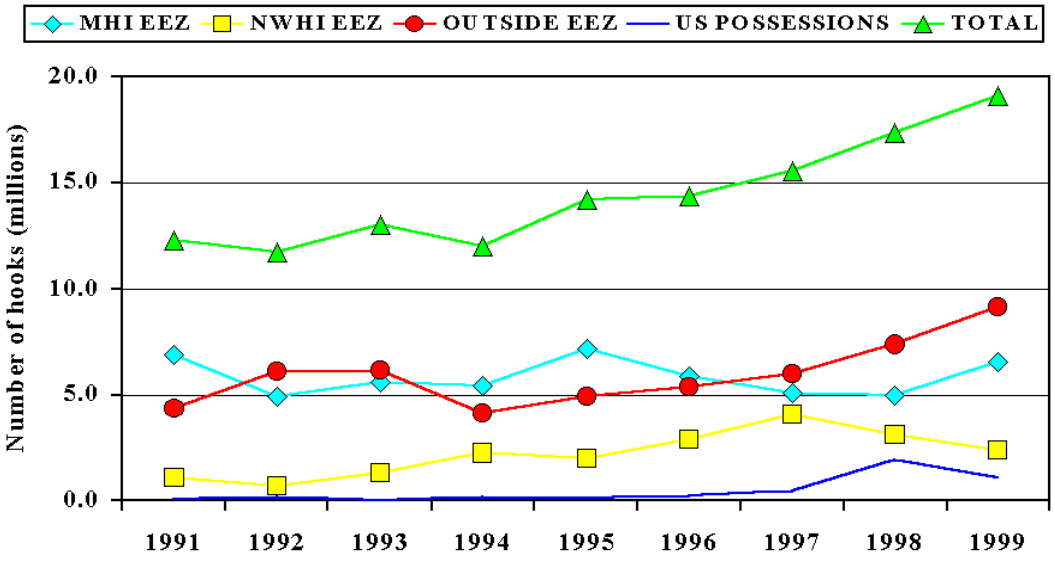
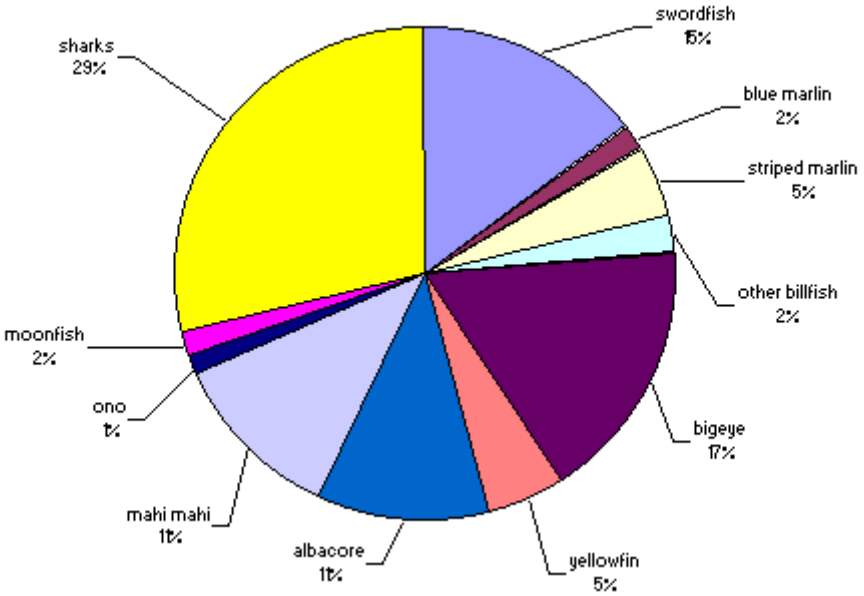


Table 3.10.3-2: Number of Active Vessels, Total Landings, and Total Fishing Effort by the Hawai'i-based Longline Fishery, 1991 to 1999. Source: Ito and Machado, 1999.

Year	Number of Active Vessels	Number of Trips	Total Landings[1]	Total Effort[2]
1991	141	1,671	19.6	12.3
1992	123	1,266	21.1	11.7
1993	122	1,192	25.3	13.0
1994	125	1,106	18.4	12.0
1995	110	1,125	22.5	14.2
1996	103	1,100	21.5	14.4
1997	105	1,125	27.1	15.6
1998	114	1,140	28.6	17.4
1999[3]	119	1,137	28.3	19.1

[1] In millions of pounds
[2] In millions of hooks
[3] NMFS, SWFSC-HL, preliminary and unpub. data.

Figure 3.10.3-5: Average Species Composition (Numbers of Fish) of the Hawai'i-based Pelagic Longline Fishery, 1991-1998. Source: WPRFMC, 1998a.



There has been considerable inter-annual variation in the species composition of the longline landings, due to changes in the fishery with respect to targeting. Figure 3.10.3-6 shows landings of swordfish and three principal tuna species in the longline fishery from 1991 to 1998. Swordfish landings peaked in 1993 before declining by 50 percent in 1994, and remained around this reduced level between 1994 and 1998. By contrast, tuna landings all showed a strong increase after 1991, with landing volumes more than doubling for albacore and bigeye tuna.

Species composition is also affected by the area fished. For example, in 1998 bigeye tuna landings are higher for vessels fishing in the MHI and NWHI than for vessels fishing on the high seas outside the EEZ. The 1998 swordfish landings were highest outside the EEZs, and lowest inside the EEZs (Figure 3.10.3-7). These compositions may also vary by year.

Some Hawai'i-based vessels target primarily swordfish, some target yellowfin and bigeye tunas, and some switch between fisheries. Some longliners fish all year, and others switch to other fisheries during midwinter, especially high seas longlining based out of California. Compared with vessels targeting swordfish or mixed species, vessels targeting tuna typically are smaller and fish different grounds. The primary operational difference is the depth at which the hooks are set. Hooks are set considerably deeper (especially the depth of the

center of the mainline sag) on trips targeting tuna than on trips targeting swordfish. In addition, tuna sets use bait, while swordfish fishing uses a combination of bait and lightsticks.

The distribution of effort with respect to species targeted (based on composition) changed between 1991 and 1999, as shown in Figure 3.10.3-8. The number of trips targeting tuna rose steadily after 1992. Trips targeting swordfish declined by more than 50 percent after 1994, and declined to a low of 65 trips in 1999. Mixed-target trips declined precipitously between 1991 and 1994, with a modest increase around 300 trips between 1995-1999.

Figure 3.10.3-6: Trends in Hawai'i-based Pelagic Longline Landings by Target Species, 1991-1998. Source: WPRFMC, 1998a.

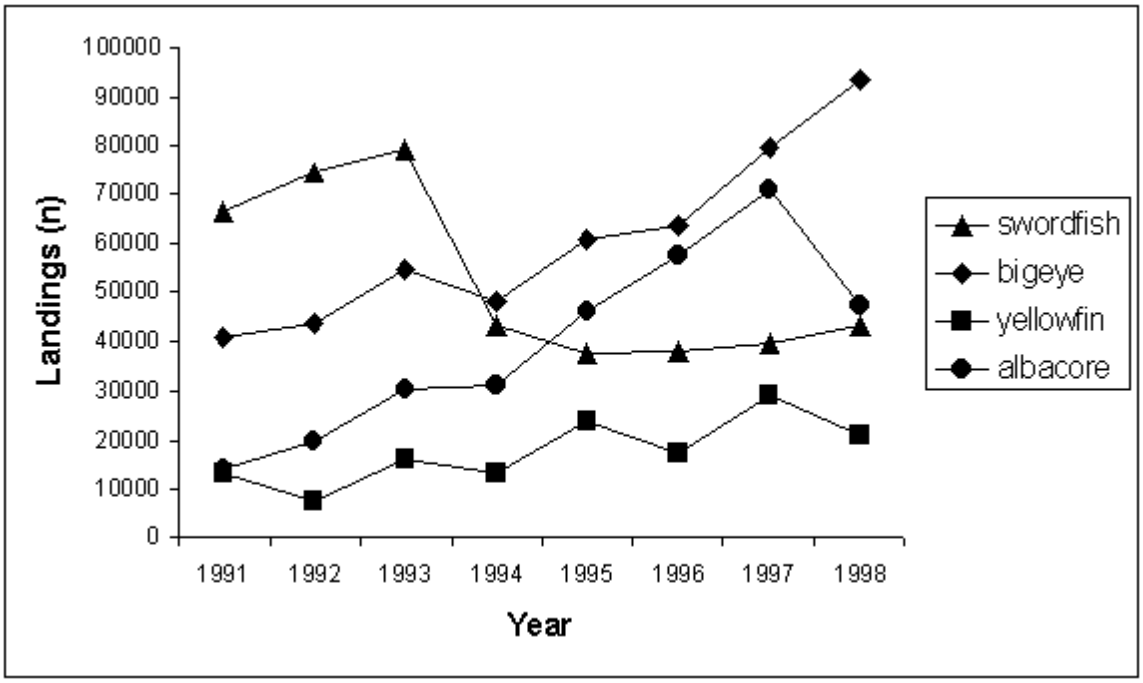


Figure 3.10.3-7: 1998 Species Composition (percent) for (A) Main Hawaiian Islands; (B) Northwestern Hawaiian Islands; (C) Outside the EEZ. Source: WPRFMC, 1998a.

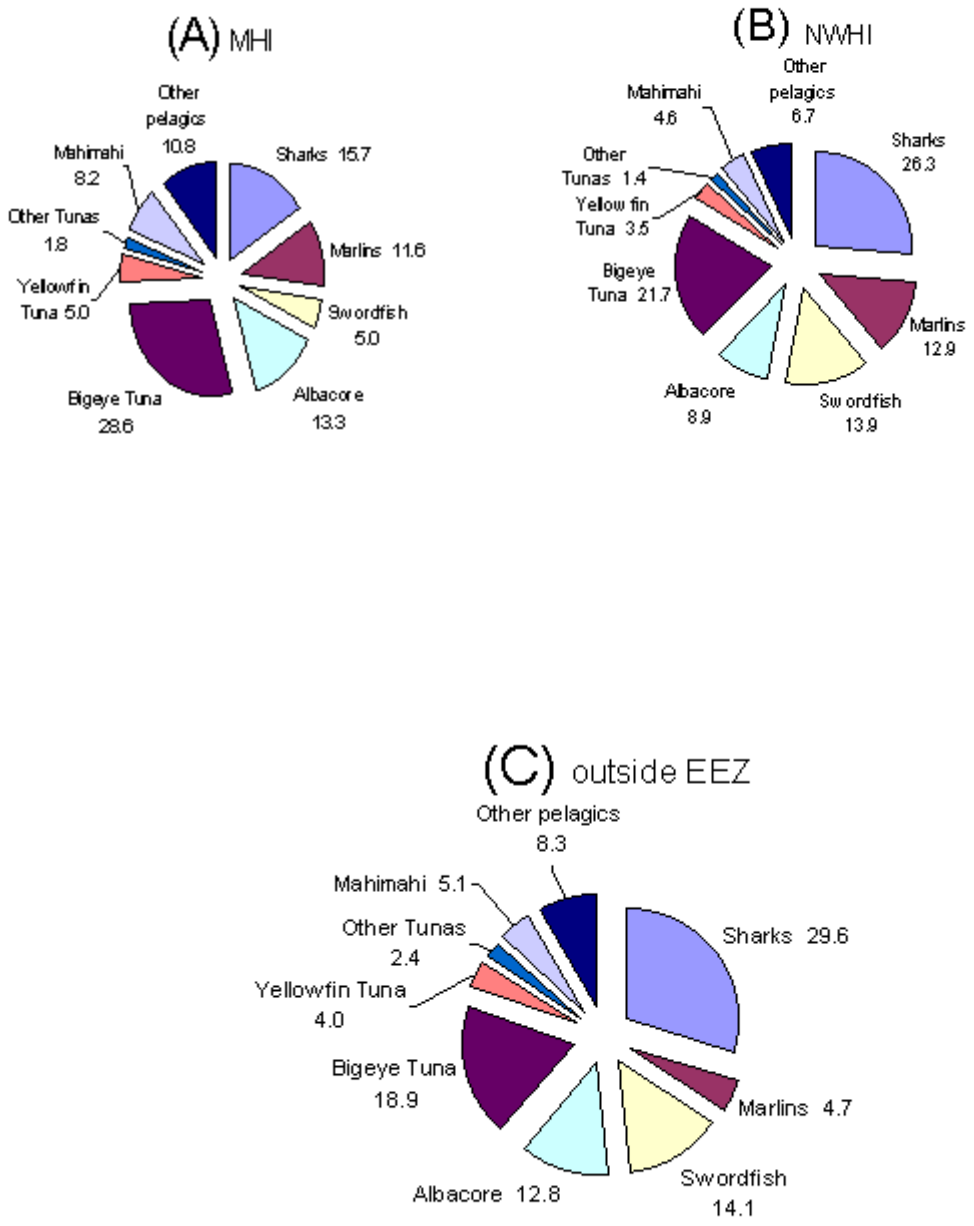
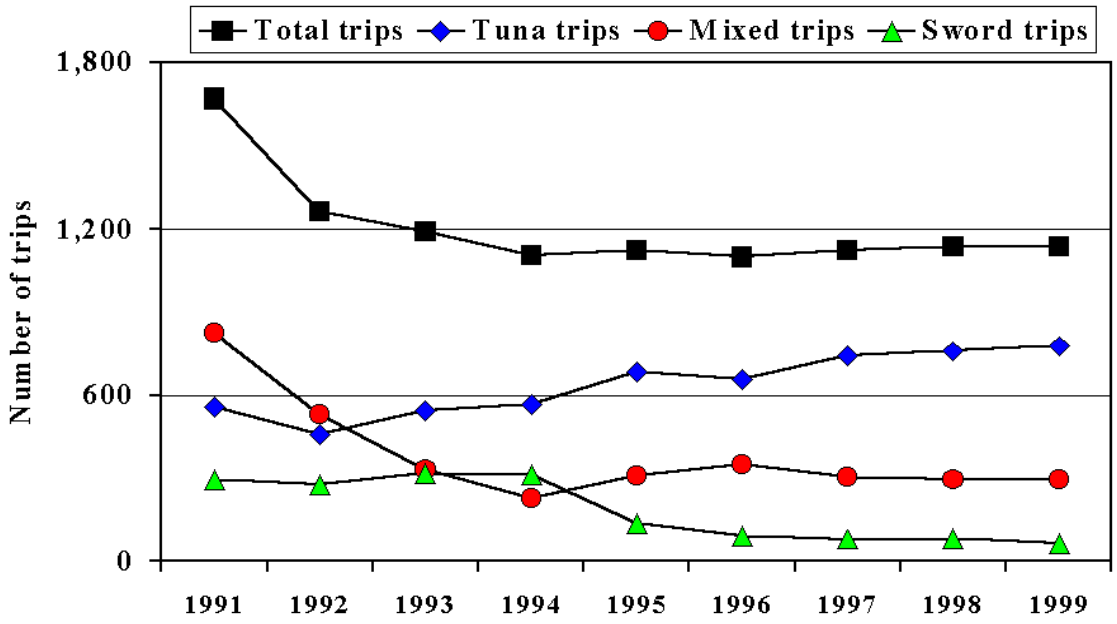


Figure 3.10.3-8: Fishing Effort with Respect to Target by the Hawai'i-based Longline Fishery, 1991-1999. Source: WPRFMC, 1998a.

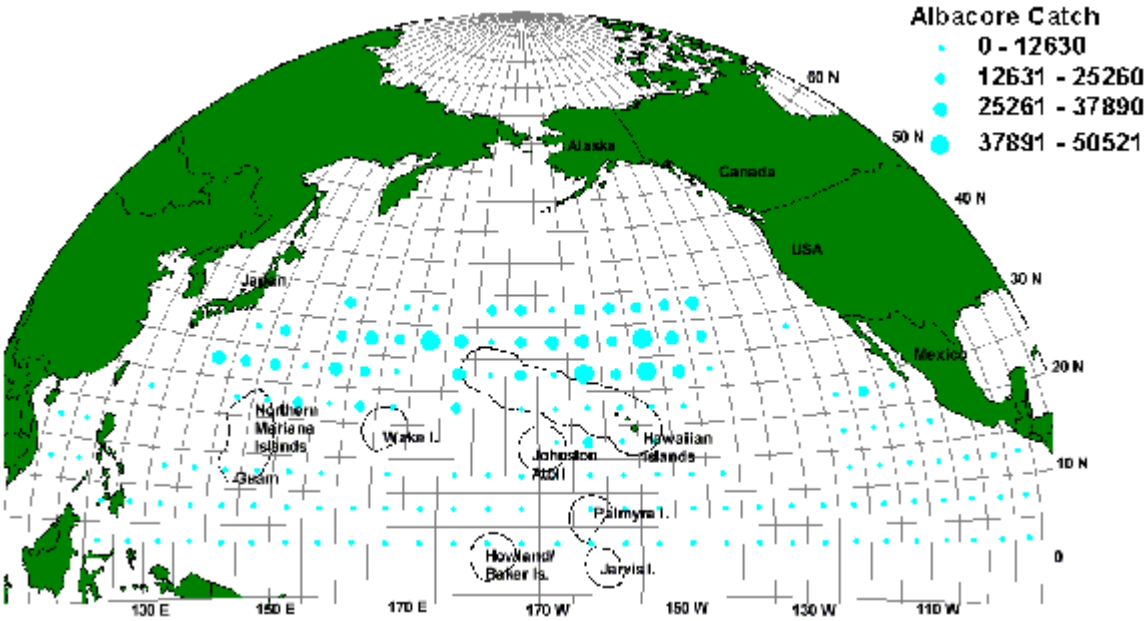


International Pacific Longline Fisheries

Hawaii-based longline vessels land less than 1 percent of the total landings of all Pacific pelagic species and only 7 percent of the landings by longline vessels. This section provides an overview of the international fisheries and is presented here to provide an overall perspective of the environment in which the Hawaii-based longline fisheries operate. More detailed landings data for international fisheries is presented in Sections 3.13 and 3.14.

