The Hawaii-based Longline Fishery for Swordfish, *Xiphias gladius*

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ABSTRACT

This report profiles the Hawaii-based domestic longline fishery for broadbill swordfish, *Xiphias gladius*. This fishery grew rapidly during 1989–91, mostly due to the arrival and participation of recent entrants. Swordfish became the dominant species landed by Hawaii's fisheries in 1990 and the most important in terms of ex-vessel revenue in 1991. In 1993, 88 longliners fishing for swordfish logged 650 trips, fished 7,533 days, set 6.6 million hooks, and landed 6,000 metric tons of swordfish with an estimated ex-vessel value of $26.5 million. Swordfish is delivered as a fresh product. Most swordfish landed in Hawaii is exported to mainland U.S. cities by air freight.

Introduction

Longlining for broadbill swordfish is a relatively new fishery in Hawaii. In 1988, the fishing vessel *Magic Dragon* began experimentally targeting swordfish using techniques based on the Florida longline fishery. During 1989, a few Hawaii tuna longline and lobster vessels experimented with longlining for swordfish for at least part of the year. Good catches by those vessels led to increased effort as well as national attention (Freeman, 1989).

Domestic U.S. longline vessels from the Gulf of Mexico (Gulf vessels) were among the first to join the growing longline fleet operating from Hawaii (Kawamoto et al.[1]). These new participants initially targeted yellowfin and bigeye tuna, but in early 1990 some vessels began targeting swordfish. Longlining for swordfish by many of the Gulf vessels was discouraging at first due to poor catches and the high cost of bait and light sticks. Catches of swordfish increased as these fishermen became more experienced.

The decline in Atlantic swordfish landings, catch rate, and average fish size in the late 1980's (Berkeley, 1989; Pollack, 1990) as well as prospects of good swordfish catches in Hawaii influenced many Atlantic swordfish longline fishermen to relocate to Hawaii. These experienced fishermen from the U.S. east coast began arriving in Hawaii in early 1990. A few longline vessels from the west coast also entered the fishery at the same time as Gulf longliners and east coast longliners. In addition, many tuna longline vessels were able to switch to targeting swordfish with minor modification to gear and operations.

By the end of 1990, swordfish were the dominant species landed in Hawaii (Ito[2]) with landings (by weight) exceeding those of any other species. By 1991, the monofilament main line, hydraulic reel, and other techniques of the swordfish fishery were widespread throughout the longline fleet. The Western Pacific Regional Fishery Management Council (WPRFMC) passed an emergency rule in October 1990 to arrest the rapid growth of the longline fishery. The emergency rule was replaced by a 3-yr moratorium on new entry in April

[1] Kawamoto, K. E., R. Y. Ito, R. P. Clarke, and A. A. Chun. 1989. Status of the tuna longline fishery in Hawaii, 1987–88. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Cent. Admin. Rep. H-89-10, 34 p. Honolulu Lab., NMFS, 2750 Dole St., Honolulu, HI 96822-2396.

[2] Ito, R. Y. 1992. Western Pacific pelagic fisheries in 1991. U.S. Dep. Commer., NOAA, Natl. Mar. Fish Serv., Southwest Fish. Cent. Admin. Rep. H-92-15, 38 p. Honolulu Lab., SWFSC, NMFS, 2570 Dole St., Honolulu, HI 96822-2396.

1991. The moratorium was to provide a period of stability during which data could be collected for assessing the impacts of the increased longline effort on small-boat pelagic fisheries in Hawaii. The longline fishery is now under a limited-entry plan.

Despite the initial rapid growth, participation of vessels in the longline fishery declined slightly in 1992–93. Increasing operational costs from longer trips and lower swordfish prices were the primary reasons for decreased activity. Most of the longliners exiting the fishery were vessels originally from the Gulf and west coast. However, longlining for swordfish is still the largest commercial fishery in Hawaii.

Hawaii has gained the reputation of being an important source of fresh swordfish for U.S. mainland markets. Characteristics and operations of this segment of the Hawaii-based longline fleet, catch per unit effort (CPUE), landings, size of fish, and the swordfish market are described here, and data sources and problems reviewed. We also discuss trends and outlook for this fishery.

Data and Methods

Monitoring of longline fleet activity in Hawaii is conducted primarily by the Fisheries Monitoring and Economics Program (FMEP) of the National Marine Fisheries Service (NMFS) Honolulu Laboratory. Hawaii-based domestic longline fishing vessels either target swordfish or bigeye and yellowfin tuna, or follow a mixed-species target strategy. Trip types[3] contributing substantial amounts of swordfish are from longliners targeting either swordfish or mixed species. Longliners targeting tunas make incidental catches of swordfish and contribute only a small fraction of total swordfish catch (Yoshida, 1974; Kawamoto et al.[1]). Therefore, only data from swordfish and mixed-target longline trips are used in this report. The data originate from shore-side samples, federal longline logbooks, federal longline permit applications, voluntary observer reports, and personal interviews.

Estimates of landings were derived from shore-side sampling conducted by FMEP in conjunction with the Hawaii Division of Aquatic Resources (HDAR) during 1989–93, and from a combination of this sampling and Federal longline logbooks for 1991–93. In the sampling program, weights of individual fish were recorded along with observations on degree of processing or damage. Landed swordfish have typically been headed, gilled, and gutted. The sample weight of each fish was raised to an estimated whole weight. Raising factors, which were species-specific, varied from 1.1 to 1.5 depending on degree of processing or damage. The raising factors were based on rates used by the seafood industry in Hawaii.

Numbers of vessels and trips were derived from the shore-side sampling data for 1989–90 and from federal logbooks for 1991–93. The federal logbooks were also the source of detailed information on fishing operation: effort (i.e. vessels, trips, sets, hooks), fishing area, and CPUE (number caught per 1,000 hooks).