The international longline fishery for tuna and swordfish covers a vast area, and participants are from many countries. Participants include major fleets from Japan, Taiwan, and Korea. More than 3,000 longline vessels from Japan, Taiwan, Korea, and other countries fish these and other waters and interact with the same species. Collectively, North Pacific longliners in 1997 landed 110,196 mt of the major species: 11,118 mt of swordfish, 18,271 mt of albacore, 42,986 mt of bigeye, and 37,821 mt of yellowfin (SPC's Oceanic Fishery Program *in* Cousins *et al.*, 2000). In that same year, the Hawai'i-based longline fleet landed 8,100 mt or about seven percent of the total. Figures 3.10.3-9 and 3.10.3-10 show trans-Pacific, international fishing grounds for albacore, bigeye and yellowfin tuna, and swordfish. Some of the highest catch rates for albacore tuna and swordfish occurred on grounds used by the Hawai'i-based longline fleet for the same fisheries.

Figure 3.10.3-9: Pelagic Longline Fishing Catch (in metric tons) for Albacore and Bigeye Tuna in the North and Central Pacific Ocean for 1997. Source: NMFS SWFSC-HL; SPC's Oceanic Fishery Program, from Cousins, Dalzell and Gilman, 2000.



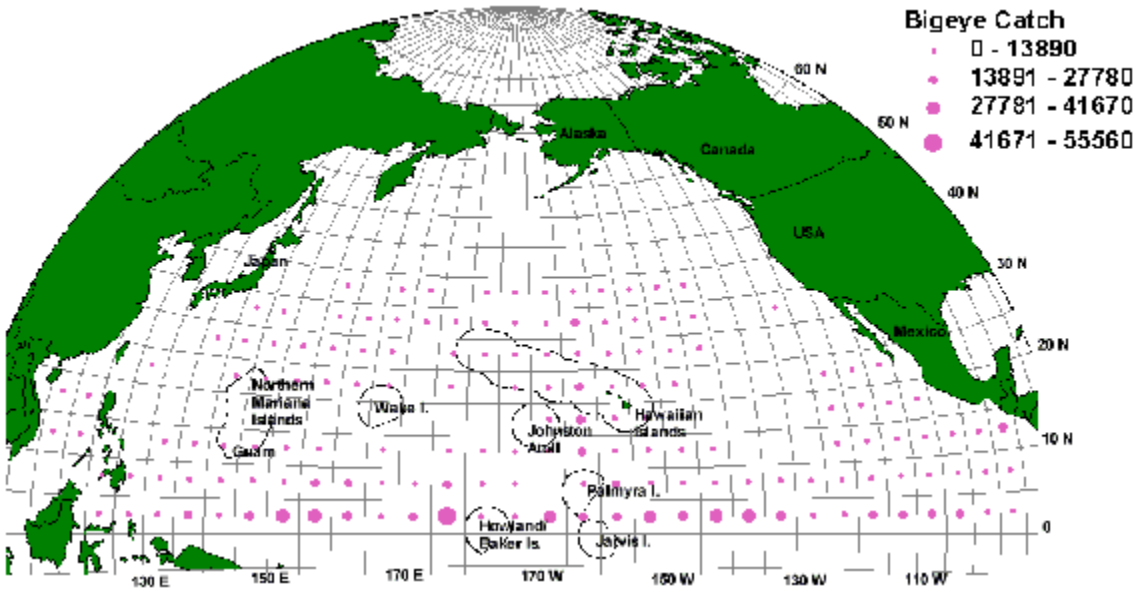
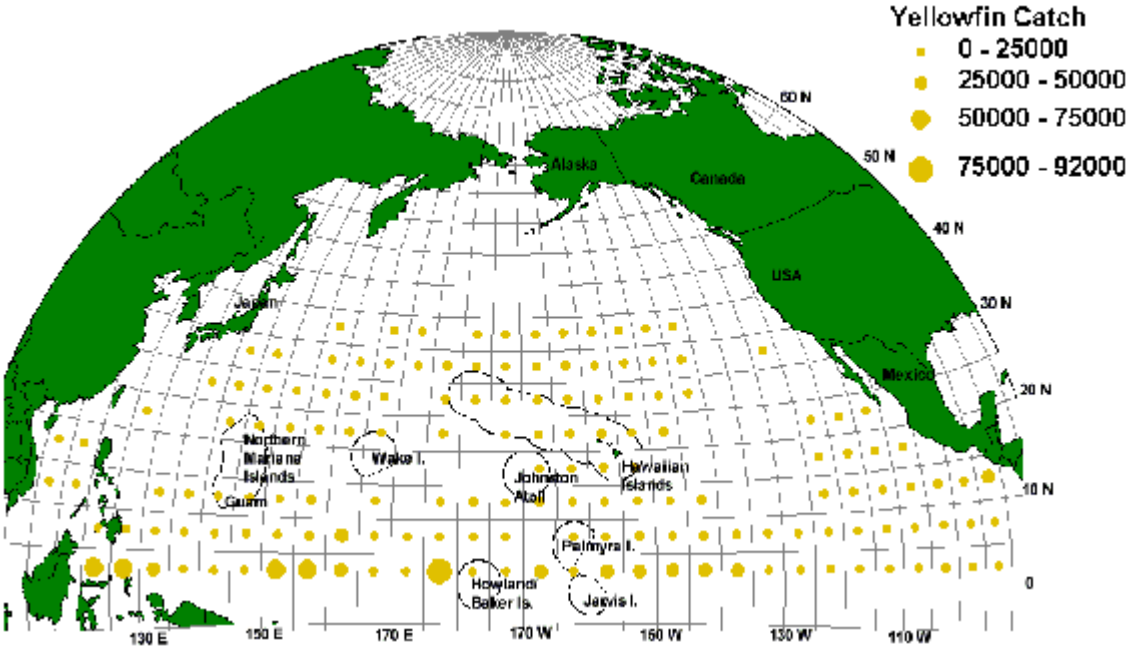


Figure 3.10.3-10: Pelagic Longline Fishing Catch (in metric tons) for Yellowfin Tuna and Swordfish in the North and Central Pacific Ocean for 1997. Source: NMFS SWFSC-HL; SPC's Oceanic Fishery Program, from Cousins, Dalzall and Gilman, 2000.



3.10.3.1.1 Directed Tuna Longline Fishery

Some of the Hawai'i-based longline vessels target tuna, typically using line-shooters to deploy deep set longline gear (as deep as 400 meters). This portion of the fleet land a small number of swordfish and a substantial number of other pelagic species (billfish, *mahimahi*, and others). Vessels that target swordfish typically set their gear at shallower depths and do not use line-shooters, however some shallow set effort is classified as "targeted tuna effort" because of the preponderance of tuna in the species composition. Much of the available secondary information on trips made by these vessels does not distinguish between deep and shallow set gear, but the directed tuna fishery is identified by species composition. The 92 vessels that targeted tuna in 1998 made 760 trips (an average of 8.3 fishing trips per vessel), averaging 10.4 days of fishing per trip (Tables 3.10.3-3 and 3.10.3-4).

Gear

Modern tuna longlining evolved from techniques developed in Japan several hundred years ago as a relatively simple method to harvest large yellowfin tuna and albacore (WPRFMC, 1995). The longlining technique is preferred for harvesting large, high-quality tuna for *sashimi* markets. Longline gear consists of a main line set horizontal to the ocean surface. Branch lines (gangions) are clipped to the mainline at regular intervals, and each gangion has a single baited hook. One set of gear can consist of thousands of hooks clipped to a single mainline buoyed by floats and extending across several miles of ocean. Longlining allows a vessel to distribute effort over a large area to harvest fish that are not concentrated enough in numbers to be caught by other methods, such as purse seining.

The main line is typically 30 to 100 km (18 to 60 nm) long, with 400 to 2,000 baited hooks set each day (the average is 800 in Hawai'i's fishery). The branch lines are typically 11 to 15 meters (35 to 50 feet) long. Radar reflectors and radio beacons are used to keep track of the line. To target deeper-swimming bigeye tuna, line-shooters are sometimes used to deploy line faster than the vessel is traveling to allow the mainline to sink deeper. These deeper sets use no lightsticks (WPRFMC, 1995). Tuna fishers typically set gear deep by attaching more hooks (than swordfish gear) between floats (15 to 30 or more hooks per float). These fishers set and soak gear in the day and haul in the afternoon. They use *sanma* for bait, and do not use lightsticks (Ito and Machado, 1999). Monofilament longline gear is the norm because it is more flexible in configuration and can target various depths more easily than is possible with traditional, tar-coated rope longlines (Cousins *et al.*, 2000). However, some vessels use stainless steel wire leaders (WPRFMC, 2000f).

To catch tuna in good condition, it is necessary to use freshwater ice since saltwater will freeze the fish. Therefore, any vessel targeting tuna or intending to land tuna must carry freshwater ice instead of or in addition to saltwater ice. Most of the vessels in the fleet carry ice from shore, while some augment this ice with desalinated ice made on the vessel from seawater.

Vessels

Vessels that focus on tuna are often aggregated in the literature with swordfish vessels. Therefore it is necessary to provide an initial discussion of the longline fleet in order to differentiate the tuna vessels.

Vessel Length and Variation

A vessel cost-earnings study conducted in 1993 (Hamilton *et al.*, 1996) found that smaller vessels generally targeted tuna. For that study, small vessels were considered those 56 feet or less in length. Of the 30 active vessels in that category, 22 targeted only tuna and eight had trips that resulted in larger landings of swordfish. For the 48 vessels of medium length, between 56 and 74 feet in length, 16 targeted tuna. Of the 44 large vessels (those more than 74 feet in length) three targeted tuna. The overall effort targeting tuna has been increasing in several ways. The number of vessels taking targeted tuna trips fluctuated annually in the 1990s and is now relatively stable at about 90. However, the number of trips and hooks has been rising, so there are more trips per vessel and more hooks per trip.

Number of Vessels

The number of fishing vessels used for tuna trips decreased by almost half between 1991 and 1992, from a high of 104 in 1991 to a low of 55 in 1992. Table 3.10.3-3 shows the number of vessels, trips, and hooks for the directed tuna longline fishery in 1991-1999. It must be noted that these vessels are not exclusively targeting tuna, some also target mixed species and/or swordfish. This decrease was followed by an increase to 83 in 1994. The number has been relatively stable since 1994 with 87 vessels targeting tuna in 1999. Federal logbooks of catch and effort extend only from 1991, following a requirement for vessels to maintain logbooks and catch records. The overall fishing effort in number of trips has increased by 50 percent after 1991. In number of hooks deployed, effort has risen constantly, from 5.2 million in 1991 to 15.4 million in 1999.

Table 3.10.3-3: Number of Vessels, Vessel Trips, and Hooks Used in Directed Tuna Longline Trips, 1991 to 1999. Source: Adapted from Ito and Machado, 1999.

Year	Number of Active Vessels	Number of Trips	Number of Trips per Vessel [2]	Number of Hooks[1]	Number of Hooks per Trip[2]
1991	104	556	5.3	5.2	9,353
1992	55	458	8.3	5.3	11,572
1993	61	542	8.9	6.5	11,993
1994	83	568	6.8	7.0	12,324
1995	78	682	8.7	9.7	14,223
1996	76	657	8.6	10.4	15,829
1997	83	745	9.0	12.2	16,376
1998	92	760	8.3	13.5	17,763
1999*	87	776	8.9	15.4	19,845

[1] In millions of hooks (includes hooks from shallow sets for tuna)
[2] These numbers are calculated by the analysts and were not provided in the source.
* Preliminary

Operational Characteristics

Longline gear targets large tuna suitable for the raw fish or *sashimi* markets. Overall catch rates in relation to the number of hooks used on longline gear are very low (fish of any species caught on two percent of the hooks set is considered a good catch rate), but these fish are of higher value than those caught by other methods (WPRFMC, 1995).

Time of Day Fished

Tuna fishing most often occurs during daylight hours. Fishers typically set and soak the gear in the morning and haul in the afternoon (Ito and Machado, 1999).

Bait

Tuna-targeting longlines tend to use saury as bait. Saury bait tends to sink faster than squid, which often has pockets of air trapped within the mantle (Cousins *et al.*, 2000). Saury is also known by its Japanese name, *sanma*.

Length of Trip

To catch tuna, a vessel may travel one to two days from port and a few hundred kilometers. Longline trips typically last about 14 to 21 days when yellowfin and bigeye tuna are targeted.

In 1991-1998, the average distance to first set increased for tuna trips, especially after 1995 (Table 3.10.3-4). The maximum distance to the first set varied significantly during this period, from 945 miles in 1994-1995 to 1,866 miles in 1996. The average number of fishing

days per vessel increased from eight in 1991-1992 to ten beginning in 1995. The maximum number of fishing days per vessel varied between 14 and 28 during the period. The average distance to first set was less than the average for swordfish or mixed fishing trips, but the average number of days was similar for tuna trips and for mixed fishing trips.

The total number of fishing days increased virtually every year, reaching 7,874 in 1998. However, the average number of days fished per vessel varied from 60.7 in 1994 to 91 in 1997 (Table 3.10.3-4).

Table 3.10.3-4: Hawai'i-based Longline Vessel Activity, Tuna Target Trips, 1991-1998. Source: Modified using data from WPRFMC, 2000d and WPRFMC, 2000c.

Year	Days Fished Annually	Miles to First Set		Number of Days Fishing per Trip		Fleet
	per Vessel	Average	Maximum	Average	Maximum	Total
1991	41.2	240	1,508	7.7	18	4,280
1992	70.5	260	1,156	8.5	14	3,879
1993	77.8	222	1,432	8.8	14	4,747
1994	60.7	252	945	8.9	16	5,041
1995	89.3	273	945	10.2	20	6,964
1996	89.1	284	1,866	10.3	28	6,773
1997	91.0	288	1,002	10.1	19	7,549
1998	85.6	384	1,154	10.4	17	7,874

Note: Include shallow sets that were dassified as targeting tuna.

Crew Size

According to a 1993 study (Hamilton *et al.*, 1996), vessels targeting tuna carried an average of 3.7 crew members plus a skipper. Most operate with a captain and crew of three when fishing for tuna.

Fishing Grounds

This section discusses the fishing grounds in which tuna are caught–no distinctions are made between tuna caught in targeted effort with deep sets and tuna caught while targeting swordfish. The geographic distribution of various species show considerable overlap as does the distribution of effort. Tuna fishing effort (number of hooks) and fishing area change seasonally (Diaz-Soltero, 1998b). Targeting specific species of fish also changes the distribution of effort. In the beginning of the year effort is concentrated between latitudes 15° N. and 35° N. and longitudes 150° W. and 180°. In the second quarter, fishing effort expands to the south and spreads further east and west to about longitudes 145° W. and 170° E. Fishing effort in the third quarter expands to its greatest extent. In the fourth quarter effort contracts in comparison to the previous quarter.

Fishing areas for tuna vary by season, depending on the species. Figures 3.10.3-11 through 3.10.3-13 show how these patterns shifted quarterly for albacore, bigeye, and yellowfin tuna during the period 1991 through 1994.

Seasons

During the 1991 to 1994 period, the number of hooks set in the third quarter represented about 17.5 percent of the annual total number set, while the numbers set in the first, second, and fourth quarters were about equal, with each representing 27.5 percent of the total sets made each year (Curran *et al.*, 1996). Bigeye tuna had highest catch rates during the fourth and first quarters.

Figure 3.10.3-11: Albacore Tuna Catch (kg) by Quarter, Average for 1991-1994. Source: Curran *et al.*, 1996. (Note: The distribution of effort may have changed since expansion of directed tuna effort after 1994. Also note that the catch data include all trip types not only tuna effort.)

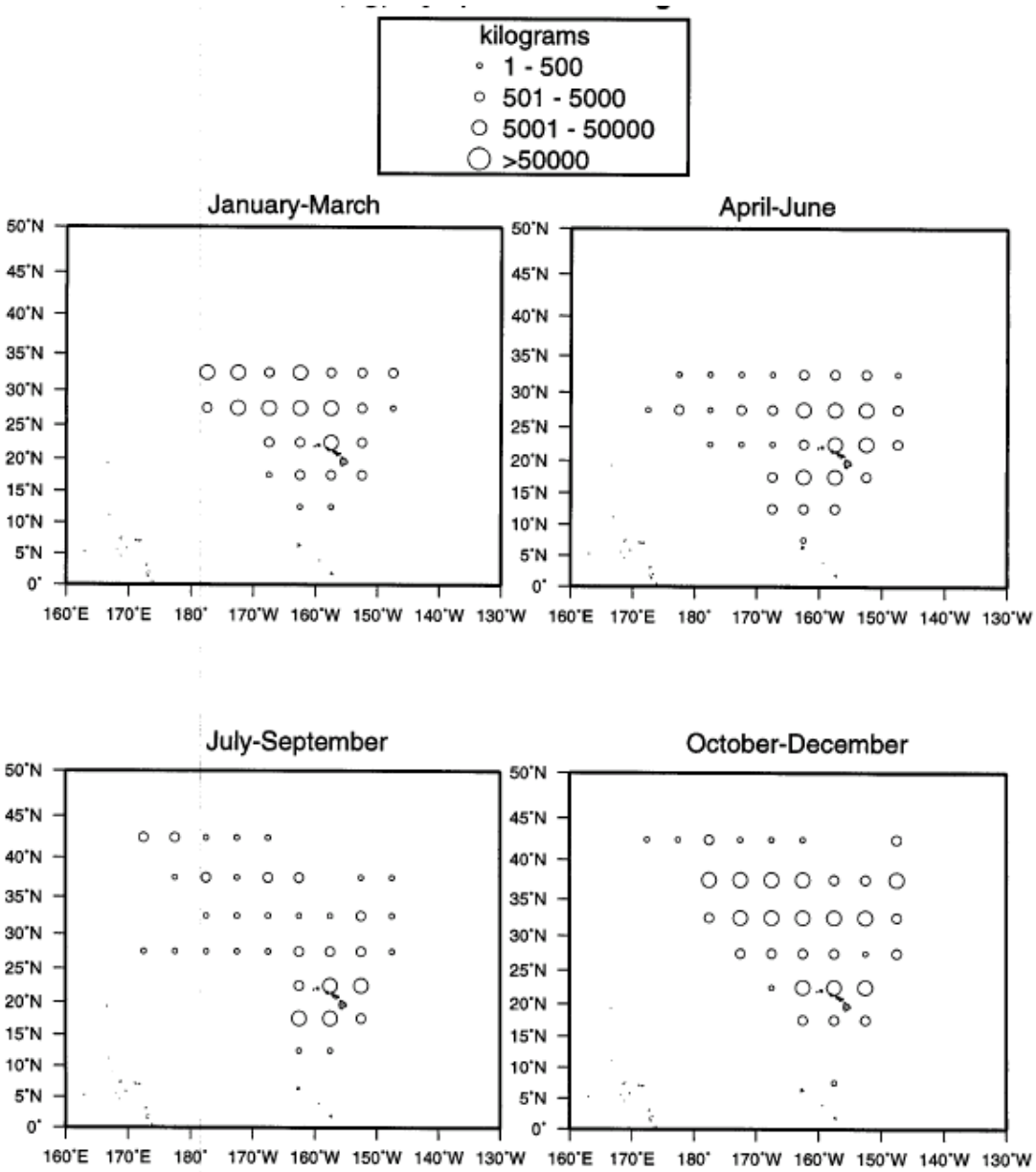


Figure 3.10.3-12: Bigeye Tuna Catch (kg) by Quarter, Average for 1991-1994. Source: Curran *et al.*, 1996. (Note. The distribution of effort may have changed since expansion of directed tuna effort after 1994. Also note that the catch data include all trip types not only tuna effort.)

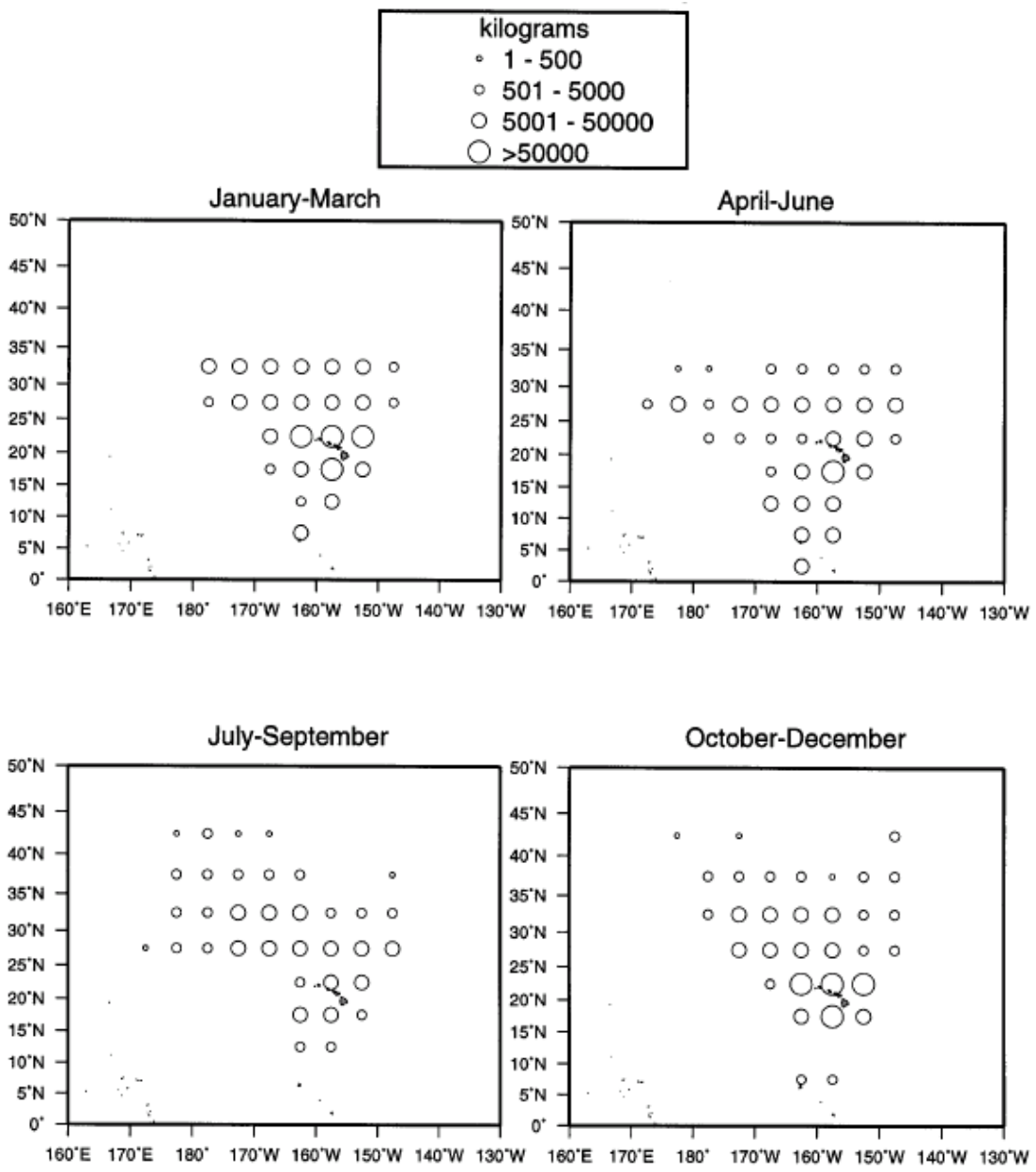
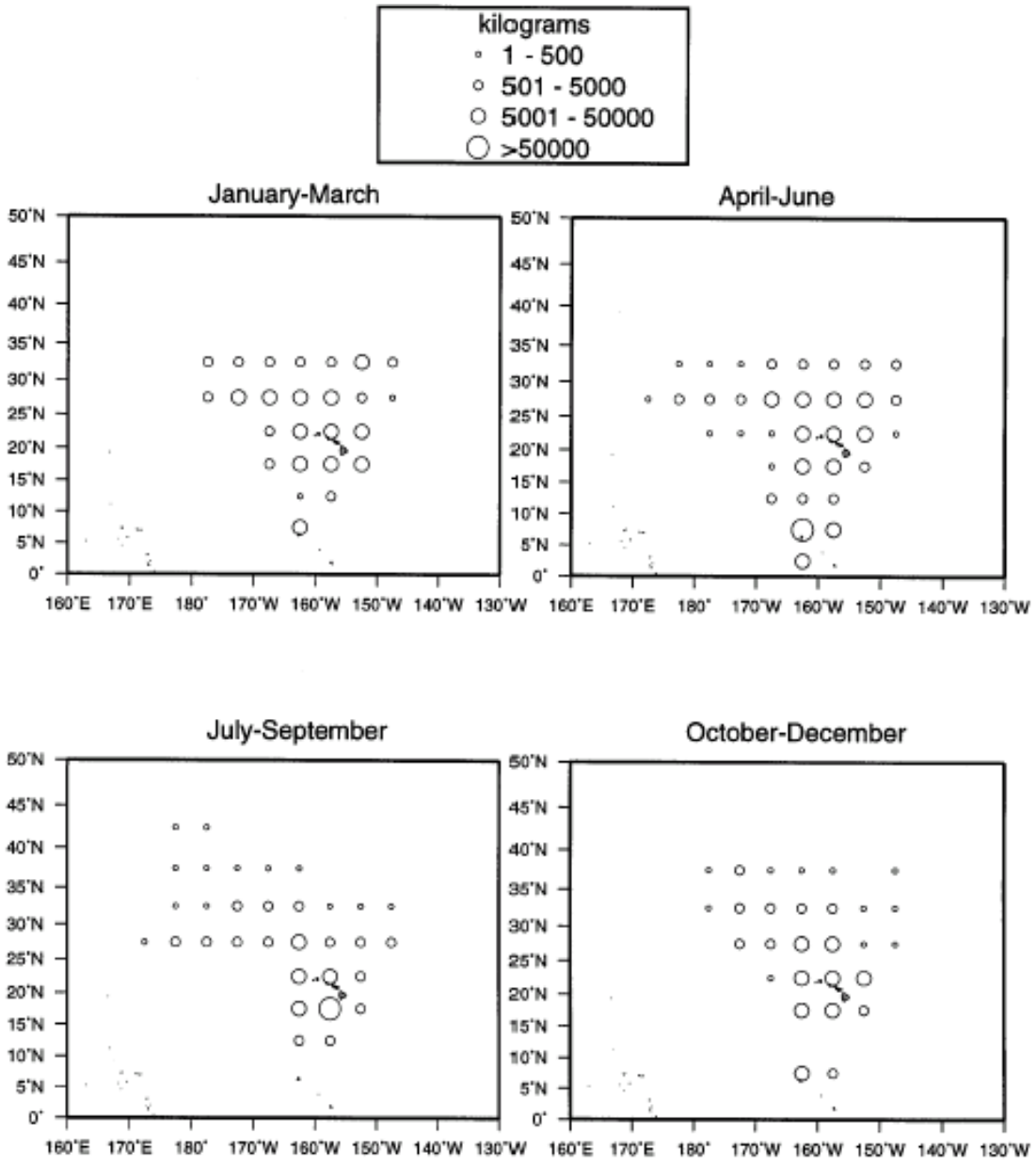


Figure 3.10.3-13: Yellowfin Tuna Catch (kg) by Quarter, Average for 1991-1994. Source: Curran *et al.*, 1996.(Note. The distribution of effort may have changed since expansion of directed tuna effort after 1994. Also note that the catch data include all trip types not only tuna effort.)



Participants

Demographic information specific to the tuna target fleet that use deep-set gear is unavailable, however inferences from secondary information are possible. Most vessels in the tuna fishery are homeported in Honolulu, as are most of the crew. A total of 120 vessel owners and captains responded to a vessel cost-earnings survey conducted in 1993 (Hamilton *et al.*, 1996). Of these, 37 (31 percent) were identified as targeting tuna. Of the 37, 22 were owner-operators, eight were hired captains, and seven were absent owners. At that time the ethnicity of those targeting tuna was 23 Korean, seven Caucasian, two Japanese, one Hawaiian, and four other heritage. Since 1993, there have been changes in the demographic composition of the fleet.

A survey of 130 longline permit holders in 1999, the following ethnicity existed: 48 (40 percent) Vietnamese, 45 (37 percent) Caucasian, 25 (21 percent) Korean, three Hawaiian, two Japanese, one Samoan, and six mixed heritage. Reports from fishers suggest that only about four of the Vietnamese have line-shooters. Given that a line-shooter is necessary for successful tuna targeting (as opposed to mixed trips) few of the Vietnamese appear to be engaged in targeting tuna. In comparison, most of the vessels that targeted tunas in 1999 had line-shooters and are owned by non-Vietnamese. (Cook, 2000).

Changes in Gear

Probably the most significant change over the past several years has been the shift of longline effort from swordfish into tuna. The number of swordfish-directed trips declined from 319 in 1993 to just 65 in 1999. The number of mixed trips remained relatively constant although there may have been some substantial changes in species composition. Meanwhile, tuna-directed trips increased from 542 in 1992 to 776 trips in 1999 over the same period. Investment to reconfigure gear is substantial since a line-shooter, new hooks, floats, mainline all must be purchased and installed.

3.10.3.1.2 Directed Swordfish and Mixed Swordfish/Tuna Longline Fishery

In general, on trips targeting swordfish or both swordfish and tuna, fishers do not use line shooters. Typically these vessel set gear at shallower depths and use less hooks than they would if targeting tuna, however some deep-set effort can result in mixed target landings as classified by species composition. Vessels making trips for swordfish travel farther from port than trips targeting mixed species. Thirty-two vessels targeted swordfish, with 84 trips averaging 14.6 days fishing in 1998. During 1998, 50 vessels made 296 mixed trips, averaging 11.4 fishing days each (Table 3.10.3-5).

Targets

Trips that target swordfish, including mixed swordfish/tuna trips, are often interchangeable in terms of gear and operations. One of the main determinants is the storage life of tuna in

ice. The vessels in this fishery have ice but not freezing capacity. Therefore, if they land tuna early during their trip they must return to port in less than three weeks, and trip length will be similar to the length of a tuna trip. If tuna are caught late in the trip, the trip can be longer. Depth of the set is manipulated by changing the speed of the vessel and the speed at which the mainline is deployed. Increasing numbers of vessels are fishing more opportunistically, fishing for swordfish and tunas, either in the same set or on the same trip (Diaz-Soltero, 1998b).

Gear

On swordfish and mixed trips, fishers usually set four to five hooks between floats to allow the main line to stay within the upper 30 to 90 meters of the water column. A line shooter is not used. During the 1990s, targeting swordfish vessels used one lightstick for every hook, while mixed trips generally attached a lightstick every three to five hooks (Ito and Machado, 1999).

Swordfish-directed sets typically sets 30 to 100 km (18 to 60 nm) of mainline, with 700 to 1,000 hooks each set (Diaz-Soltero, 1998b). The branch lines are typically 11 to 15 meters (35 to 50 feet) long. Floats are attached to the mainline at about 500-meter (1,650 ft) intervals, float lines are 10 to 20 meters (30 to 70 feet) long. Radar reflectors and radio beacons are used to keep track of the line. Swordfish target sets often have two to three gangions (branch lines) between floats. Four to six hooks are deployed between floats when swordfish are targeted, and the line is kept relatively taut so that it stays within the first 30 to 90 meters of the water column (Cousins *et al.*, 2000). That same study stated that monofilament longline gear is more flexible in configuration and can target various depths more easily than is possible with traditional, tar-coated rope longlines. However, some vessels use stainless steel wire leaders (WPRFMC, 2000f).

Vessel Length and Variation

A vessel cost-earnings study conducted in 1993 (Hamilton *et al.*, 1996) found that smaller vessels generally do not target swordfish or mixed fisheries. For that study, small vessels were considered those 56 ft or less in length. For the 48 vessels of medium length (between 56 and 74 ft) 31 targeted swordfish either occasionally or full-time. Of the 44 large vessels, those more than 74 feet, almost all targeted swordfish either occasionally or full-time.

Number of Vessels

The numbers of boats used for trips targeting swordfish and mixed species decreased in the early 1990s. However, the numbers for both groups have been relatively constant since the mid-1990s (Table 3.10.3-5). It should be noted that the distinction between swordfish and mixed target effort is somewhat arbitary and does not reflect any real operational differences, nor does it reflect the opportunistic nature of swordfish vessels to target either

swordfish or tuna. The information on vessels in Table 3.10.3-5 is not additive – nearly every vessel that targeted swordfish also had mixed-target effort in the same year.

Table 3.10.3-5: Summary of Vessels, Trips, and Hooks by Trip Type by the Hawai'i-based Longline Fishery, 1991 to 1999. Source: Adapted from Ito and Machado, 1999.

Year	Number of Active Vessels[1]	Number of Trips	Number of Trips per Vessel[3]	Total Number of Hooks[2]	Number of Hooks per Trip[3]
Swordfish					
1991	98	291	3.0	2.4	8,247
1992	66	277	4.2	2.8	10,108
1993	19	319	16.8	4.0	12,539
1994	74	310	4.2	3.5	11,290
1995	44	136	3.1	1.2	8,824
1996	33	92	2.8	0.93	10,109
1997	26	78	3.0	0.84	10,769
1998	32	84	2.6	1.0	11,905
1999*	31	65	2.1	0.7	10,769
Mixed trip[4]					
1991	94	823	8.8	4.7	5,711
1992	72	530	7.4	3.7	6,981
1993	59	331	5.6	2.6	7,855
1994	51	228	4.5	1.5	6,579
1995	49	307	6.3	2.4	7,818
1996	51	351	6.9	3.1	8,832
1997	44	302	6.9	2.5	8,278
1998	50	296	5.9	2.9	9,797
1999[5]	50	296	5.9	3.0	10,135

[1] Not additive between swordfish and mixed trip vessels since a vessel may be counted separately in both.
[2] In millions of hooks (includes hooks from deep sets for mixed targets)
[3] These numbers are calculated by the analysts and were not provided in the source.
[4] Mixed trips target a combination of swordfish and tuna species.
[5] NMFS, SWFSC-HL, preliminary and unpublished data.