Landings for 1992–93 were estimated as the product of the number of each species kept, from logbook data, and the corresponding average weight from shore-side sample data (Ito[2]). Logbook data were not used to estimate landings in 1991 due to a number of problems with implementation of the logbook program in the first year (Dollar[4]). Shore-side sample data were used for 1991. Logbook data were compared for accuracy with the shore-side data for total numbers and species identification. Proper species identification for marlins and total number kept were inaccurate during the first year (1991). Accuracy in total numbers improved in 1992 and 1993, but improper species identification, especially for marlins, is an ongoing problem requiring education of fishermen.[5]

Vessel characteristics were summarized from the fishing permit applications of vessels actively longlining for swordfish. All domestic longline vessels based in Hawaii have been required to have a federal longline fishing permit since 1990. Gear and technology, fishing procedures, processing and storage of the catch, and market information were derived from voluntary observer reports (Dollar[6]; Dollar et al.[7]) and personal interviews with industry personnel.

[3] Criteria for determining trip type from logbook data are described in Dollar, R. A. 1994. Annual report of the 1993 longline western Pacific longline fishery. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Cent. Admin. Rep. H-94-06, 38 p. Honolulu Lab., SWFSC, NMFS, 2750 Dole St., Honolulu, HI 96822-2396.

[4] Dollar, R. A. 1992. Annual report of the 1991 longline western Pacific longline fishery. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Cent. Admin. Rep. H-92-11, 26 p. Honolulu Lab., NMFS, 2750 Dole St., Honolulu, HI 96822-2396.

[5] Proper marlin identification has been encouraged by the distribution of informational material by FMEP staff to vessel operators.

[6] Dollar, R. A. 1991. Summary of swordfish longline observations in Hawaii, July 1990–March 1991. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Cent. Admin. Rep. H-91-09, 13 p. Honolulu Lab., NMFS, 2750 Dole St., Honolulu, HI 96822-2396.

[7] Dollar, R. A., R. Y. Ito, K. E. Kawamoto, and K. C. Landgraf. 1991. Summary of swordfish longline observations in Hawaii, July–October 1990. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Cent. Admin. Rep. H-91-03, 10 p. Honolulu Lab., NMFS, 2750 Dole St., Honolulu, HI 96822-2396.

The Fishery

Vessel Characteristics

Hawaii-based longliners that fished for swordfish at least 2 yr during 1991–93 (N=93) were typically steel- or fiberglass-hull vessels with a mean age of 11 and 12 yr respectively (Table 1). Most vessels were 20–24 m in length, though they ranged from 8 to 30 m (mean = 20 m; Fig. 1). Steel-hulled vessels were slightly larger than fiberglass-hulled vessels. All vessels had diesel engines, with an average of 460 horsepower (hp; range 200–700 hp).

Figure 1
A typical Hawaii-based swordfish longline vessel.

Fishing Gear and Technology

Longlining for swordfish employs hundreds of branch lines attached to a single main line set horizontally below the ocean's surface. The monofilament main line is stored on a large hydraulic-powered reel (Fig. 2A); over 80 km of main line can be stored on one reel. Larger vessels may also have an additional main-line reel to store spare main line or to sometimes set more than one reel of main line. Monofilament branch lines are stored in plywood boxes or plastic bins (Fig. 2B). Alternatively, small spools (hand carts) are sometimes used to store monofilament branch lines and float lines (Fig. 2C). The most commonly used float is an orange high-density foam buoy (Fig. 2D). Large polyethylene floats, floats with radar reflectors, radio buoys, and strobe-light buoys are also used. These buoys and floats support the main line and aid in locating the gear. Gear characteristics are detailed in Table 2. With minor modifications to gear and techniques, vessel operators can set gear to target swordfish, bigeye tuna, or yellowfin tuna.

Table 1
Characteristics of Hawaii-based swordfish longline vessels (from National Marine Fisheries Service, Pacific Area Office permit data).

Hull type	Number	Mean age (yr)	Length (m)		
			Mean	Maximum	Minimum
Steel	84	11	23	30	16
Fiberglass	9	12	19	24	8

Many of the larger vessels use temperature probes, satellite or global positioning system (GPS) navigation, automated track plotting, satellite weather imaging, and communications systems to aid in locating fish. However, some longliners take a low-technology approach to keep capital and operating costs down.

Longline gear is deployed by spooling the main line off the reel while maintaining a slight tension on the drag. A few vessels are equipped with a line shooter to maintain tension on the main line from the reel to the point where it leaves the boat. The depth of fishing is controlled by a number of factors including branch line and float line length, weights attached to branch lines, length of main line set between floats, and amount of tension or slack in the main line. The high frequency of floats used in longlining for swordfish keeps the main line close to the surface. The shape of the catenary formed by the main line is not as deep as that formed when longline gear is set to target bigeye tuna (Suzuki and Warashina, 1977; Berkeley et al., 1981; Sakagawa et al., 1987; Boggs, 1992).

Light sticks greatly increase efficiency in catching swordfish (Freeman, 1989) either by attracting swordfish directly or by attracting swordfish prey (Berkeley et al., 1981). A chemical light stick is attached to the branch line about 2 m above the hook (Dollar[6]). Chemical light sticks glow for up to 12 hr.

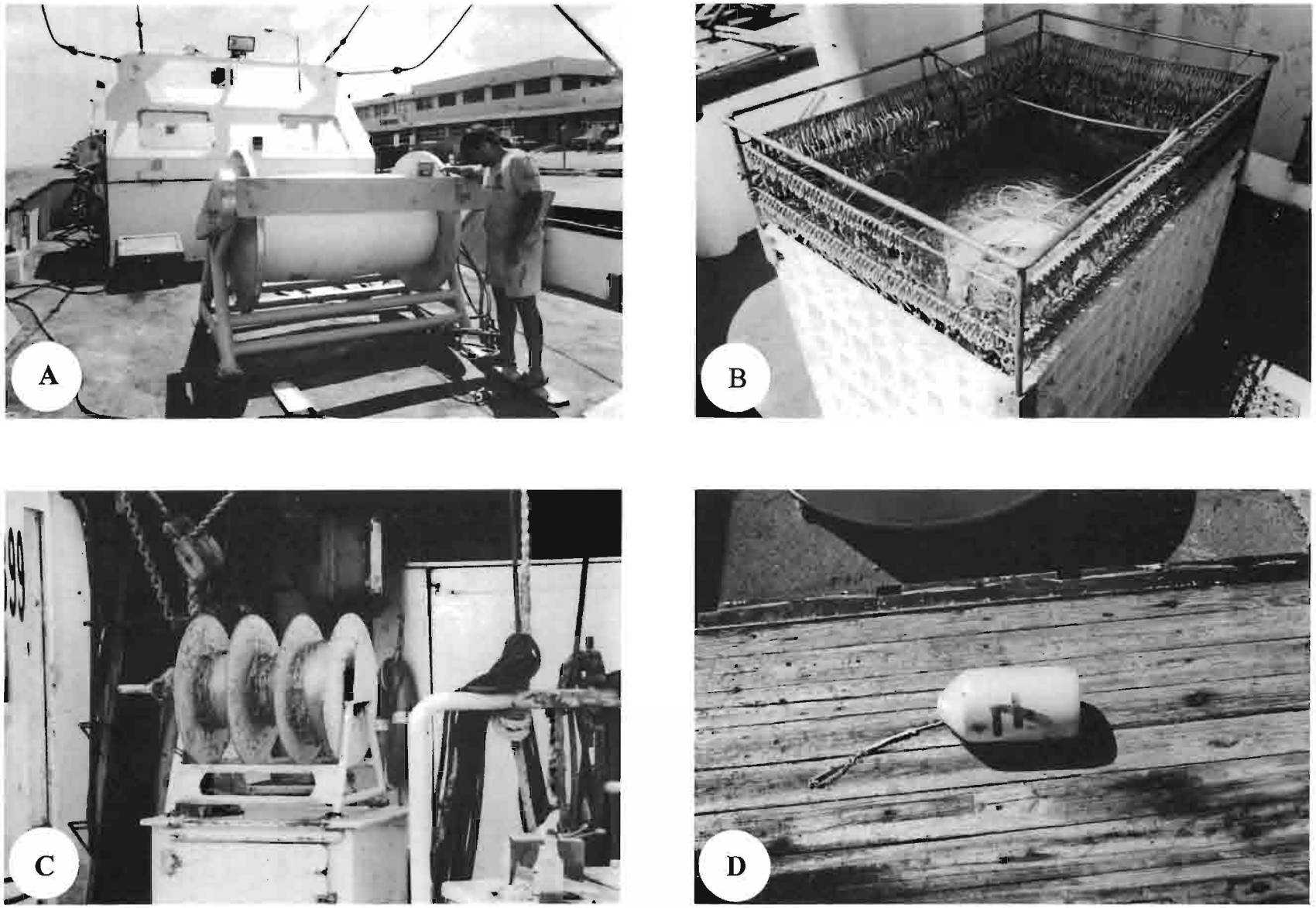

Figure 2
Main components of swordfish longline gear: (A) hydraulic reel with main line, (B) leader bin with branch lines, (C) hand cart with branch lines, and (D) orange high-density foam buoy.

Table 2
Characteristics of swordfish longline gear used on Hawaii-based longline vessels (Dollar[1]).

Gear	Characteristics
Lines	Monofilament stored on hydraulic reels
Main line length	30–80 km
Main line diameter	3.0–4.0 mm
Estimated distance between floats	90-160 m
Branch line length	13 m
Branch line diameter	2.1 mm
Hooks	8/0–10/0 Mustad[2]
Hooks per set	Range 450–1800, mean 724
Lightsticks	Cyalume[2] (break-activated) and World Plastics (thaw-activated)
Bait	Argentine shortfin squid, *Illex argentinus*

[1] Dollar, R. A. 1991. Summary of swordfish longline observations in Hawaii, July 1990–March 1991. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Cent. Admin. Rep. H-91-09, 13 p. Honolulu Lab., NMFS, 2750 Dole St., Honolulu, HI 96822-2396.
[2] Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

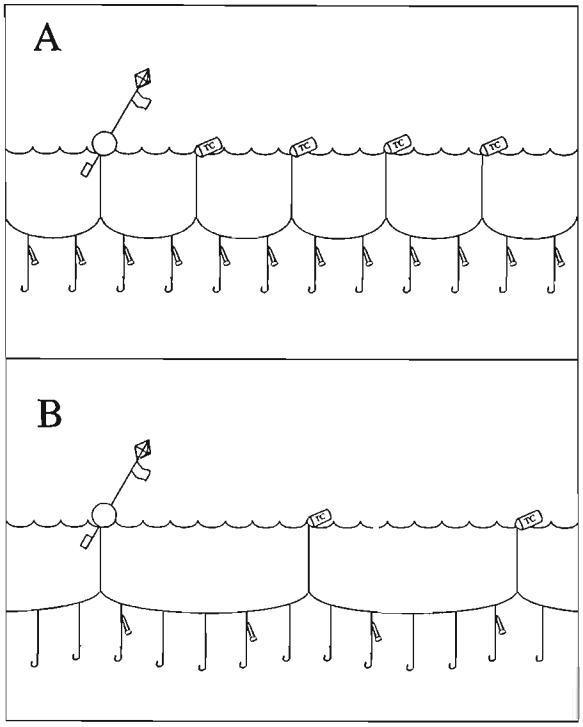

Figure 3
(A) East coast and (B) Gulf style longline gear configurations used by Hawaii-based longliners fishing for swordfish.

Large high-quality Argentine shortfin squid, *Illex argentinus*, was the preferred bait, with whole squid hooked in the mantle. Dyes were sometimes used to color the squid in an attempt to make them more appealing.