Operational Characteristics

The number of trips per vessel has decreased in recent years, most significantly for swordfish vessels (Table 3.10.3-5). Swordfish vessels fished about the same number of hooks per trip during the period 1991-1999, but mixed-trip vessels continued to increase the number of hooks they fish per trip.

One longline set is made per day of fishing, and for very long main lines the deployment and retrieval may take almost 24 hours. Often the end of the line that was deployed first is retrieved last, so individual hooks may fish for a few hours, with an average soak time of about 12 hours. Generally, the gear is set in the evening, soaked overnight, and hauled the following morning (Ito and Machado, 1996).

Bait

Squid is the primary bait used in the swordfish fishery. These fishers also use locally caught scad, imported squid, sardines, herring, and saury (WPacFIN).

Longlining for swordfish in the North Pacific is a relatively new fishery for the United States, and the introduction of chemical lightsticks in the late 1970s revolutionized the industry. These buoyant lights are attached by rubber bands or line clips to the branch lines about two meters above the hook. The lightsticks produce a chemical luminescence for up to 24 hours. The lights are available in a variety of colors and are thought to attract either small fish, upon which swordfish prey, or the swordfish themselves.

Length of Trip

To catch swordfish, a vessel can travel from two to ten days (steam time) and up to 3,200 km (2,000 miles), depending on the season. Longline trips typically last about 30 to 45 days when swordfish are targeted.

The average distance for a swordfish trip, averaged 747 miles between 1991 and 1998 (Table 3.10.3-6). For mixed trips the distance averaged 392 miles. Both of these averages are higher than to first set tuna trips. Swordfish trips averaged 13 days of fishing, while mixed trips averaged nine days, virtually the same duration as tuna trips. However, the average maximum length of mixed trips was virtually the same for mixed-species and swordfish trips.

Table 3.10.3-6: Hawai'i Longline Vessel Activity, Swordfish and Mixed Target Activity, 1991-1998. Source: Modified using data from WPRFMC, 1999d.

Year	Days Fished Annually	Miles to First Set		Days Fishing per Trip		Fleet
	per Vessel	Average	Maximum	Average	Maximum	Total
			Swordfish			
1991	32.5	585.0	1,792	10.9	26	3,184
1992	53.5	733.0	1,871	12.7	26	3,531
1993	54.7	820.0	2,122	13.5	29	4,322
1994	55.4	833.0	2,814	13.2	26	4,098
1995	42.0	884.0	2,097	13.6	27	1,848
1996	35.5	790.0	2,037	12.7	28	1,170
1997	41.4	623.0	1,973	13.8	27	1,076
1998	38.2	708.0	1,522	14.6	24	1,223
			Mixed			
1991	55.0	276.0	1,408	6.3	22	5,171
1992	57.4	404.0	1,543	7.8	21	4,136
1993	55.1	522.0	1,616	9.8	23	3,249
1994	32.5	323.0	1,298	7.3	19	1,660
1995	59.6	397.0	1,609	9.5	26	2,920
1996	72.5	410.0	1,547	10.5	30	3,695
1997	73.2	365.0	1,323	10.7	36	3,221
1998	68.2	439.0	1,611	11.5	24	3,409

Crew Size

Vessels targeting swordfish have an average crew size of 5.4 (a captain and 4.4 crew members). Those that target both swordfish and tuna have a crew of five plus a captain (Hamilton *et al.*, 1996).

Fishing Grounds

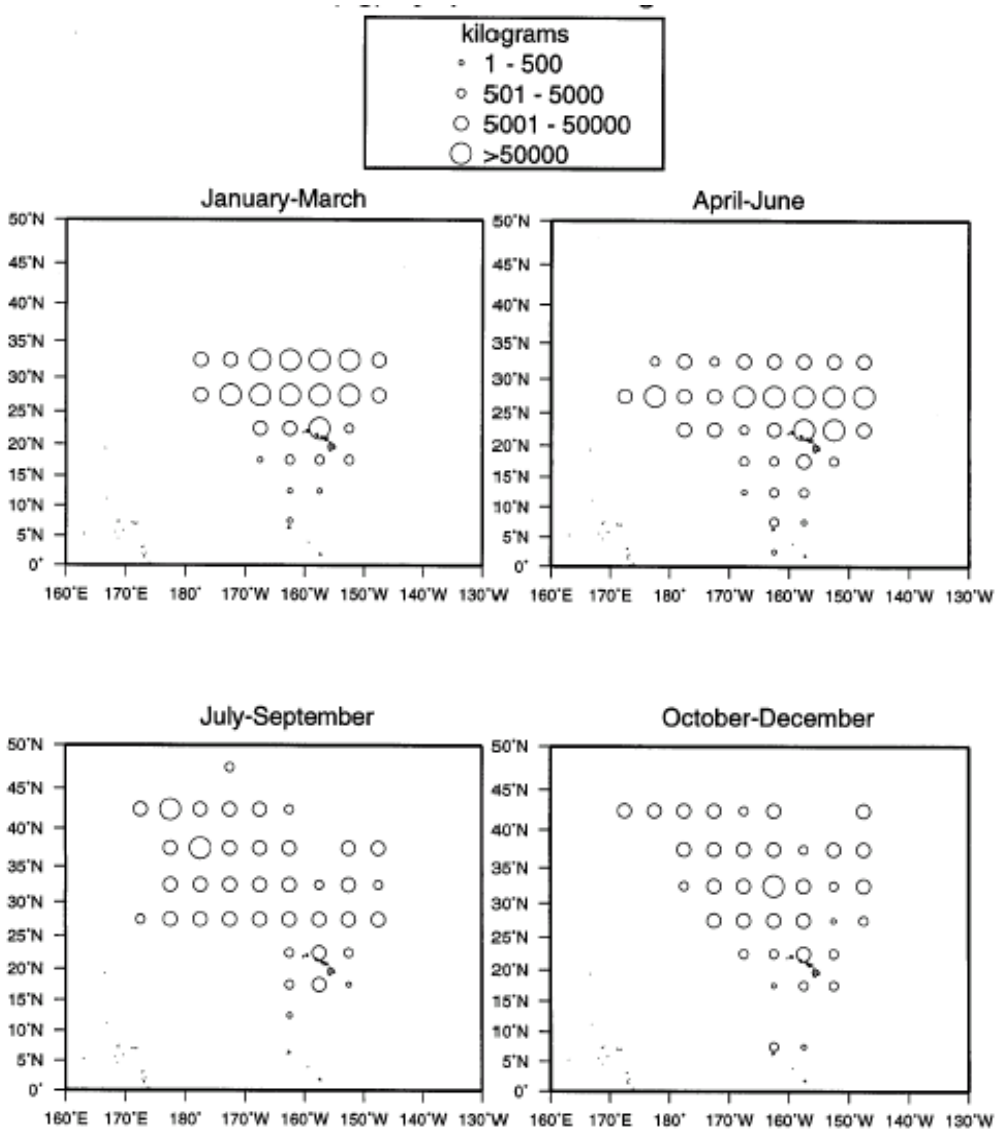
Early in the history of the longline fishery, the fishery was conducted in close range around the NWHI. In early 1991, longline fishing was prohibited around the NWHI. The area closure was created to protect endangered Hawaiian monk seals.

Many new entrants into the longline fishery in the late 1980s and early 1990s did not have line- shooters. These vessels fished which led to gear conflicts. They set their gear shallow in the vicinity of FADs which led to gear conflicts. A further longline exclusion zone of 50 to 75 nm around the MHI was implemented through Amendment 5 to alleviate gear conflicts between small boats (handline/troll fishers, charter boat operators, recreational fishers) and longline fishers.

A Vessel Monitoring System (VMS) is used to enforce the two longline exclusion zones. Other enforcement methods include U.S. Coast Guard at-sea surveillance, boardings, and overflights.

The directed swordfish fishing grounds for 1991 through 1994 are presented in Figure 3.10.3-14. Compared to the tuna grounds shown in Figures 3.10.3-11 to 3.10.3-13, grounds for yellowfin tuna, bigeye tuna, and swordfish overlap significantly. Those vessels targeting swordfish focus primarily on the area to the northeast of the Hawaiian Islands. Note that Figure 3.10.3-14 represents swordfish landings by all Hawaii longliners not just those vessels that had swordfish or mixed target effort.

Figure 3.10.3-14: Swordfish Catch (kg) by Quarter, Average for 1991-1994. Source: Curran *et al.*, 1996.



Swordfish are targeted in areas of rapid change in sea surface temperature. During the 1991 to 1994 period (Figure 3.10.3-14), fishing during the first two quarters took place primarily north of the MHI in a broad swath. During the last two quarters it occurred over an even broader area, and catch rates from any one area were lower. In more recent years swordfish have been caught east of the MHI by longliners working the grounds on their way to Hawai'i from California. However, most swordfish fishing now occurs in the North Pacific transition zone (R. Ito, pers. comm., February 2001).

Seasons

Hawai'i-based longline fishing effortfor swordfish is seasonal. Trip activity for swordfish and mixed trips is highest in the first and second quarters and substantially lower in the third and fourt quarters (R. Ito, pers. comm., February 2001). The numbers set in the first, second, and fourth quarters are about equal, with each representing about 27.5 percent of the total sets made each year. During the third quarter, fishers schedule maintenance work, and some go east to fish off the U.S. mainland coast (Curran *et al.*, 1996).

Participants

Most of the swordfish and mixed trip vessels are homeported in Honolulu, as are most of the crew. A number of these vessels and crew came from the Gulf of Mexico and East coast fisheries in the early 1990s when it appeared that the longline fishery off Hawai'i was more promising and the fisheries off the East coast and in the Gulf. In addition, East coast fisheries were more regulated in comparison to Hawai'i fisheries; thus a move into the region was seen as promising because of the less constraining regulatory environment. In recent years increasing numbers of Hawai'i-based longliners ave fished outside the EEZ off California/Mexico in the winter.

Most of the shallow-setting longliners were owned by Vietnamese and do not have line-shooters. Therefore, Vietnamese operators are more likely to target swordfish or swordfish tunas.

Between 1993 and 1999 the number of trips by vessels targeting swordfish and mixed species decreased from 650 to 361 respectively. Many East coast swordfish vessels left the Hawai'i-based longline fishery in 1994 and the Gulf of Mexico six vessels that made up part of the fleet became more proficient at targeting swordfish (Ito 1995). Based on ethnicity information from the two surveys, it is apparent that the East coast boats targeting swordfish were owned and operated by Caucasians, and the Gulf vessels remaining in the fishery were owned and operated by Vietnamese.

Of the Vietnamese-owned vessels, about 20 percent are owner-operated, although almost every vessel in this subfleet has at least one member of the owner's family onboard (Dang, pers. comm.). About 20 percent of the crewmembers on Vietnamese- and Korean-owned longline vessels are related to the vessel's owner (Dang, pers. comm.).

Other Fisheries for These Vessels

A fleet of longliners that target swordfish operates out of ports in southern California. As reported in Cousins *et al.* (2000), these vessels range in size from 15 to 30 meters. When the swordfish fishing slows around Hawai'i in midwinter a number of longliners from Hawai'i travel to California and continue fishing. They target grounds further east than they can reach from Hawai'i during this period. Then as the fishing improves to the west, they

ultimately move back to Hawai'i. This portion of the Hawai'i-based longline fleet completes logbooks when operating from California but is not required to carry observers unless they disembark in Hawai'i.

In the latter part of 1997, 15 longline vessels migrated to California and fished mainly swordfish for the remainder of the year. The number of Hawai'i-based longline vessels migrating to California increased slightly in 1998 (WPRFMC, 1999d). There were 18 Hawai'i-based longline vessels that transited to California in the latter part of 1998 (Ito and Machado, 1999). Six East Coast vessels returned in 1998 but switched from targeting swordfish to tuna (Ito & Machado, 1999). In 1999,over 30 Hawai'i-based longliners fished out of California (NMFS, 2000e; Dang, pers. comm.).

3.10.3.1.3 Catch and Landings Data

This section shows combined data for all longliners operating out of Hawai'i. The 114 active longline vessels in 1998 landed 28.6 million pounds of billfish, tuna, sharks, and other species. The greatest landings were for swordfish (7.2 million pounds), followed by bigeye tuna (7.1 million pounds). This volume included 43,776 individual swordfish and 98,795 individual bigeye tuna. There were 99,919 sharks, of which more than 90 percent of which were blue sharks. Most of the sharks were caught outside the U.S. EEZ.

Total Landings

The Hawai'i-based longline landings trip types and combined, is presented for 1991 to 1998 in Tables 3.10.3-7 through 3.10.3-11. Tables 3.10.3-7 and 3.10.3-8 show total landings by the longline fishery. The largest swordfish landings were in the early 1990s and declined substantially in 1994. After 1994 landings were relatively constant. Striped marlin landings were highest in 1991. Blue marlin landings were highest in 1995. Landings of other billfish varied throughout the years. Landings of bigeye increased more or less consistently, with 1998 being a record year. Albacore landings were less than one million pounds prior to 1993 and peaked in 1997 at 3.6 million pounds. Yellowfin tuna landings varied annually between 0.6 million and 2.5 million pounds. Skipjack tuna landings peaked in 1988 at 4.1 million pounds and ranged between 1.2 million and 2.6 million pounds after 1990. Small amounts of highly valued bluefin tuna were not landed until 1992, and the greatest volume landed was 60,000 pounds in 1995.

Table 3.10.3-7: Hawai'i-based Longline Billfish Landings – (Including Swordfish), 1987-1998. Source: Data were compiled from federal logbooks and market monitoring information by NMFS SWFSC-HL and HDAR staff, *in* WPRFMC, 1999d.

Year	Pounds Landed (Thousands)			
	Blue Marlin	Striped Marlin	Swordfish	Other Billfish
1987	100	600	50	100
1988	200	1,100	50	200
1989	800	1,300	600	300
1990	800	1,100	4,190	100
1991	700	1,500	10,100	400
1992	800	1,000	12,600	300
1993	800	1,040	13,100	220
1994	800	720	7,000	220
1995	1,280	1,200	6,010	410
1996	1,030	920	5,520	260
1997	1,070	780	6,350	320
1998	870	830	7,190	380
Average	**761**	**1,024**	**6,001**	**275**

Table 3.10.3-8: Hawai'i-based Longline Landings of Tuna Species, 1987-1998. Source: Data were compiled from federal logbooks and market monitoring information by NMFS SMFSC-HL and HDAR staff. P8798N.xls (22 April 1999) *in* WPRFMC, 1999d; and Ito, pers. comm., March 2001.

Year	Pounds Landed (Thousands)		
	Albacore	Bigeye	Yellowfin
1987	300	1,800	600
1988	700	2,700	1,300
1989	600	3,100	2,200
1990	400	3,020	2,230
1991	690	3,400	1,620
1992	730	3,280	760
1993	970	4,660	1,390
1994	1,100	3,940	1,340
1995	1,930	4,580	2,150
1996	2,610	3,950	1,390
1997	3,620	5,400	2,520
1998	2,450	7,110	1,590
Average	**1,342**	**3,912**	**1,591**

Table 3.10.3-9 presents the mean whole weight of individual fish for the three main target categories for longline fisheries collected from the Honolulu fish auction. The tuna fishery consistently landed smaller billfish and tuna, in comparison to swordfish and mixed trips.

Table 3.10.3-10 presents the numbers of fish caught by area for 1997 and 1998. The table also includes comparative references for number of trips, hooks, hooks per trip, and lightsticks. More trips were taken outside the EEZs than inside the EEZs, with more hooks per trip and a greater number of total hooks outside of the EEZ. Hook data are presented to provide some measure of level of effort.Species composition is also affected by the area fished (Figure 3.10.3-7). Vessels fishing in the EEZs of U.S. possessions have higher landings of bigeye tuna than those fishing within the MHI, NWHI, or outside the EEZ. The 1998 swordfish landings were highest outside the EEZ and NWHI EEZ, and lowest in the EEZs of the U.S. possessions and MHI EEZ.

The catch per thousand hooks set, or catch per unit effort (CPUE), varies by year. Table 3.10.3-11 presents that information by trip type and fleet total for the years 1991 through 1998. The CPUE for bigeye and albacore by targeted tuna vessels appears to be trending up from 1992 through 1998, while CPUE for yellowfin stayed relative constant from 1991 through 1998. The CPUE for swordfish in swordfish trips declilned from 1991 through 1994 and have increased since then. There is no readily discernible trend in CPUE for other major

species by swordfish target vessels. Mixed trip CPUE for swordfish increased dramatically from 1991 through 1993, declined in 1994 and have since increased through 1998. Figure 3.10.3-15 presents 1998 species composition by target species.

Table 3.10.3-9: Whole Weight of Individual Fish, in Pounds, by Trip Type, 1997-1998. Source: Ito and Machado, 1999.