Longline gear, technology, and fishing techniques used by the Hawaii-based longline fishery for swordfish originate from the U.S. east coast and the Gulf longline fisheries. The major differences between the east coast and Gulf styles are the number of hooks set between floats and the frequency at which the light sticks are attached (Fig. 3). The east coast style of swordfish longlining is similar to the Florida style, in which 2–3 hooks are set between floats (Berkeley et al., 1981); a light stick is attached to each branch line with a rubber band. The Gulf style is similar to the method of longlining for yellowfin in the Gulf of Mexico (Wilson, 1988). The Gulf longliners set about 3–5 hooks between floats and attach one light stick for every 3–5 branch lines. Both styles of gear configuration are utilized by Hawaii-based longliners fishing for swordfish, and both styles are effective.

Fishing Area

Most effort by Hawaii-based longliners fishing for swordfish occurred north of the Hawaiian Islands. Fishing extended from 50 mi. off the main and northwestern Hawaiian Islands to far outside the Hawaii Exclusive Economic Zone (EEZ), with some trips in excess of 2,000 mi. from Honolulu. The northern range of the fishery approached 50°N, the northernmost distribution of swordfish as described by Bartoo and Coan (1989). The fishery extended latitudinally from 5° to 48°N and longitudinally from 175°E to 140°W (Fig. 4). In general, area fished expanded westerly from 1991 through 1993.

As a vessel approaches the fishing grounds, fishermen look for frontal zones where a rapid change in sea-surface temperature occurs (Sakagawa, 1989), and exploratory fishing for swordfish is focused in these areas. Concentrated fishing follows if a productive area is located. Fishing activity is also affected by moon phase. Fishermen have remarked that swordfish catch is better near the full moon, so more fishing occurs then.

The most seaworthy Hawaii-based longline vessels have the capability to fish in the North Pacific throughout the year. However, the majority of longliners fishing for swordfish traveled farther to fishing grounds during the summer, when seas were calm, and tended to fish closer to the Hawaiian Islands in the fall and winter, when seas become rough. Many longliners also

fish close to Hawaii during the spring months, when swordfish abundance near the Islands exhibits a seasonal peak (Uchiyama and Shomura, 1974; Dollar[8]). The high price and increased abundance of bigeye tuna influences many vessel operators to target tunas during the winter season.

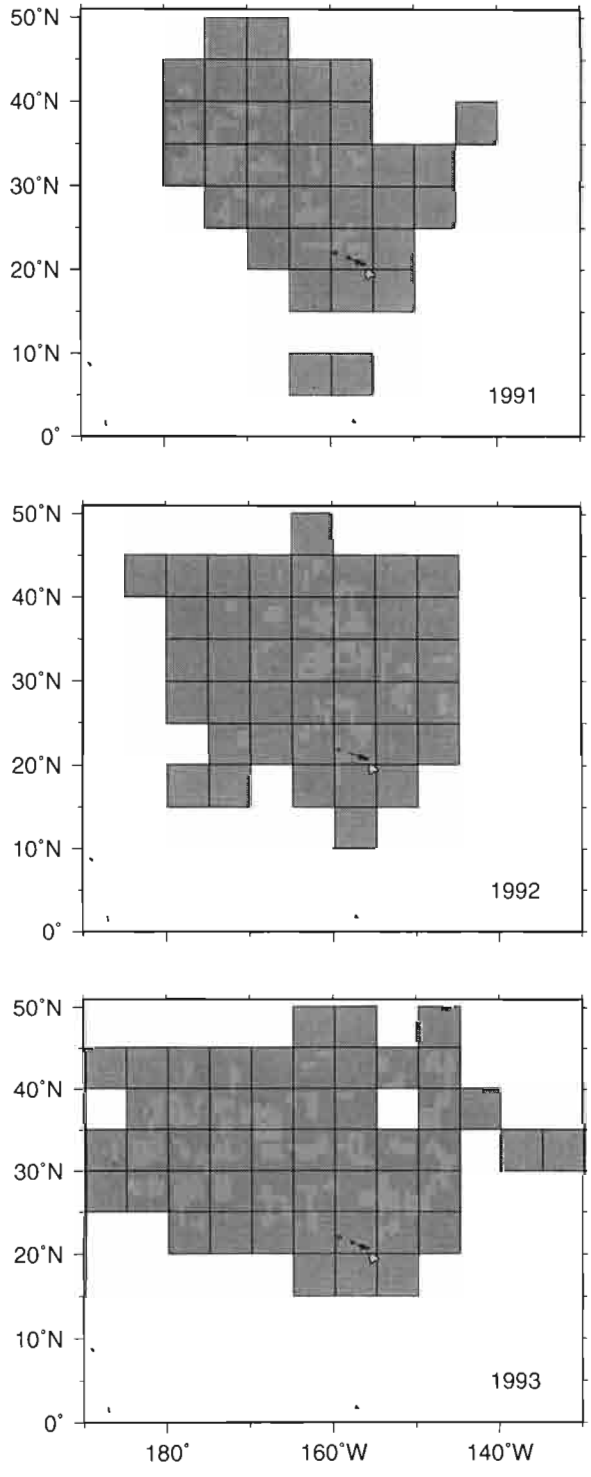

Figure 4
Geographic area fished by the Hawaii-based longline fleet fishing for swordfish, 1991–93.

Fishing Procedures

Swordfish longline gear is usually set during the late afternoon or evening (Table 3). Setting the gear takes about 4–6 hr depending on the amount of gear and sea conditions. Typically, about 48–64 km of longline gear is set. After setting the gear the vessel either idles near the end of the longline or travels back to the starting point of the set. The boat maintains visual and radio contact with the longline by attaching a strobe buoy and a radio buoy at the end of the gear. The longline gear is soaked overnight for 6–10 hr.