Year	Billfish (lb)			Tunas (lb)				Miscellaneous (lb)				
	Swordfish	Blue Marlin	Striped Marlin	Bigeye Tuna	Yellowfin Tuna	Albacore	Bluefin Tuna	Mahimahi	Ono	Moonfish	Mako	Thresher
Swordfish Trips												
1991	165.1	185.6	71.6	96.8	123.6	44.1	164.3	15.0	35.3	103.5	107.2	173.2
1992	192.7	277.7	83.4	94.6	101.4	37.5	194.6	10.4	36.5	77.5	130.5	235.0
1993	180.2	173.6	78.4	83.3	92.8	34.4	183.7	13.0	36.4	99.5	141.3	260.6
1994	173.3	202.1	83.6	94.7	94.7	34.2	205.2	10.6	40.1	76.0	118.5	195.8
1995	184.8	151.9	79.9	93	102.4	37	176.3	7.8	34.2	80.3	140.5	---
1996	169.2	239.1	81.7	110.5	108.9	48.6	225	18.8	37.7	88	233	---
1997	167.0	108.3	96.9	85.1	107.5	43.3	236.5	12.2	36.4	101.8	74.2	---
1998	182.4	148.0	109.4	97.7	113.3	47.5	230	13.5	39.0	76.0	123	---
Tuna Trips												
1991	82.7	152.7	51.0	76.5	87.9	57.9	---	14.9	31.2	97.2	154.6	188.0
1992	77.3	144.0	59.0	71.4	68.8	56.0	159.0	13.9	33.8	98.9	157.9	157.3
1993	121.1	145.2	58.8	84.0	87.0	57.5	219.7	13.1	31.7	101.2	152.9	188.7
1994	90.7	156.7	59.6	77.4	81.2	48.9	247.0	12.1	33.7	103.5	176.2	166.9
1995	124.3	151.6	55.8	74.7	77.3	51.4	342.0	11.9	30.2	100.9	181.6	176.0
1996	144.0	143.1	56.4	64.1	63.7	53.0	200.8	15.5	30.8	104.9	172.9	194.1
1997	167.7	133.5	60.7	68.9	75.4	55.2	---	13.5	28.7	103	165.6	156.3
1998	125.7	146.6	55.7	71.3	69.9	56.0	---	16.1	32.0	101.4	175.4	166.2
Mixed Trips												
1991	142.4	186.5	66.0	91.5	132.2	49.0	191.7	14.7	33.7	96.4	148	177.5
1992	162.4	178.0	81.2	80.6	119.8	44.6	191.8	10.4	39.0	99.5	139.7	192.5
1993	158.4	169.0	74.5	99.8	106.5	36.4	217.1	12.6	36.9	113	141.9	208.8
1994	118.7	174.6	67.6	93.5	128.5	57.2	153.5	12.4	38.6	96.0	141.5	148.4
1995	161.3	168.7	63.8	91.3	125.4	46.2	223.6	9.2	34.2	93.6	172.9	136.5
1996	151.2	164.7	62.4	58.1	113.0	51.4	249.0	17.4	33.1	94.8	174	127.4
1997	160.1	136.8	77.8	83.7	115.2	48.4	240.6	11.9	33.9	100.7	160.4	173.4
1998	175.8	205.7	73.6	83.3	97.2	50.2	163.3	16.1	33.0	91.5	199.8	187.8

Table 3.10.3-10: Hawai'i-based Longline Catch (Number of Fish Caught) by Area Fished,[19] 1997-1998. Source: NMFS longline logbook summaries (LLCS 22 April 1999), *in* WPRFMC, 1999d.

Species	1997				1998			
	All Locations	MHI EEZ	NWHI EEZ	Outside of U.S. EEZs	All Locations	MHI EEZ	NWHI EEZ	Outside of U.S. EEZs
Blue Marlin	8,255	4,085	1,519	2,457	5,350	1,698	1,217	2,125
Striped Marlin	12,637	4,193	4,109	4,080	14,347	4,856	5,757	3,408
Swordfish	39,682	4,873	5,148	29,627	43,776	4,721	10,611	28,269
Mahimahi	49,319	11,660	6,321	30,730	22,183	7,664	3,527	10,157
Moonfish	8,254	2,847	2,887	2,314	9,184	3,585	1,862	3,462
Ono (wahoo)	8,312	2,525	1,789	3,668	8,281	2,305	761	4,068
Sharks	85,838	16,476	17,921	49,935	99,919	14,685	20,152	59,180
Albacore	71,084	19,025	17,118	30,887	48,833	12,482	6,802	25,621
Bigeye Tuna	79,784	21,397	30,168	26,149	98,795	26,723	16,629	37,762
Yellowfin Tuna	29,045	10,982	5,139	10,990	21,721	4,678	2,713	8,004
Trips[20]	**1,162**	**687**	**390**	**660**	**1,181**	**581**	**305**	**734**
Hooks (1,000s)	**15,564**	**5,057**	**4,096**	**5,969**	**17,366**	**4,970**	**3,095**	**7,362**
Hooks per Trip	**13,394**	**7,361**	**10,502**	**9,044**	**14,704**	**8,554**	**10,148**	**10,030**
Lightsticks (1,000s)	**879**	**132**	**128**	**619**	**1,224**	**99**	**310**	**814**

[19] Only the three areas with the largest catches are included in this table. The balance would include catches in U.S. possessions or catches where locations were not verified.

Total trips are not additive across areas because trips may intersect more than one area. Totals may also differ between tables because of different data compilation dates.
MHI: Main Hawaiian Islands NWHI: Northwestern Hawaiian Islands EEZ: Exclusive Economic (200 mile) Zone

Table 3.10.3-11: Hawai'i-based Longline Catch-per-unit-effort (Number of Fish per Thousand Hooks) by Trip Type, 1991-1998. Source: Ito and Machado, 1999.

Year	Billfish (No. of Fish per 1000 Hooks)				Tunas (No. of Fish per 1000 Hooks)		Miscellaneous (No. of Fish per 1000 Hooks)				
	Swordfish	Blue Marlin	Striped Marlin	Other Billfish	Bigeye Tuna	Yellowfin Tuna	Albacore	Mahimahi	Ono	Moonfish	Sharks
Fleet Mean											
1991	5.38	–	–	–	3.32	1.08	1.14	3.21	0.22	0.25	5.77
1992	6.34	0.39	1.37	0.48	3.75	0.67	1.69	4.84	0.21	0.28	8.10
1993	6.11	0.39	1.4	0.43	4.21	1.23	2.34	2.00	0.34	0.35	11.87
1994	3.61	0.39	0.94	0.43	4.01	1.13	2.59	2.75	0.21	0.42	9.56
1995	2.64	0.62	1.59	0.83	4.22	1.67	3.23	4.22	0.46	0.45	7.14
1996	2.65	0.46	1.10	0.54	4.41	1.22	3.98	1.62	0.31	0.51	7.01
1997	2.55	0.53	0.81	0.58	5.13	1.87	4.57	3.17	0.53	0.53	5.52
1998	2.52	0.31	0.83	0.66	5.69	1.25	2.81	1.28	0.48	0.53	5.75
Swordfish Trips											
1991	15.36	–	–	–	2.29	0.79	1.53	3.62	0.06	0.02	15.94
1992	14.76	0.20	0.78	0.13	1.61	0.46	3.09	4.78	0.06	0.03	19.74
1993	13.03	0.29	1.01	0.19	2.42	0.68	3.85	2.33	0.13	0.03	26.65
1994	10.34	0.21	0.45	0.08	1.01	0.41	4.48	2.62	0.04	0.01	23.43
1995	12.87	0.65	0.69	0.16	2.35	1.13	5.52	6.76	0.16	0.02	27.58
1996	14.17	0.19	0.50	0.14	1.43	0.71	5.79	2.26	0.23	0.04	25.52
1997	15.41	0.39	0.58	0.17	3.13	1.87	2.87	10.24	0.29	0.01	14.2
1998	14.5	0.29	0.42	0.07	2.33	0.75	2.45	1.53	0.12	0.01	23.01

Table 3.10.3-11: (continued)

Year	Billfish (No. of Fish per 1000 Hooks)				Tunas (No. of Fish per 1000 Hooks)			Miscellaneous (No. of Fish per 1000 Hooks)			
	Swordfish	Blue Marlin	Striped Marlin	Other Billfish	Bigeye Tuna	Yellowfin Tuna	Albacore	Mahimahi	Ono	Moonfish	Sharks
					Tuna Trips						
1991	0.41	–	–	–	3.7	0.7	1.12	2.18	0.39	0.53	1.71
1992	0.27	0.37	2.15	0.72	4.74	0.53	0.86	1.67	0.34	0.59	2.4
1993	0.21	0.41	1.84	0.66	4.68	1.48	1.6	1.51	0.55	0.68	2.56
1994	0.16	0.29	1.24	0.62	5.52	1.16	2.03	2.03	0.32	0.71	2.22
1995	0.22	0.49	1.76	0.98	4.39	1.42	3.19	2.38	0.57	0.6	2.83
1996	0.17	0.38	1.17	0.64	4.73	1.13	3.98	1.03	0.36	0.68	2.9
1997	0.14	0.41	0.75	0.67	5.68	1.57	5.05	1.46	0.59	0.66	2.68
1998	0.2	0.25	0.85	0.75	6.13	1.28	3.02	0.84	0.55	0.67	3.09
					Mixed Trips						
1991	5.84	–	–	–	3.41	1.64	0.97	4.13	0.12	0.05	5.16
1992	8.6	0.56	0.71	0.42	3.96	1.04	1.81	9.43	0.14	0.02	7.33
1993	10.39	0.49	0.9	0.28	5.51	1.41	2	2.66	0.15	0.01	13.5
1994	4.12	1.3	0.71	0.37	3.92	2.69	0.8	6.56	0.06	0.02	11.64
1995	6.52	1.16	1.43	0.62	4.67	3	2.02	10.22	0.21	0.08	12.74
1996	7.56	0.84	1.02	0.35	4.26	1.68	3.45	3.42	0.16	0.08	15.3
1997	9.96	1.16	1.17	0.28	3.12	3.3	2.77	9.11	0.35	0.06	16.37
1998	9.22	0.58	0.87	0.44	4.81	1.29	1.95	3.25	0.27	0.04	12.16

Figure 3.10.3-15 presents 1998 species composition by number of fish for trips targeting tuna. These trips resulted in an average of 31.4 percent bigeye tuna with an incidental catch of one percent swordfish and bycatch of 15.8 percent sharks. This compares to bigeye catch of 5.1 percent and 13.6 percent on swordfish and mixed targeted trips, respectively (Figure 3.10.3-16). Swordfish targeted trips caught a higher percentage of sharks than mixed target trips and a slightly higher percentage of swordfish. While the area fished influences catch composition, it is a primary indicator, by season, of target species. The catch of bigeye tuna was higher for vessels fishing in EEZs of U.S. possessions than for those fishing within the MHI, within the NWHI, or outside the EEZ.

Figure 3.10.3-15: Targeted Tuna Species Composition by Trips: Percentage of Number of Fish by Species, 1998. Source: Ito and Machado, 1999.

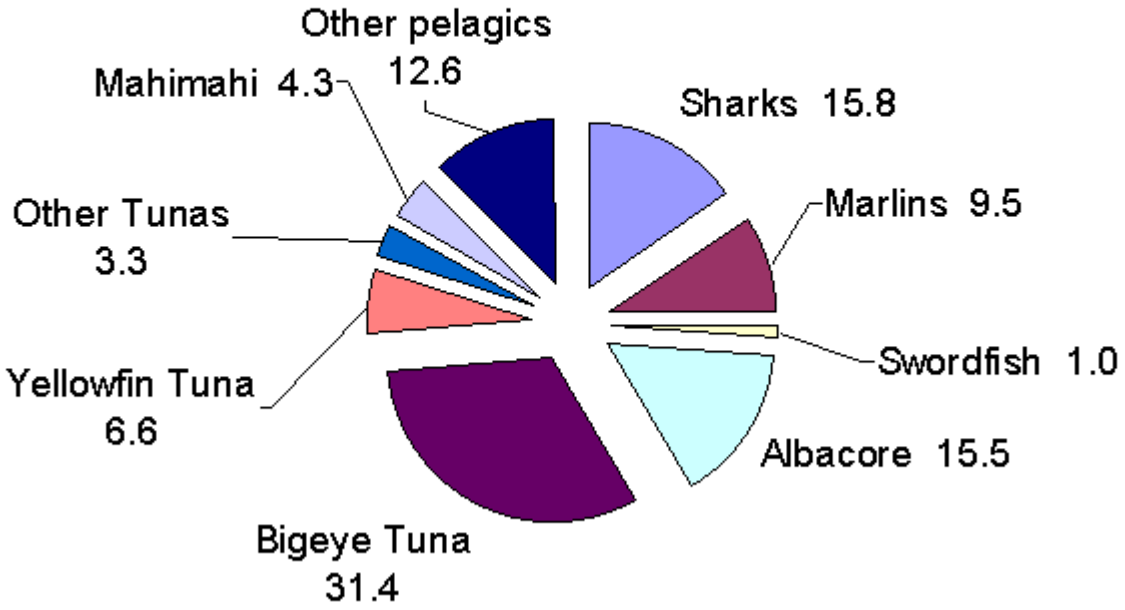
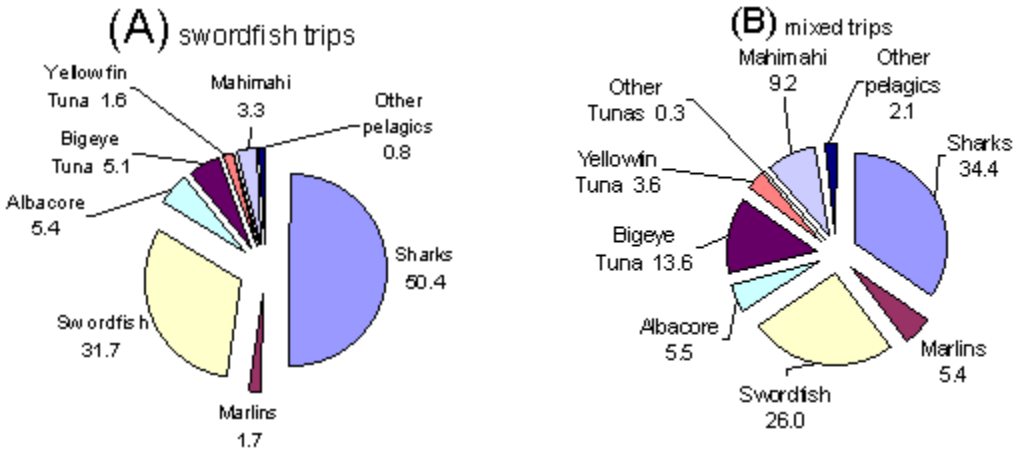


Figure 3.10.3-16: Targeted (A) Swordfish Trips and (B) Mixed Trips: Percentage of Number of Fish Caught by Species, 1998. Source: Ito and Machado, 1999.



Incidental Catch of Shark

The major incidental species in the swordfish and mixed target fisheries is sharks. The CPUE for sharks in both swordfish and mixed target trips is higher than for any other species (See Table 3.10.3-11). It should be noted that the current high levels of shark landings in recent years are likely to decline significantly because of bans on shark finning approved by the U.S. Congress and the State of Hawai'i Legislature in 2000. The historic data are presented in this subsection concerning sharks to reflect the recent past and are taken from Amendment 9 to the Pelagics FMP (WPRFMC, 2000b).

As FMP Amendment 9 pointed out (WPRFMC, 2000b), one aspect of shark biology that has direct relevance to fisheries is the high level of urea (or more generally, non-protein nitrogen [NPN] compounds) in the flesh because of sharks' primitive excretory and osmoregulatory system. This factor makes handling, processing, and storing sharks difficult. NPN compounds give the flesh an unpleasant flavor, and many shark species have to be specially processed to rapidly remove the compounds. These compounds also contribute to rapid spoilage. Blue sharks are particularly high in NPN compounds and thus there are limitations on their marketability. For example, blue sharks can be held on ice for no more than about five days.

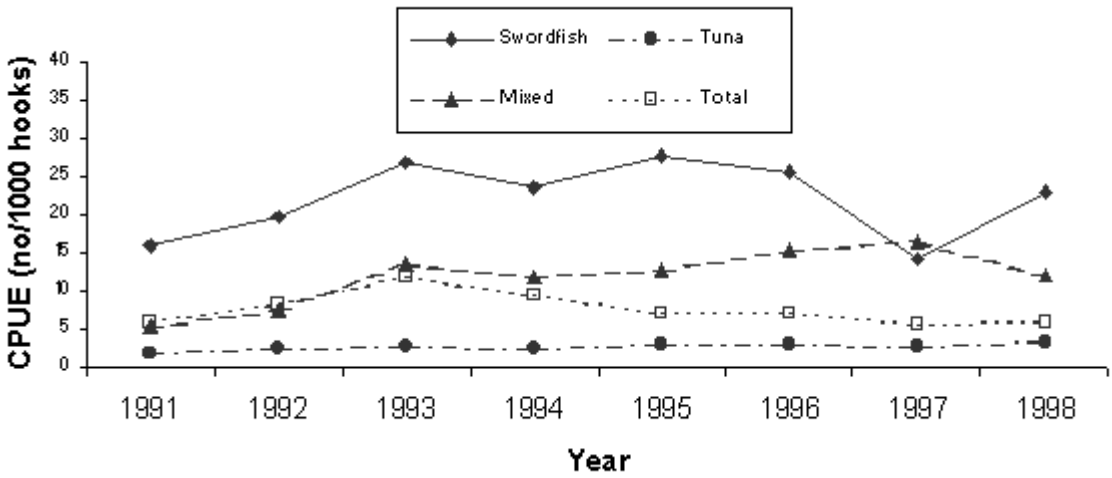
Table 3.10.3-12 lists all shark species caught in 1994-1999, based on logbook data. Although absolute catches cannot be accurately determined from these data (because observer effort does not match actual fleet effort), it is safe to say that the great majority of sharks observed are all blue sharks – 94 percent based on these data.

Table 3.10.3-12: Observed Shark Species and Reported (Logbook) Catches, Average Number and Percent Total, 1994-1999. Source: WPRFMC, 2000b.