Retrieval begins early in the morning. The vessel approaches and hauls aboard the strobe and radio buoys. The main line is tied to the main line reel and the haul-back process begins. Branch lines are coiled in the bins or on hand carts. The vessel slows down to haul fish aboard. Fish are processed and iced down soon after they are caught. Bait for the next day of fishing is removed from the freezer and allowed to thaw midway through the haul-back process. Retrieval time can vary considerably depending on number of fish caught and on sea conditions.

[8] Dollar, R. A. 1993. Annual report of the 1992 longline western Pacific longline fishery. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Cent. Admin. Rep. H-93-12, 25 p. Honolulu Lab., SWFSC, NMFS, 2570 Dole St., Honolulu, HI 96822-2396.

Table 3
Typical operating schedule of a Hawaii-based longline vessel fishing for swordfish.

Time	Activity
1630–1730	Gear preparation for setting longline.
1730–1930	Start setting gear (start time varies daily).
2130–2330	End set and clean up (approximately 4 hr to set gear).
2330–0500	Soak gear overnight and sleep.
0500–0600	Search for light/radio buoy.
0600–1430	Haul gear, process and store fish (approximately 8 hr to haul gear; however, the time to complete hauling gear depends on amount of gear set, number of fish caught, and tangles and breakage in the main line).

Processing and Storage of the Catch

Swordfish are headed, gutted, and finned immediately upon capture. The kidneys are removed and the visceral cavity scraped to remove any remaining slime or tissue. In general, marlins, tunas, and other fishes are left whole. Tunas and other pelagic species deteriorate in quality faster than swordfish, so bycatch is sometimes released alive or discarded early in the trip. Another reason for releasing or discarding bycatch is to conserve space for swordfish in the fish hold.

Most vessels have well-insulated, refrigerated fish holds. In addition, some have on-board saltwater ice makers. Saltwater ice, which is colder than freshwater ice, is used to chill and store the swordfish. To prevent tunas and other bycatch from freezing, they are packed in freshwater ice.

Effort

Number of Vessels

The number of Hawaii-based longliners that fished for swordfish increased more than 10-fold during 1989–93, from 11 in 1989 to a high of 114 in 1991, and then decreased to 88 vessels in 1993 (Fig. 5). Of 93 longline vessels that fished for swordfish in 1991–93, 50 were originally from the Gulf, 18 from the east coast, 15 from the west coast, and 10 were Hawaii longline vessels.

Trips and Sets

The number of swordfish-targeted and mixed-target trips increased dramatically from an estimated 43 in 1989 to 1,115 in 1991, and then declined to 650 in 1993 (Fig. 6). The total number of sets directed at swordfish and at mixed species including swordfish also decreased from 8,331 in 1991 to 7,533 in 1993. However, sets inside the Hawaii EEZ decreased dramatically, while sets outside increased (Fig. 7). The main reasons for the shift in fishing areas were higher swordfish catch rates outside the EEZ, and emergency federal regulations implemented in 1991, which closed areas around the Hawaiian Islands.[9]

[9] The area around the northwestern Hawaiian Islands was closed due to interactions with the Hawaiian monk seal, *Monachus schauinslandi*, and near-shore areas around the main Islands were closed due to gear conflicts with small trolling and handline vessels (Western Pacific Fishery Management Plan amendments #3 and #5 respectively).

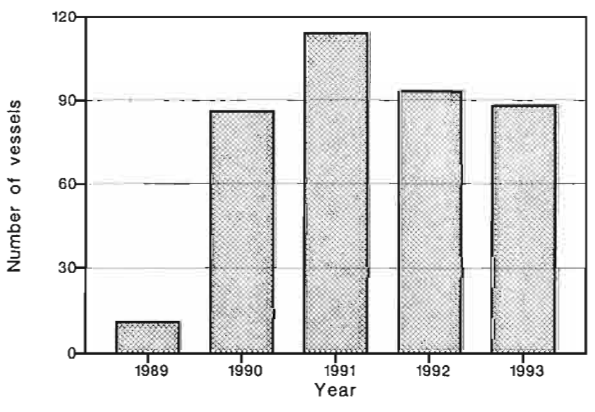

Figure 5
Hawaii-based longline vessels fishing for swordfish, 1989–93.

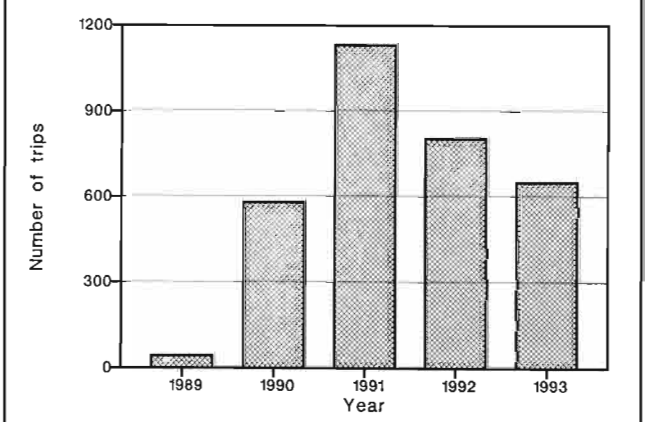

Figure 6
Trips by Hawaii-based longline vessels fishing for swordfish, 1989–93.

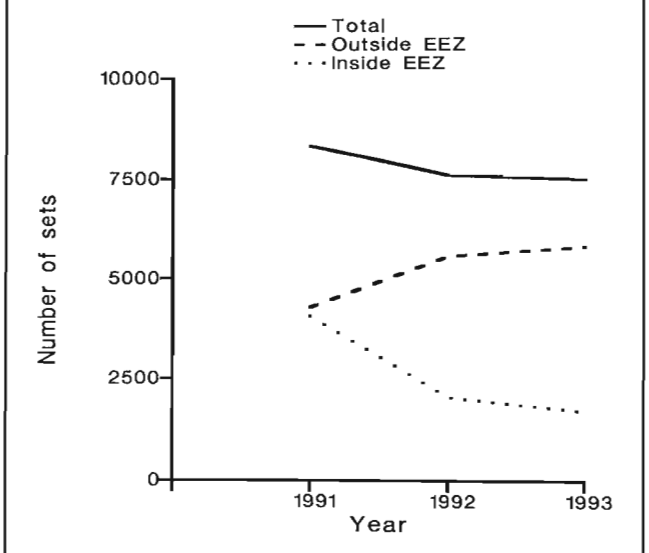

Figure 7
Sets made by Hawaii-based longline vessels fishing for swordfish, 1991–93, inside and outside the Hawaii EEZ.

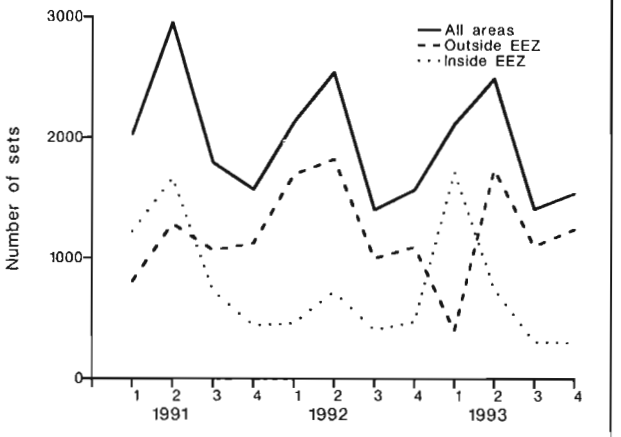

Figure 8
Quarterly number of sets made by Hawaii-based longline vessels fishing for swordfish inside and outside the Hawaii EEZ, 1991–93.

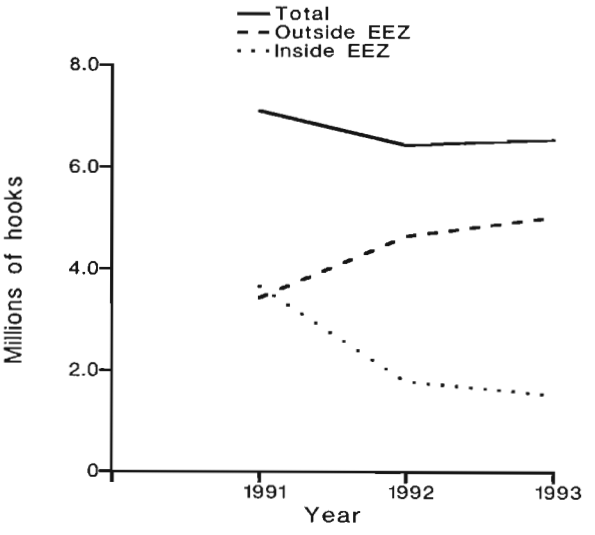

Figure 9
Hooks set by Hawaii-based longline vessels fishing for swordfish inside and outside the Hawaii EEZ, 1991–93.

Average number of sets per trip increased from 7.5 in 1991 to 11.6 in 1993. Sets per trip ranged from 5 to 27. The distance covered on trips and the number of fishing days increased. Transit time to the fishing grounds varies throughout the year, increasing during spring and summer (10–12 days) and decreasing during winter (5–7 days). The number of sets was highest during the second quarter and lowest in the third or fourth quarter of each year (Fig. 8).

Hooks

The total number of hooks set by longliners fishing for swordfish in 1991 was 7.1 million. Hooks set decreased to 6.5 million in 1992 and remained about the same in 1993 (Fig. 9). The decreased effort was a direct result of fewer vessels fishing in 1992 and 1993. Slightly more hooks were set inside than outside the EEZ in 1991, but more hooks were set on the high seas outside the EEZ in 1992 and 1993. The average number of hooks set per vessel per day changed little during 1991–93 (range: 842 hooks in 1992 to 868 hooks in 1993).

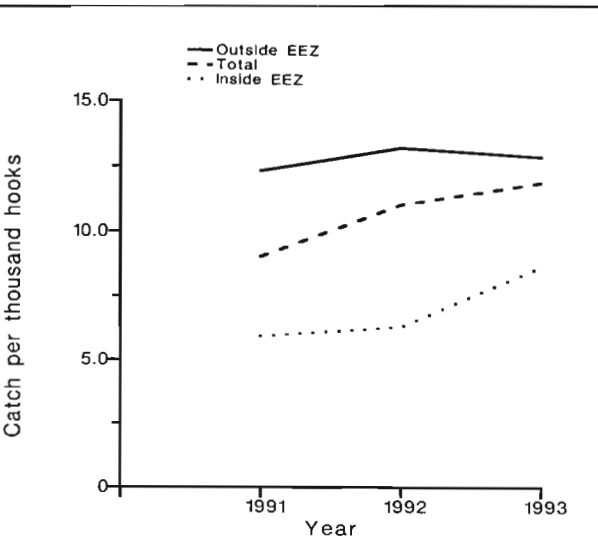

Figure 10
Hawaii swordfish catch per 1,000 hooks inside and outside the Hawaii EEZ, 1991–93.

CPUE

Swordfish CPUE (catch per 1,000 hooks for swordfish and mixed-target trips) rose from 9.0 in 1991 to 11.9 in 1993 (Fig. 10). Swordfish catch rates were much higher outside than inside the EEZ. However, fishermen commented that they had to travel farther from Hawaii to sustain high catch rates.