Common Name	Latin Name	Number	Percent
Blue shark	*Prionace glauca*	94,504	94.00
Oceanic whitetip	*Carcharhinus longimanus*		
Other (unidentified) sharks		2,457	2.44
Smooth hammerhead	*Sphyrna zygaena*		
Scalloped hammerhead	*Sphyrna lewini*		
Unid hammerhead	*Sphyrna spp.*		
Tiger	*Galeocerdo cuvier*		
Galapagos	*Carcharhinus galapagensis*		
Dusky	*Carcharhinus obscurus*		
White	*Carcharodon carcharias*		
Bigeye thresher	*Alopias superciliosus*		
Pelagic thresher	*Alopias pelagicus*		
Common thresher	*Alopias vulpinus*		
Unid. thresher	*Alopias spp.*		
Thresher sharks		2,266	2.25
Shortfin mako	*Isurus oxyrinchus*		
Longfin mako	*Isurus paucus*		
Unid. mako	*Isurus spp.*		
Mako sharks		1,313	1.31
Crocodile shark	*Pseudocarcharias kamoharai*		
Salmon shark	*Lamna ditropis*		
Silky shark	*Carcharhinus falciformis*		
Sandbar	*Carcharhinus plumbeus*		
Cookie cutter	*Isitius plodius* (or *brasiliensis*)		
Bignose	*Carcharhinus altimus*		
Total		**100,539**	**100.00**

Figure 3.10.3-17 shows blue shark CPUE trends as reported for the Hawai'i-based longline fishery for 1991-1998. Overall, there was a decline in aggregate blue shark CPUE during this period. However, the apparent decline is misleading because mainly it is due to a shift in effort away from swordfish target, where blue shark catch rates are higher, relative to tuna-targeted trips. Blue shark catch rates by trip type, show no obvious declining trends for CPUE (Figure 3.10.3-17).

Figure 3.10.3-17: Annual Catch Rates of Blue Sharks in the Hawai'i-based Longline Fishery by Trip Type, 1991-1998. Source: WPRFMC, 2000b.



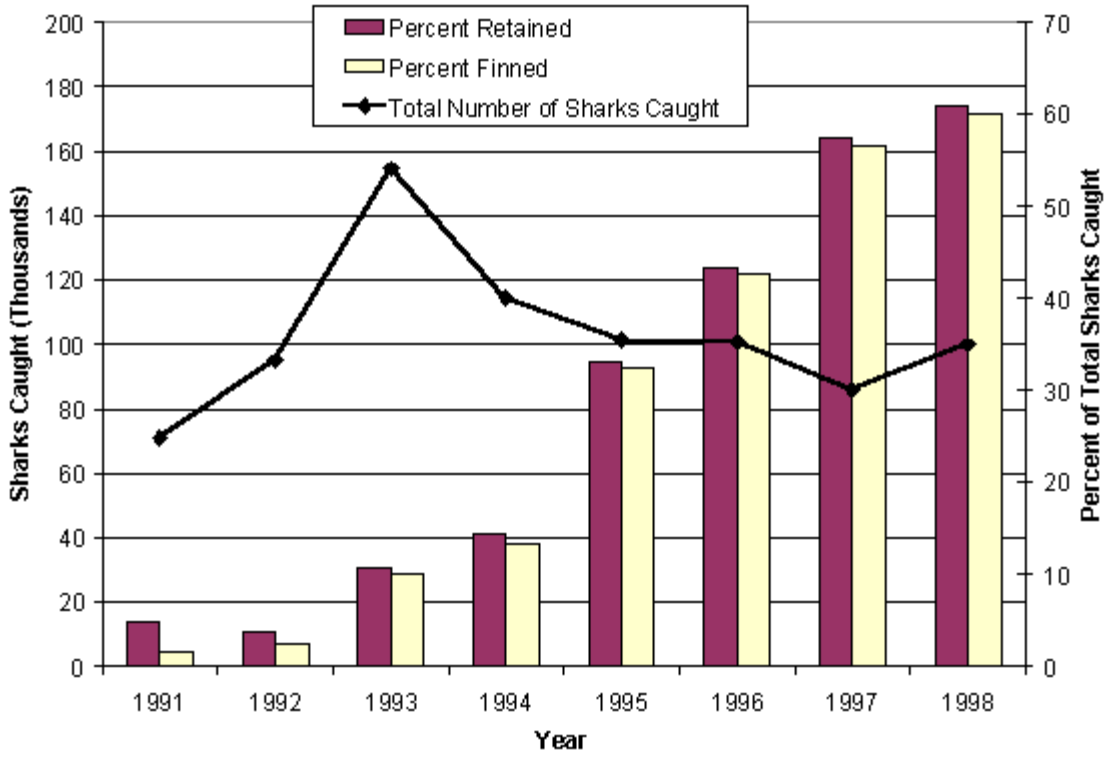
The nature of fishing operations, changes in strategy dictated by the target species' resource status, and the status of market demand for both target species and shark products influence the number of sharks caught and the number retained. The fishing strategy differs for swordfish and tuna trips and the difference has relevance for shark incidental catch (Bigelow *et al.*, 1999 *in* WPRFMC, 2000b). Swordfish sets are shallow, while tuna sets are deeper. In addition, some vessels use stainless steel wire leaders while others use monofilament. Depth of set affects species composition of shark incidental catch[21], and wire leaders result in higher capture rates (because sharks are less likely to bite through the leader and escape). Swordfish vessels use monofilament leaders but have high blue shark catch, while tuna vessels use wire leaders but have low shark CPUE. Overall, shark CPUE is about ten times higher in sets targeting swordfish than in tuna-targeted trips (see Figure 3.10.3-17). Aside from depth of set, this higher catch rate in contrast to tuna fishing rates may be due to the fact that swordfish fishing occurs at generally higher latitudes, where blue shark are more abundant, in contrast to tuna fishing. Nonetheless, a higher percentage of sharks were actually finned on trips where tuna were targeted: about 85 percent, compared to 48 percent for swordfish target trips, and 40 percent for mixed trips in which sets were made for both tuna and swordfish.

The number of sharks finned increased up until it was banned under Hawai'i state law in 2000, and by an act of the U.S. Congress in December 2000. While the total number of

[21] Matsunaga and Nakano (1999), analyzing historic catches of sharks aboard Japanese research and training longline vessels, found that oceanic whitetip and silky sharks were more commonly caught in shallow sets. However, the researchers found no difference in CPUE for shallow and deep sets for blue sharks, and the CPUE of thresher sharks was greater on deep sets than on shallow sets (NMFS, 2000j).

sharks caught in the longline fishery remained relatively constant over the five years from 1994 to 1998 (see Figure 3.10.3-18), the number landed (predominantly finned) increased substantially, from 2,289 in 1992 to 60,857 (of which 60,083 were finned and 774 retained whole) in 1998 (Ito and Machado, 1999). Because of prohibitions on U.S. vessels the landings of sharks, particularly blue shark by Hawaii-based longliners is expected to decline dramatically.

Figure 3.10.3-18: Annual Shark Catch and Disposition in the Hawai'i-based Longline Fishery. Source: Ito and Machado *in* WPRFMC, 2000b.



During fishing operations a mix of factors contributed to a decision to retain a shark. Particularly active or "green" sharks may be cut loose, or a skipper may decide that the attention given to boating and processing shark is interfering with proper handling of target species fish. Broader marketbo factors, specifically an increase in demand for shark fins in the early 1990s, contributed to the large increase in the number of fins retained. In Hawai'i a small and apparently static market exists for meat from mako and thresher sharks. However, blue sharks represent approximately 95 percent of the shark catch for the fleet. Because of the physical characteristics and market value of this species, only the fins were retained. The increase in the number of fins retained came primarily from blue sharks. Since blue shark meat cannot be kept for more than a few days (given the practice of using ice), and no local market exists, there has been no corresponding increase in the number of blue sharks retained for its flesh (WPRFMC, 2000b). In the future the ban on shark-finning is likely to lead fishermen to release blue sharks before they bring them on board.

Hawai'i-based longliners retain only thresher and mako shark carcasses for sale as fresh fish. This is the case due to ease of handling and market demands. Sharks are delivered as a whole carcass or fins. According to logbook data, 471 mako and 145 thresher sharks were kept by the fleet in 1998. NMFS data, as reported in McCoy and Ishihara (1999) estimated that this number would amount to a total dressed weight of around 31,500 kg, valued at $42,000.

One vessel operator targeted sharks with bottom longline gear during 1998 and 1999 (WPRFMC, 2000b). Although the operator was not actually finning, it was this activity that precipitated a public process resulting in passage of Pelagics FMP Amendment 9, which included a definition of bottom longlining and prohibit its use for PMUS, which includes many of the coastal sharks. Based on reports from one of the bottom longline trips in 1999, blue sharks were not caught and there was little bycatch. The vessel landed small sharks in a headed and gutted form, brought in fillets from larger sharks and fins from various species, and also landed jaws, hides, and gall bladders from tiger sharks. One of the measures of that amendment was to define bottom longline and prohibit its use for PMUS, which includes many of the coastal sharks.

Foreign high-seas longliners operating in the North Pacific have been transshipping shark fins through Hawai'i for most of this decade. While vessels are from Japan, Korea, and Taiwan, most transshipments are made by Korean ultra-low temperature longliners. These vessels stay out at sea for months at a time, freezing *sashimi*-grade bigeye tuna. Fish are periodically transferred at sea to refrigerated carrier vessels (or "reefers"). The fishing vessels are also re-supplied with fuel and provisions at sea by tankers. These tankers pull into Honolulu to purchase fuel and supplies, providing a convenient mechanism for the transshipment of shark fins. The tanker captains purchase shark fins from the high-seas longliners they service. U.S.-flagged vessels, including some Hawai'i-based longliners, are contracted on a casual basis to transport fins from tankers to Honolulu. Typically, these vessels meet the tanker as it heads into Honolulu and receive the cargo in international waters. As reported in WPacFIN, five Hawai'i-based longline vessels with limited entry permits were contracted to receive shark fins from foreign tankers outside the EEZ in 1996, up from three vessels in 1995.

Landed Weight

The total landings by species by overall fleet total for 1987 to 1998 are presented in Table 3.10.3-13. Swordfish landings were relatively constant after 1994, as were landings of yellowfin and bluefin tuna. Shark landings increases dramatically during the period. Bigeye tuna showed a large increase in landings in the last two years. Shark data were primarily extrapolated.

The most significant characteristic of the Hawai'i-based fleet's operation is that catch is iced because the market demand is for fresh rather than frozen fish. Combined with the relatively small vessel size (vessels longer than 101 ft are not allowed in the fishery to limit

fishing capacity), the need to deliver iced product imposes significant constraints on these vessels in processing, storing, and preserving non-target species (WPRFMC, 2000b).

Landed Ex-vessel Value

The gross revenue generated by the longline fisheries has been fairly constant in recent years (Table 3.10.3-14). In 1987-1998, the overall annual ex-vessel revenues for many species, including swordfish, other billfish, yellowfin tuna, and *mahimahi* all decreased. Only the annual gross revenues from sharks and bigeye showed increases[22].

The price received per pound decreased for many species in 1987-1998 (Table 3.10.3-15), especially in 1998. During 1998 the prices for swordfish, bigeye tuna, yellowfin tuna, bluefin tuna, and thresher shark were the lowest since 1989. Ex-vessel prices for several species in 1970-1998 are shown in Figure 3.10.3-19.

The inflation-adjusted value of the combined longline landings is presented in Table 3.10.3-16. These values were adjusted for the Honolulu CPI, which is a better measure of local inflation than the national average. The value in 1998 was about the same as for the previous four years when adjusted for inflation. The fishery produced its highest real (inflation adjusted) ex-vessel value from 1991 to 1993. These values were much lower in the late 1980s.

[22] Note: Longline landings and ex-vessel gross revenue estimates were compiled by the NMFS SWFSC-HL. They represent weight estimates using federal logbooks (since 1991) and monitoring of average weight per fish and average price per pound at the market. From 1987 to 1990, estimates rely on NMFS shoreside and market monitoring (WPRFMC, 1999d).

Table 3.10.3-13: Hawai'i-based Longline Fleet Landings (Thousands of Pounds) of Selected Pelagic Species, 1987 to 1998. Source: Ito and Machado, 1999.

Year	Billfish (Thousand lb)				Tunas (Thousand lb)				Miscellaneous (Thousand lb)			
	Swordfish	Blue Marlin	Striped Marlin	Other Marlin	Bigeye	Yellowfin	Albacore	Bluefin	Mahimahi	Ono	Moonfish	Sharks
1987	50	110	600	100	1,790	580	330	–	50	50	150	40
1988	50	230	1,110	150	2,740	1,310	680	–	40	90	180	100
1989	620	770	1,340	290	3,140	2,160	550	–	180	200	270	200
1990	4,190	760	1,100	120	3,020	2,230	370	–	350	70	250	200
1991	10,120	660	1,500	350	3,420	1,620	690	–	520	110	510	290
1992	12,570	760	1,010	300	3,280	760	730	20	590	90	320	420
1993	13,100	750	1,040	220	4,660	1,390	970	90	320	140	450	1,740
1994	7,000	800	720	220	3,940	1,340	1,100	40	380	90	520	1,720
1995	6,010	1,280	1,200	410	4,580	2,150	1,930	60	570	200	630	3,490
1996	5,520	1,030	920	260	3,950	1,390	2,610	50	370	140	760	4,300
1997	6,350	1,070	780	320	5,400	2,520	3,620	50	520	240	820	5,010
1998	7,190	870	830	380	7,110	1,590	2,450	40	340	260	920	6,000

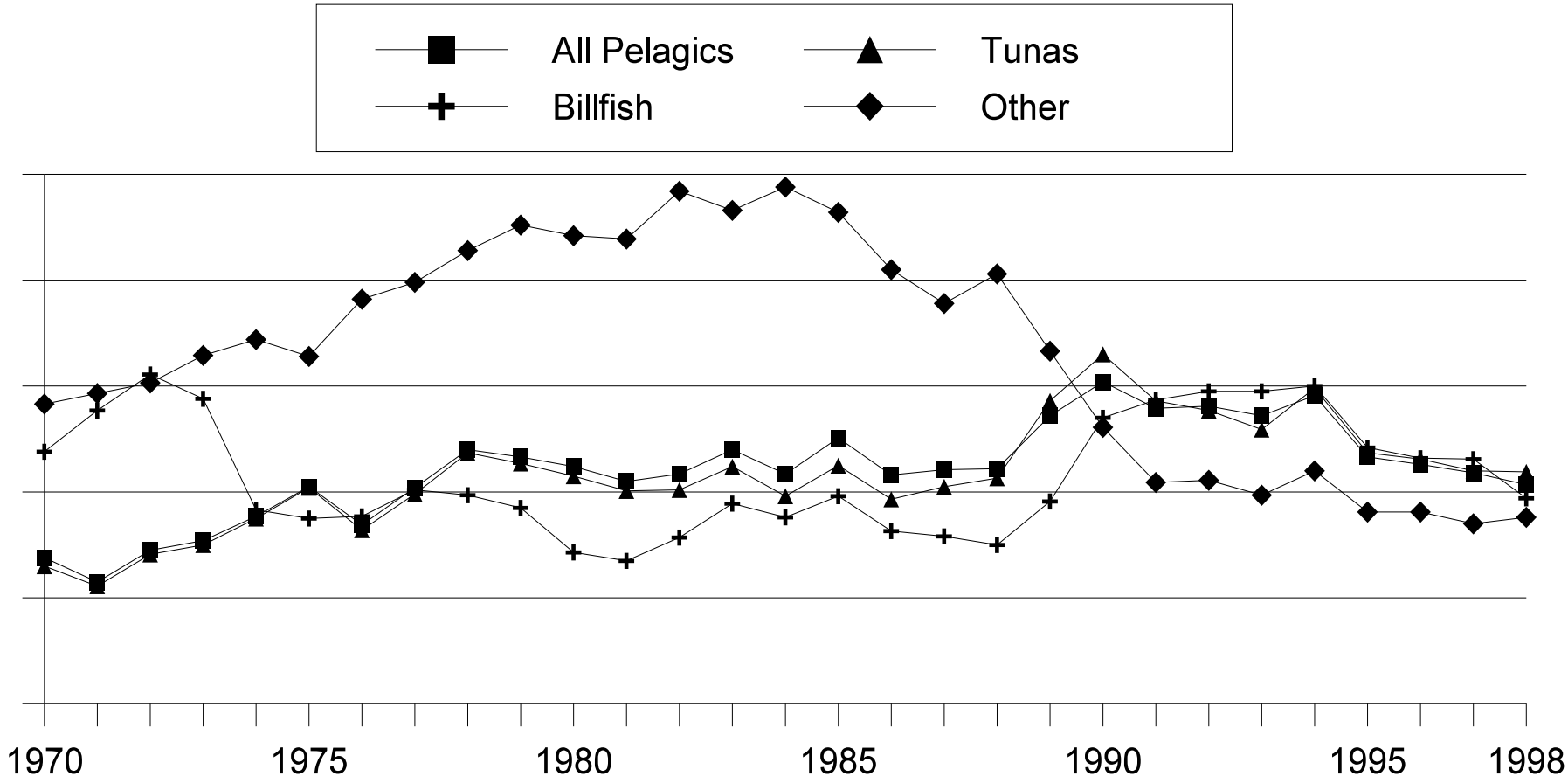
Table 3.10.3-14: Hawai'i-based Longline Fleet Ex-vessel Gross Revenue ($Thousands) by Species, 1987 to 1998. Source: Ito and Machado, 1999.