Swordfish CPUE varied considerably throughout the year (Fig. 11). CPUE outside the EEZ was consistently higher than CPUE inside; it peaked in the first quarter and was lowest in the second or third quarter. CPUE within the EEZ was highest in the second quarter and lowest in the fourth quarter. Peak CPUE outside the

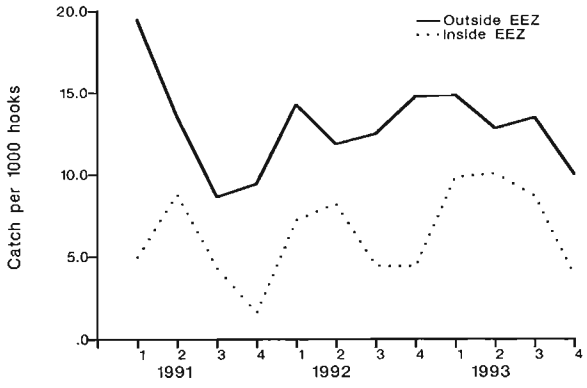

Figure 11
Quarterly swordfish catch per 1,000 hooks by Hawaii-based longline vessels, 1991–93.

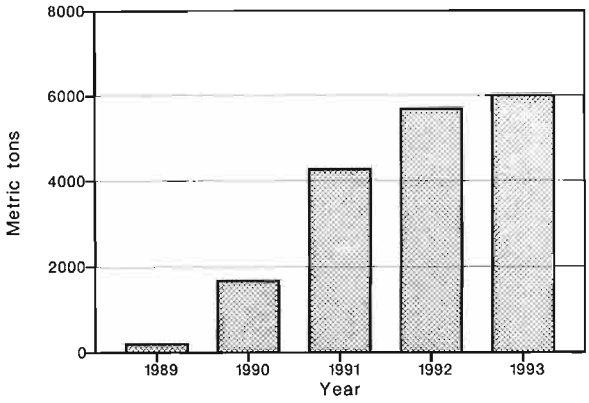

Figure 12
Swordfish landings by Hawaii-based longline vessels fishing for swordfish, 1989–93.

EEZ occurred one quarter earlier than peak CPUE within the EEZ throughout 1991–93.

Landings

Swordfish

It has been estimated that Hawaii-based longliners accounted for about 15% of the Pacific-wide harvest and about 42% of the total eastern central Pacific catch (WPRFMC[10]). Hawaii-based longline landings of swordfish increased dramatically between 1989 and 1992. In 1990, swordfish became the dominant species landed in Hawaii's pelagic fisheries (Ito[2]). Estimated landings of swordfish by longliners fishing for swordfish increased from about 200 t in 1989 to 6,000 t in 1993 (Fig. 12). Much of the increase during the past 3 yr is a result of fishermen acquiring more knowledge of the fishery, modifying fishing techniques, and expanding the area of fishing.

Species Composition

The swordfish component of total longline landings (by weight) ranged from 60% in 1989 to 74% in 1992, and averaged 68% over the 5-yr period (Fig. 13). Tunas were the next largest component of total landings. Bigeye tuna (10.8%), yellowfin tuna (6.0%), and albacore (2.4%) were the most important tuna species represented. Marlin landings were composed mostly of striped

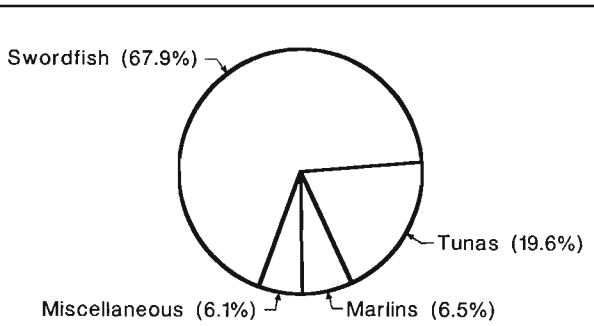

Figure 13
Species composition of landings by Hawaii-based longliners fishing for swordfish, 1989–93.

marlin (3.3%) and Pacific blue marlin (2.8%). Other marketable species, mainly mahimahi (dolphin), moonfish, ono, pomfrets, and sharks, contribute a small portion of the landings (all species combined, 6.1%).

Sharks are the largest portion (by number) of longline catch in Hawaii (Dollar[4,8,11]), but relatively few are landed. The estimates of sharks landed were of those sold fresh, and do not include sharks that had been finned. Mako and thresher sharks were sold as a fresh product but nearly all blue and other sharks were released. Since shark fins were not observed in the shoreside sample, the volume and value of shark fins could not be estimated. The names of pelagic species

[10] Western Pacific Regional Fishery Management Council. 1994. Amendment 7 to the Fishery Management Plan for the Pelagic Fisheries of the Western Pacific Region. WPRFMC, 1164 Bishop St., Rm. 1405, Honolulu, HI 96813.

[11] Dollar, R. A. 1994. Annual report of the 1993 western Pacific longline fishery. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Cent. Admin. Rep. H-94-06, 38 p. Honolulu Lab., SWFCS, NMFS, 2750 Dole St., Honolulu, HI 96822-2396

commmonly caught by longliners fishing for swordfish are listed in Table 4.

Size of Fish

Small and badly damaged (i.e. eaten by sharks or whales) swordfish have little or no commercial value and are often discarded at sea or given away to friends at port upon the vessel's return. Data on these fish were not available based on the current sampling protocol, and therefore the shore-side sample was biased towards a higher number of larger, more marketable fish.

Mean weight of whole swordfish showed a slight net increase in 1989–93 (Table 5), increasing from 67.0 kg in 1989 to 81.3 kg in 1992, then decreasing to 80.0 kg in 1993. Weights of individual fish were broadly distributed, with standard deviation exceeding 45 kg. Swordfish landed in 1989–93 (Fig. 14) appeared to have a higher frequency of large fish than those landed in 1987–88 (Ito[2]), prior to the exploitation of swordfish by Hawaii-based longliners. The weight-frequency distributions were bi-modal in most years, but uni-modal in 1990. The modes of these distributions were below the 71–80 kg size class in all years except 1993, when a mode was observed at 81–90 kg. The modal peaks shifted by 1–2 size classes each year.