Year	Billfish ($Thousands)				Tunas ($Thousands)				Miscellaneous ($Thousands)			
	Swordfish	Blue Marlin	Striped Marlin	Other Marlin	Bigeye	Yellowfin	Albacore	Bluefin	Mahimahi	Ono	Moonfish	Sharks
1987	170	140	810	240	6,510	1,500	520	–	100	150	240	60
1988	160	190	1,200	260	9,160	3,270	910	–	110	240	270	100
1989	1,130	640	1,370	290	10,640	5,070	710	–	400	450	350	100
1990	9,710	710	1,530	160	10,940	5,750	550	–	590	200	330	120
1991	21,450	510	1,490	320	12,760	4,440	910	40	670	230	590	170
1992	24,130	880	1,280	310	11,710	2,210	910	260	830	220	350	220
1993	26,590	640	1,070	200	16,640	3,810	1,170	1,330	440	270	390	510
1994	16,240	1,020	1,220	290	14,620	3,910	1,360	680	540	240	570	500
1995	13,460	1,110	1,080	300	15,340	6,110	2,080	980	810	330	600	860
1996	13,740	1,030	1,140	230	14,140	4,250	3,390	880	760	300	810	1,780
1997	14,040	910	980	310	17,390	6,740	4,450	810	640	370	940	2,010
1998	11,940	1,090	990	250	21,110	3,970	3,040	250	580	490	960	1,510

Table 3.10.3-15: Hawai'i-based Longline Ex-vessel Prices per Pound (Based on Estimated Whole Weight) by Species, 1987 to 1998. Source: Ito and Machado, 1999.

Year	Billfish ($)				Tunas ($)				Miscellaneous ($)			
	Swordfish	Blue Marlin	Striped Marlin	Other Marlin	Bigeye	Yellowfin	Albacore	Bluefin	Mahimahi	Ono	Moonfish	Sharks
1987	3.23	1.02	1.39	3.56	1.86	1.5	–	2.31	2.6	1.55	1.65	0.83
1988	2.87	0.84	1.02	3.33	1.81	1.3	–	2.73	2.56	1.49	1.17	0.81
1989	2.28	0.84	1.1	3.24	2.14	1.3	–	2.26	2.47	1.28	0.85	0.4
1990	2.32	0.92	1.38	3.33	2.19	1.48	–	1.97	2.52	1.31	0.71	0.43
1991	2.12	0.78	0.99	3.73	2.74	1.32	8.63	1.28	2.1	1.15	0.64	0.46
1992	1.92	1.16	1.27	3.57	2.91	1.24	12.33	1.4	2.46	1.1	0.76	0.5
1993	2.03	0.85	1.03	3.57	2.74	1.21	13.42	1.36	1.94	0.86	0.64	0.56
1994	2.32	1.28	1.7	3.71	2.92	1.24	15.53	1.41	2.7	1.1	0.68	0.52
1995	2.24	0.87	0.9	3.35	2.84	1.08	17.26	1.42	1.64	0.95	0.65	0.62
1996	2.49	1	1.24	3.58	3.06	1.3	18.26	2.05	2.13	1.07	0.66	0.68
1997	2.21	0.85	1.27	3.22	2.68	1.23	15.59	1.24	1.56	1.14	0.35	0.27
1998	1.66	1.26	1.19	2.97	2.5	1.24	7	1.72	1.88	1.04	0.41	0.19

Figure 3.10.3-19: Hawai'i Commercial Ex-vessel Pelagic Prices, All Gear Groups, Inflation-adjusted, 1970 to 1998. Source: WPRFMC, 1999d.



While nominal prices have been relatively constant in recent years, inflation-adjusted pelagic prices declined for all major species groups in the five years before 1998 (Table 3.10.3-16). Prices for other species peaked in the 1980s, while those for billfish and tuna peaked in the early 1990s. The market for tuna weakened due to the decline in tourists arriving from Japan and due to a weak export demand. Swordfish prices also fell substantially on the U.S. East coast.

Table 3.10.3-16: Hawai'i-based Longline Landings and Gross Revenue, 1987-1998. Source: WPRFMC, 1999d.

Year	Pounds (Thousands)	Nominal Gross Revenue ($Thousands)	Adjusted Gross Revenue ($Thousands)	Honolulu Consumer Price Index
1987	4,100	10,450	16,252	116
1988	6,750	16,050	23,540	123
1989	9,950	21,150	29,350	130
1990	13,050	28,650	37,183	139
1991	19,750	43,820	53,055	149
1992	21,130	43,880	50,743	156
1993	24,930	54,380	60,933	161
1994	17,990	41,370	45,231	165
1995	22,660	43,780	47,011	168
1996	21,520	42,750	44,838	172
1997	27,116	50,043	51,294	176
1998	28,575	46,651	46,651	180
Average	**18,127**	**36,915**	**42,173**	**153**

Note: Longline landings and ex-vessel gross revenue estimates were compiled by NMFS, SWFSC-HL. They represent weight estimates using federal logbooks (since 1991) and monitoring of average weight per fish and average price per pound at the market. From 1987 to 1990, estimates rely on NMFS shoreside and market monitoring (WPRFMC, 1999d).

3.10.3.1.4 Cost / Net Revenues / Impacts

To evaluate the overall impacts of a fishery on an economy, it is necessary to estimate gross and net revenues, costs, and impacts on the economy (for greater detail, section 3.10.2.2). While gross revenues are easily calculated from landings information, cost data must be collected from vessel owners and operators. This is a difficult task that has not been done in the Hawai'i-based longline fishery since 1994-1995. A study (Hamilton *et al.*, 1996) was done to prepare a baseline net revenue estimate for the fishery (1993 basis) that had become limited entry just two years earlier. The cost data, when combined with landed gross revenue information, allow calculation of estimated economic activity (including operating and fixed costs, net revenues, and wages). In turn these calculations can be used in conjunction with an input/output model (see Section 3.10.2.2) to estimate induced and indirect economic effects of the fishery on the local economy. Together, these calculations

can then be used to estimate economic impats of the current fishery and of alternative management measures.

Costs per trip were estimated using 1993 data. This calculation resulted in an average profit of $1,186 per trip. Using this assumption, total wages and profit for the estimated 616 direct participants in the 1993 fishery (based on crew levels found in Hamilton *et al.*, 1996) amount to $15.7 million, or about one-third of the gross revenue. Indirect economic impacts account for an additional estimated 89 jobs for a total estimated 705 jobs.

Cost

As indicated above, the most recent and comprehensive vessel cost study was conducted in 1994-1995 (Hamilton *et al.*, 1996). Costs and revenues for an average vessel by trip target for 1993 are presented in Table 3.10.3-17 along with other relevant data. The purchase price of a vessel has changed in recent years. A number of large, steel vessels have since joined the fleet and were not incorporated in the cost/earning study. These vessels came from other longline fisheries (especially the Gulf of Mexico) and from new construction. These vessels have larger engines and are capable of faster speeds. On average, the newer vessels use more fuel than vessels studied in 1994-1995. These factors combined imply that the current subfleet that targets swordfish and mixed species has both higher fixed costs and higher operating costs per vessel than modeled (adjusted for inflation). Most vessels that target swordfish recently have been acquired by their current owners, most of whom typically have debt payments amounting to about $10,000 per month (J. Cook, pers. comm.; M. Dang, pers. comm.).

The study examined a number of factors affecting costs and earnings. It was found that larger vessels earned higher gross revenues. The vessels with the highest net returns tended to pay lower wages per crew member but had slightly more crew (on average). The study found that medium-sized vessels targeting mixed species were the most profitable overall, followed by small tuna boats.

Variable and fixed costs were higher for swordfish vessels than for other vessels and the study suggested several reasons. Swordfish trips are longer, so the vessels have larger engines and greater speed to reach the grounds. Therefore, fuel costs are much higher, as shown in Table 3.10.3-17. Also, catch per trip is much higher on swordfish trips compared to tuna trips, so the swordfish vessels have much larger fish holds. Swordfish vessels used more lightsticks per set and were more likely to sell their fish through export brokers, who charge shipping costs as well as commissions. While vessels suited for the swordfish fishery can target tuna (with the proper gear additions) vessels that do so are overcapitalized for the tuna fishery and are therefore at a distinct cost disadvantage.

Hamilton *et al.* (1996) examined their cost/revenue information to determine what fishers could do to increase profitability and return on investment (Table 3.10.3-17). The authors assumed that vessels were already covering their operating costs, as well as minimizing their

trip costs and maximizing their trip revenues. It was determined that the only path to increased profitability was by increasing the number of trips per year or by switching targets (which was not covered in the analysis). In the years since that study was conducted, a significant portion of the fleet switched to directed tuna fishing, which had been determined to have the lowest profitability in the study. Such a change in fishing patterns points to exogenous changes such as differences in catch rates, ex-vessel prices, or other fishing opportunities. It also suggests that the net revenue determinations contained in the model are not applicable now, except perhaps on a fleetwide basis.

Costs for a vessel to change gear from targeting swordfish to targeting tuna amount to about $12,000 (J. Cook, pers. comm.; M. Dang, pers. comm.). Included is the addition of a line-shooter ($5,000); tuna hooks, line, and wire ($4,000); and 100 hard floats ($3,000). About 20 person-days of labor are required to install the line-shooter and rig the tuna gear.

Table 3.10.3-17: Hawai'i-based Longline Vessel Costs and Earnings, 1993. Source: Hamilton *et al.,* 1996.

Trip Target	All	Tuna	Swordfish	Mixed
Number of Boats	95	32	21	32
Number of Trips/Yr	10.8	12.6	7.7	10.8
Trip Length	20.2	13.8	32.2	18.8
Travel Days	9.6	4.6	18.2	9
Fishing Days	10.6	9.2	14	9.8
Crew	4.4	3.7	4.4	5
Purchase Price	$266,801	$172,188	$445,714	$236,344
Additional Investment	$105,857	$133,493	$93,780	$83,677
Gross Trip Revenue	$50,600	$27,954	$82,386	$53,961
Trip Fixed Costs	$11,242	$9,323	$17,441	$8,564
Fuel & Oil	$5,521	$2,208	$8,740	$6,954
Ice	$819	$855	$391	$1,059
Bait & Lightsticks	$8,528	$2,463	$15,989	$10,200
Handling	$6,081	$2,714	$13,019	$5,396
Provisions	$1,480	$1,013	$1,914	$1,648
Gear and Supplies	$2,875	$1,114	$5,319	$2,980
Crew's Income	$9,010	$5,724	$12,036	$10,285
Captain's Income	$3,613	$3,110	$6,432	$2,518
Excise Tax	$245	$140	$412	$270
Trip Operating Costs	$38,172	$19,341	$64,252	$41,310
Total Trip Cost	$49,414	$28,664	$81,693	$49,874
Net Trip Revenue	$1,186	-$710	$693	$4,087

Net Revenues

Net trip revenue from the model represented in Table 3.10.3-17 shows that in 1993 an average trip generated $1,186 to the owner or about 2.3 percent of gross sales. This amount varied among trip types from a high of $4,087 for mixed trips to a net loss of $710 for tuna trips. The numbers have not been adjusted for changing costs, ex-vessel prices, or landed weights. For that reason, the information for overall fleet landings is probably the most useful.

Using the net trip revenue information from Table 3.10.3-17 averaged for all vessels ($1,186 per vessel trip) and multiplying by the 1,140 trips undertaken in the fishery in 1998 results in net estimated revenues of $1,352,040 to vessel owners. This is after tax and on an average. In addition, 1993 crew and captain income from fish sales totaled $14,390,220 ($10,271,400 for crew and $4,118,820 for captains). The combined income and profit total was $15,742,260. If this total is applied to 1998 gross of $46.7 million, there would be a[n] (inferred) 33.7 percent return for wages and profit. This percentage is within the bounds for other fisheries in the United States.

Crew shares

The 1993 study (Hamilton *et al.*, 1996) determined an average fleetwide crew size of 4.4 crew and one captain per vessel. Using this estimate with the 1998 fleet size of 114 vessels results in an estimated 502 crew and 114 captains, for a total of 616 fishers[23]. Using the above wages and crew shares indicates that the average annual income would be $20,461 for crew and $36,130 for captains. Of course, crew and captains on highliner vessels would be expected to make more than the average, and those on poorly performing vessels would make less.

The following information about crew income is excerpted from WPRFMC, 2000b.

> Based on a fleet survey, Hamilton *et al.* (1996) reported a combined mean captain and crew share of about 22%.[24] Shares are calculated based on gross revenue minus shared costs, which include fuel, oil, bait, ice, miscellaneous fishing gear, food, and excise taxes. The owner keeps a large proportion of the proceeds, in part to cover other operating costs. Income from shark fins, in contrast, is only shared among participating crew so finning benefits them much more directly. The authors estimated the annual average income

[23] Analysis by NMFS staff on a target fishery basis suggests that the 1999 fleet uses an average of 4.5 crew members and one captain on tuna targeting vessels and 3.5 crew members and one captain on vessels targeting swordfish and mixed species. This information is not used in the description section but is used for the analysis. The difference is considered *de minimis* in terms of overall economic impacts.

[24] Hamilton *et al.* reported highliner shares separately from shares for other vessels. On highliners, the combined crew and captain share was 21.5 percent, and on other vessels it was 22.6 percent.

(exclusive of the captain) at $25,000. Based on estimated total gross revenues from shark fins landed by the fishery, they estimate an average of $2,375 to $2,850 per crew member or 10-11 percent of the estimated annual wage. They suggest that "owners may have an incentive to encourage finning as a salary supplement to crew members in order to contain crew costs." (p. 81). On some fishing trips targeting tuna, where landings were especially poor, crew income from finning sharks actually exceeded regular crew share. However, in interviews they found that attitudes varied; some owners opposed finning while others saw it as an essential component of crew compensation.

McCoy and Ishihara (WPRFMC, 2000b) estimated 1998 dry weight shark fin landings in Hawai'i by the Hawai'i-based longline fleet amounted to 38 mt, valued at $25 to $30 per kg, for a total value of $0.95 to $1.14 million. In addition, McCoy and Ishihara attempted to estimate volumes and values for Korean fins transferred to the longliners at sea and then landed in Hawai'i. The researchers estimated an at-sea FOB price of $18 to $20 per kg and roughly 132 mt of fins, for a total value of $2.4 to $2.6 million.

Impacts

A more complete assessment of the contribution of the pelagic longline fishery to the state's economy can be obtained by combining the I/O multipliers and other coefficients from Sharma *et al.* (1999) with estimates of total sales from this fishing sector. Section 3.10.2.2 presents more details on the methodology and describes the coefficients and multipliers. The economic contribution of the longline fishery is shown in Table 3.10.3-18.

Total sales for the longline fleet do not take indirect economic impacts into account. Additional employment and income are generated in the Hawai'i economy by businesses whose goods and services are purchased by fishery participants and by businesses that use products from the fishery as inputs for production of goods and services. People earning incomes directly or indirectly from the fishery also generate additional employment and income by making expenditures within the economy.

Table 3.10.3-18: Estimated Economic Contributions by Hawai'i-based Pelagic Longline Fishing Sector for 1998.

Fishing Sector	Industry Output ($Millions)	Industry Labor Income ($Millions)	Industry Inputs ($Millions)	Industry Jobs	Total Output ($Millions)
Longline	46.65 [a]	22.53	16.36	610	55.38

[a] Inflation-adjusted gross revenue for 1998.

The longline fishery in 1998 accounted for $46.65 million or 48 percent of the value from the Hawai'i-based commercial fisheries. Longliners paid $22.53 million to labor or approximately 64 percent of the total payments to labor from Hawai'i's pelagic fisheries. The

longline fleet purchased 16.36 million in inputs, 34 percent of the total inputs purchase by Hawai'i's pelagic fishers. The longline fleet employed 610 persons, 40 percent of the people employed by Hawai'i's pelagic fishers. The total economic output of the longline fishers (including direct, indirect, and induced outputs) was $55.38 million, almost 35 percent of the total economic contribution of Hawai'i's pelagic fishers.

The longline fishery is the only Hawai'i-based pelagic fishery that is currently directly managed under the FMP. Two area closure amendments have moved the fishery outside 50 nm from the Hawaiian islands. Longlining is the only Hawai'i-based pelagic fishery subject to limited entry.

Longliners are also the only Hawai'i-based pelagic fishers that compete directly with international fleets outside the EEZ. The Hawai'i-based swordfish fleet often fishes to the north of the MHI, on grounds simultaneously used by the international fleet. The Hawai'i-based fleet targets bigeye tuna on these grounds, but also south of the MHI on grounds less frequented by the international fleet. While effort is large for the longline fleet in comparison to other Hawai'i-based fisheries, it is a very small contributor to the effort in the international Pacific pelagic longline fishery.

3.10.3.1.5 Non-fish Interactions

The discussions of turtle, seabird, and marine mammal bycatch and mortality that follow are only for the Hawai'i-based longline fleet. Much of this fleet and fleets from a number of other countries conduct their fishing effort on the same grounds and use the same type of gear. In 1999, the Hawai'i-based fleet took an estimated 710 turtles, with a mortality of 136 (19 percent). An estimated average of 1,388 black-footed albatross and 1,175 Laysan albatross were also taken. Bycatch rates were much higher in the swordfish fishery due to geographic location and the setup, method, and timing of gear use. Marine mammal interactions with the longline fleet are very uncommon but do occur occasionally.

Turtles

The two major sources of information on sea turtle interactions with Hawai'i-based longline vessels are the mandatory logbook and observer data collection programs administered by NMFS (2000j). The western Pacific daily longline fishing log program requires operators of longline vessels to complete and submit to NMFS a form containing catch and effort data for each set (50 CFR 660.14). Although the information is extensive, it is not as detailed and reliable as the data collected by NMFS SWR observers.

The NMFS observer program was implemented in February 1994 to collect data on protected species interactions (marine turtles have highest priority). The species of concern include all sea turtles (greens, leatherback, loggerheads, and olive ridley), Hawaiian monk seals, selected whale and dolphin species, and seabirds, including albatross species and the brown booby. Observer coverage by year is shown in Table 3.10.3-19. There are some

indications that sea turtle interaction rates vary by set target. The selection of trips to observe is based on a sampling design by DiNardo (1993) to monitor sea turtle interactions (NMFS, 2000c), and is described in detail in Section 3.12. The NMFS observer program coverage was provided for 3.4 to 5.3 percent of the total fishery effort (NMFS, 2000c). Observer data are presented in Table 3.10.3-20.

A 1998 NMFS Biological Opinion on the effects of the Hawai'i-based pelagic longline fishery on sea turtle populations concluded that the operation of the fishery was not likely to jeopardize the continued existence and recovery of any sea turtle populations. Incidental take levels were derived by calculating the average of the upper 95 percent confidence limits of the fleet's estimated annual takes and mortality for each species over a four-year period, based on data collected by NMFS observers from 1994 to 1997. These anticipated incidental take levels were updated in 1998, as a part of the 1998 BO (NMFS, 1998c)

On May 18, 2000, NMFS finalized its annual assessment of the impact of the Hawai'i-based longline fishery on sea turtles for 1999. This evaluation produced estimates of interactions for 1999, as well as updating previous years' estimates by including 1999 NMFS observer and logbook data in a refined statistical model. These results are presented in Tables 3.10.3-21 and 3.10.3-22 and indicate that in 1999, the fleet exceeded its anticipated incidental olive ridley mortalities. An ESA Section 7 consultation on the fishery and its impacts on olive ridley turtles was reinitiated on June 7, 2000.

Although data collection on protected species is the primary purpose of the Observer Program, the observers also collect catch data on the fishery and in total record five types of data: incidental sea turtle take events; fishing effort; interactions with other protected species; fishes kept and discarded, by species; and life history information, including biological specimens in some instances. The data from this program and the data from the NMFS logbooks have been used to generate estimates of the annual taking of turtles in the Hawai'i-based longline fishery between 1991 and 1999.

Table 3.10.3-19: NMFS Southwest Region Observer Program Coverage Between 1994 and 1999, and through the First Quarter of 2000. Source: NMFS Observer Program, unpub. data *in* NMFS, 2000j.

Year	Period	Trips Departed	Observed Trips	Observer Coverage (%)
1994	02/25/94 to 02/20/95	1,031	55	5.3
1995	02/20/95 to 12/31/95	937	42	4.5
1996	January - December	1,062	52	4.9
1997	January - December	1,123	40	3.6
1998	January - December	1,180	48	4.1
1999	January - December	1,136	38	3.3
2000	01/01/00 to 3/31/00	308	21	6.8

Table 3.10.3-20: NMFS SWR Observer Program Turtle Statistics, 1994-1999.
Source: NMFS Observer Program, unpub. data *in* NMFS, 2000j.

	1994	1995	1996	1997	1998	1999	Total
Observed trips departing in each year	50	47	53	40	48	38	**276**
Trips without interactions	33	34	30	21	27	14	**159**
Trips with interactions	17	13	23	19	21	24	**117**
Total interactions	27	29	50	38	61	29	**234**
Released alive	27	28	48	38	56	26	**223**
Loggerhead	11	19	27	22	47	16	**142**
Leatherback	8	4	8	12	4	1	**37**
Olive Ridley	3	3	8	3	2	6	**25**
Green	2	0	3	0	2	2	**9**
Unid. Hardshell	3	2	2	1	1	1	**10**
Released dead	0	1	2	0	5	3	**11**
Loggerhead	0	0	0	0	1	0	**1**
Leatherback	0	0	1	0	1	1	**3**
Olive Ridley	0	1	1	0	3	1	**6**
Green	0	0	0	0	0	1	**1**
Total fleet sets	10,799	11,732	11,638	11,846	12,506	12,776	**71,297**
Sets observed	509	549	642	498	591	463	**3,252**
Total fleet hooks (in thousands)	11,996	14,190	14,400	15,564	17,366	19,120	**92,636**
Hooks observed (in thousands)	525	618	749	576	767	688	**3,923**
Interaction rate per 1,000 hooks observed	0.051	0.047	0.067	0.066	0.080	0.042	**0.042**

Note: Since sampling is not random a simple extrapolation of data is likely to be biased.

Table 3.10.3-21: Estimated Turtle Take by Species, 1994-1999. Source: Appendix G; NMFS, 2000j.

Species	Anticipated Incidental Take	Estimated Takes by the Hawai'i-based Longline Fleet					
		1994	1995	1996	1997	1998	1999
Loggerhead	1994 to 1997: 305 1998 to 1999: 489	501 (315-669) 0.98	412 (244-543) 0.90	445 (290-594) 0.96	371 (236-482) 0.82	407 (259-527) 0.09	369 (234-466) 0.01
Olive Ridley	1994 to 1997: 152 1998 to 1999: 168	107 (70-156) 0.04	143 (90-205) 0.39	153 (103-210) 0.53	154 (103-216) 0.54	157 (102-221) 0.38	164 (111-231) 0.46
Leatherback	1994 to 1997: 271 1998 to 1999: 244	109 (68-153) 0.00	99 (62-141) 0.00	106 (69-148) 0.00	88 (55-124) 0.00	139 (79-209) 0.00	132 (76-193) 0.00
Green	1994 to 1997: 119 1998 to 1999: 52	37 (15-65) 0.00	38 (15-70) 0.00	40 (19-70) 0.00	38 (14-73) 0.00	42 (18-76) 0.28	45 (18-82) 0.34

Note: In yearly the columns the three numbers listed for each species show (1) the estimated take in that year based on extrapolated observer data; (2) the 95 percent confidence interval; and (3) the likelihood that the actual take exceeded the anticipated take (as shown in the second column) – the closer this number is to one the more likely it is that the anticipated take was exceed.

Table 3.10.3-22: Estimated Turtle Mortalities by Species, 1994-1999. Source: Appendix G; NMFS, 2000j.

Species	Anticipated Incidental Mortality	Estimated Mortalities by the Hawai'i-based Longline Fleet					
		1994	1995	1996	1997	1998	1999
Loggerhead	1994 to 1997: 46 1998 to 1999: 103	88 (36-141) 0.95	72 (31-115) 0.89	78 (34-127) 0.92	65 (28-102) 0.84	71 (32-112) 0.06	64 (28-102) 0.03
Olive Ridley	1994 to 1997: 41 1998 to 1999: 46	36 (8-64) 0.36	47 (7-84) 0.63	51 (11-90) 0.70	51 (8-92) 0.70	52 (11-92) 0.62	55 (11-96) 0.66
Leatherback	1994 to 1997: 23 1998 to 1999: 19	9 (0-22) 0.03	8 (0-21) 0.02	9 (1-21) 0.02	7 (0-18) 0.00	12 (1-28) 0.23	11 (1-27) 0.20
Green	1994 to 1997: 18 1998 to 1999: 15	5 (0-16) 0.01	5 (0-17) 0.02	5 (0-17) 0.02	5 (0-17) 0.02	5 (0-19) 0.06	6 (1-19) 0.06

Note: In yearly the columns the three numbers listed for each species show (1) the estimated take in that year based on extrapolated observer data; (2) the 95 percent confidence interval; and (3) the likelihood that the actual take exceeded the anticipated take (as shown in the second column) – the closer this number is to one the more likely it is that the anticipated take was exceed.

Albatrosses

The Hawai'i-based longline fishery may on occasion interact with protected black-footed and Laysan albatrosses that nest on the NWHI. These interactions are sometimes fatal for the albatrosses. The seabirds follow the longline vessels and dive on the baited longline hooks, become hooked, and drown. Neither albatross species is listed as endangered in the

Hawai'i area, but both are protected under the U.S. Migratory Bird Treaty Act. It is estimated that between 1994 and 1998, an average of 1,175 Laysan albatross and 1,388 black-footed albatross were taken in the Hawai'i-based longline fishery each year (Table 3.10.3-23) (McCracken, 2001).

Table 3.10.3-23: Estimated Annual Total Takes of Albatrosses in the Hawai'i-based Longline Fishery Based on Data from the NMFS Observers on Monitored Fishing Trips, 1994-1998. Source: McCracken, 2001; M. McCracken, pers. comm., March 2001.

Year	Black-footed Albatross			Laysan Albatross		
	Observed Take	Estimated Total Take		Observed Take	Estimated Total Take	
1994	126	1,830	(1,457 to 2,239)	73	2,067	(933 to 2,984)
1995	105	1,134	(899 to 1,376)	107	844	(617 to 1,131)
1996	59	1,472	(1,199 to 1,811)	31	1,154	(835 to 1,600)
1997	107	1,305	(1,077 to 1,592)	66	985	(715 to 1,364)
1998	46	1,283	(1,028 to 1,601)	56	981	(679 to 1,360)
1999	51	1,301	(1,021 to 1,600)	28	1,019	(688 to 1,435)

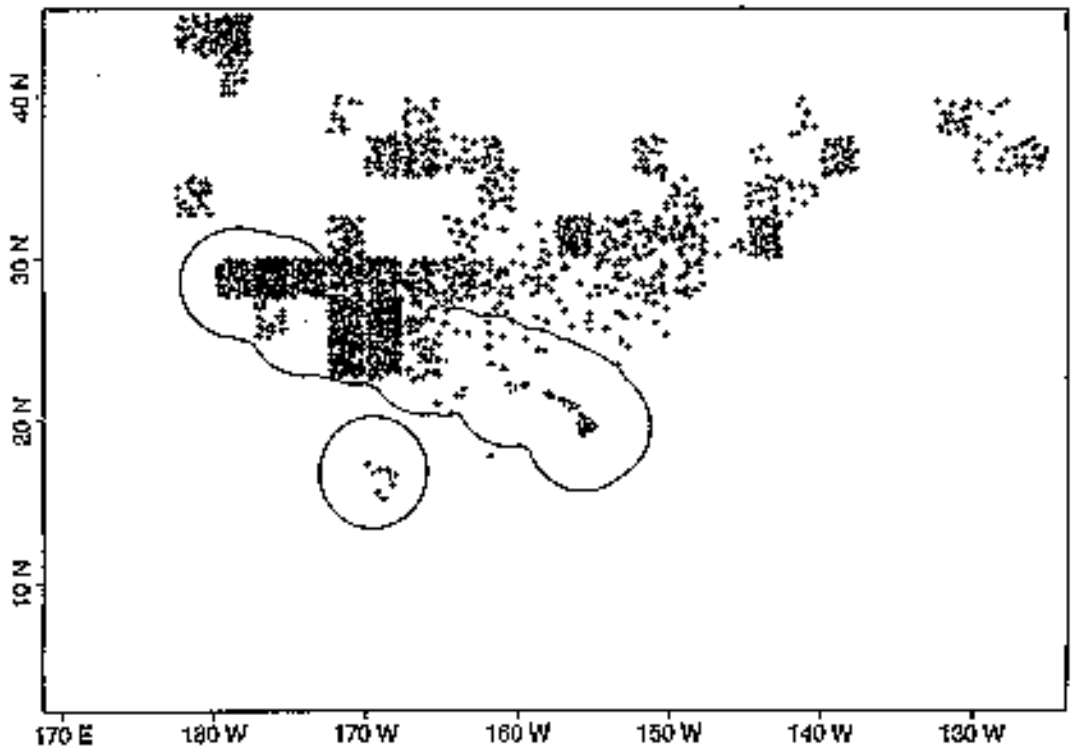
Note. The estimated total take includes all hooked or entangled seabirds, regardless of whether the seabirds were dead or released alive. Values in parentheses are 95 percent confidence bounds.

The average annual takes of black-footed and Laysan albatrosses in the Hawai'i-based longline fishery represent about 0.6 and 0.06 percent of the total estimated populations of these species, respectively. Data collected by NMFS observers show that the taking of seabirds is far higher when Hawai'i-based longline vessels target swordfish (averaging 0.758 bird take per set) than when vessels target tuna (averaging 0.013 bird take per set). One cause is that vessels targeting swordfish are more likely to operate within the foraging range of the seabirds. Black-footed and Laysan albatrosses nesting in the NWHI forage predominantly to the north and northeast of the Hawaiian archipelago, flying as far as Alaska or the western coast of the contiguous United States (Anderson and Fernandez, 1998). The region of greatest interaction between seabirds and the longline fishery is a latitudinal band between 25° N. and 40° N. stretching from the international dateline to about 150° W. longitude (Figure 3.10.3-20). Foreign longline vessels are operating in albatross foraging areas close to the northern boundary of the U.S. EEZ around the NWHI (Cousins and Cooper, 2000). The number of seabirds killed by these vessels is unknown (NMFS, 2000j).

A second reason that the incidental take of seabirds is larger for longline vessels targeting swordfish than for vessels targeting tuna relates to differences in gear configuration and the depth and time of gear deployment. Longline gear targeting swordfish generally consists of fewer hooks between floats (three to five), branch line (gangion) weights attached further from the hooks, and buoyant chemical lightsticks. During swordfish fishing the longline is set at a shallow depth (5-60 meters), and the line and baited hooks sink comparatively slowly.

Consequently, albatrosses following behind a vessel targeting swordfish have a greater opportunity to dive on hooks and become caught. In addition, vessels targeting swordfish often set their lines in the late afternoon or at dusk, when the foraging activity of seabirds may be especially high.

Figure 3.10.3-20: Seabird Interaction Rates with the Hawai'i-based Longline Fishery, 1994-1998. Source: NMFS unpub. data, 1998 in NMFS, 2000j.



Marine Mammals

All fisheries in Hawai'i, including the longline fishery, are classified as Category III under Section 118 of the Marine Mammal Protection Act of 1972. Marine mammals that are listed as endangered under the ESA and have been observed in the region where Hawai'i-based fishing vessels operate are the humpback whale, sperm whale, blue whale, fin whale, and sei whale. Other cetaceans protected under the MMPA are occasionally encountered by the Hawai'i-based fisheries. These cetaceans are mainly dolphins and the smaller beaked and toothed whales. Interactions between any species of cetaceans and the Pelagics FMP fisheries are rare (NMFS, 2000j).

Evidence of interactions between Hawaiian monk seals and the Hawai'i-based longline fishery surfaced in 1990, and included three hooked seals and 13 unusual wounds thought to have resulted from longline interactions. In 1991, NMFS created a Protected Species

Zone that extends 50 nm around the NWHI and includes the designated corridors between islands. Longline fishing is prohibited in this area. Subsequent to the establishment of the Protected Species Zone, there have been no verified reports of interactions between monk seals and the Hawai'i-based longline fishery.

Interactions between marine mammals and the Hawai'i-based longline fishing fleet are not common. Table 3.10.3-24 lists these interactions as reported in NMFS, 2000j. Very few observations of humpback whales fouled in longline and other Hawai'i-based fishery gear have been documented (Nitta and Henderson, 1993; Dollar, 1991 *in* NMFS, 2000j). False killer whales occasionally strip bait from longline hooks. To avoid this type of interaction, many Hawai'i-based longline vessels that encounter false killer whales delay setting their lines until a sufficient distance between the vessel and the whale school has been achieved (NMFS, 2000j).

Table 3.10.3-24: Reported Marine Mammal Interactions with the Hawai'i-based Longline Fishery, 1991-1998. Source: NMFS, SWFSC-HL *in* NMFS, 2000j.

Species	Year	Observation	Source
Bottlenosed dolphin	1999	Reported encounter with dolphin, which was released from the longline gear alive.	NMFS observer aboard a Hawai'i-based longline vessel. NMFS Observer Program, unpub. data.
False killer whale	1997	A whale taken by the Hawai'i-based longline fishery and released alive.	NMFS Observer Program, unpub. data
False killer whale	1998	A whale taken by the Hawai'i-based longline fishery and released alive.	NMFS Observer Program, unpub. data.
Humpback whale	1991	A whale was observed entangled in longline gear and released alive.	Hill *et al.*, 1997.
Killer whale	1991	A solitary whale was reported to remove the catch from a longline in Hawai'i.	Dollar, 1991.
Risso's dolphins	Between 1997 and 1999	At least four dolphins were taken in Hawai'i-based longline gear and released alive.	All four encounters were reported by NMFS observers. NMFS Observer Program, unpub. data.
Short finned pilot whale	1997	Taken by the Hawai'i-based longline fishery and released dead. The incident was reported by a NMFS observer onboard the vessel.	NMFS Observer Program, unpub. data
Spinner dolphin	1997	A dolphin taken by the Hawai'i-based longline fishery, and released alive.	NMFS Observer Program, unpub. data
Sperm whale	Between 1994 and 1998	An entanglement involving a whale and Hawai'i-based longline fishing vessels.	NMFS observers.
Sperm whale	1999	A whale hooked and entangled and released alive from a longliner.	A NMFS observer aboard a Hawai'i-based longline vessel. NMFS Observer Program, unpub. data.
Unidentified	1998 and 1999	Three unidentified whales were taken by the Hawai'i-based longline fishery and released alive.	Reported by NMFS observers . NMFS Observer Program, unpub. data.