Market

U.S. swordfish consumption increased dramatically during the early 1980's (Lipton, 1986). Swordfish landed in Hawaii are either sold by open auction or brokered by Hawaii seafood dealers; almost all are exported to the U.S. mainland. Swordfish are chilled with gel ice packs placed in the gut cavity, individually wrapped in plastic bags, packed in insulated air freight containers (LD-3's), and exported via air freight. The cost of freight and handling ranges from $0.25 to $0.50 a pound. Some of the more common destinations are Boston, New York, Los Angeles, and San Francisco.

Currently, the volume of swordfish consumed in Hawaii is low. Local consumers are not familiar with swordfish, and the demand for the product is low. Most local sales of swordfish are to restaurants.

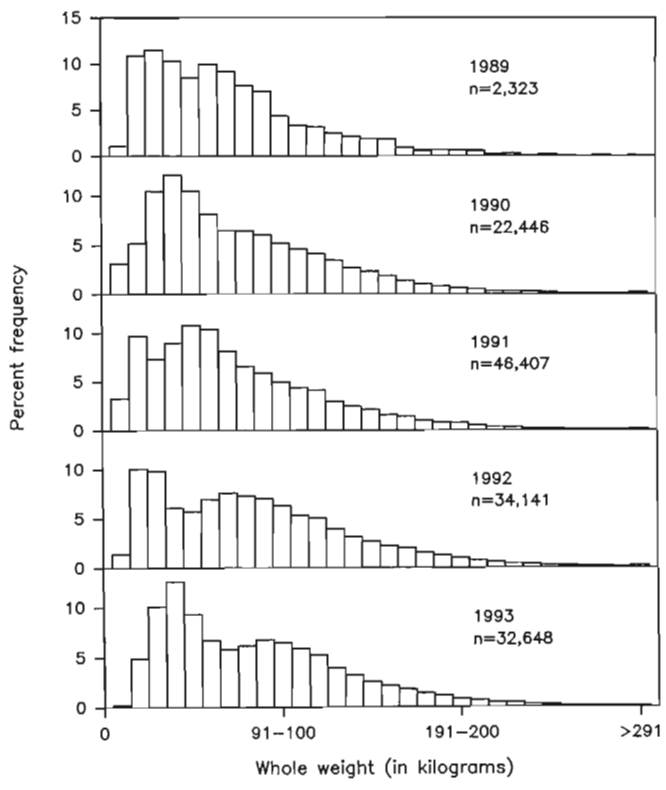

Figure 14
Annual weight-frequency distribution of swordfish landed by Hawaii-based longliners fishing for swordfish, 1989–93.

Ex-vessel Revenue

Estimated annual ex-vessel revenue generated by swordfish rose dramatically from 1989 through 1993, from $980,000 to $26.5 million (Fig. 15). Ex-vessel revenue for swordfish has been the highest of all fish species in Hawaii since 1991.

Average Prices

Estimated ex-vessel prices were based on dressed weights. The swordfish size categories used by the seafood market industry are: rats (<22.7 kg), pups (22.7–44.9 kg), and markers (>44.9 kg). Larger fish receive a higher unit price than smaller fish (Table 6). In general, mean prices for all sizes of swordfish were depressed in 1992–93. Estimated prices for rats and pups decreased from 1990 to 1992–93. Estimated price for markers declined from a high in 1990 to a low in 1992 and increased slightly in 1993.

Protected Species Interactions

Allegations of incidental takes of the Hawaiian monk seal, *Monachus schauinslandi*, in the proximity of certain islands and atolls of the northwestern Hawaiian Islands (NWHI), and a rapid

Table 4
Common and scientific names of common pelagic species caught by Hawaii-based longliners fishing for swordfish.

Common name	Scientific name
Billfish	
Swordfish	*Xiphias gladius*
Pacific blue marlin	*Makaira mazara*
Black marlin	*M. indica*
Striped marlin	*Tetrapturus audax*
Shortbill spearfish	*T. angustirostris*
Sailfish	*Istiophorus platypterus*
Tunas	
Bigeye tuna	*Thunnus obesus*
Yellowfin tuna	*T. albacares*
Albacore	*T. alalunga*
Northern bluefin tuna	*T. thynnus orientalis*
Skipjack tuna	*Katsuwonus pelamis*
Sharks	
Bigeye thresher	*Alopias superciliosus*
Shortfin mako	*Isurus oxyrinchus*
Oceanic whitetip shark	*Carcharhinus longimanus*
Blue shark	*Prionace glauca*
Miscellaneous requiem sharks	Carcharhinidae
Miscellaneous species	
Mahimahi (dolphin)	*Coryphaena hippurus*
Ono (wahoo)	*Acanthocybium solandri*
Moonfish	*Lampris guttatus*
Escolar	*Lepidocybium flavobrunneum*
Lancetfishes	*Alepisaurus* spp.
Pelagic stingray	*Dasyatis violacea*

Table 5
Mean whole weight and standard deviation (kg) of swordfish landed by Hawaii-based longline vessels fishing for swordfish, 1989–93.

	1989	1990	1991	1992	1993
Mean	67.0	73.8	71.3	81.3	80.0
S.D.	45.9	51.1	49.8	54.9	51.6

increase in the number of longline vessels in Hawaii prompted the WPRFMC to take regulatory action (55 FR 49285, on 27 November 1990). Regulations required longline vessels to maintain a fishing logbook, to have permits, and to take an observer if an operator intended to fish in the study zone around atolls and islands of the NWHI. Based on further reports of monk seals taken by the fishery, the study zone was closed permanently to longlining on 18 October 1991 (Regulation 56 FR 52214). According to logbook data, the area closures around the NWHI appear to have elimi-

Table 6
Hawaii ex-vessel swordfish prices (dollars per kg), 1989–93.

	1989	1990	1991	1992	1993
Rats (<22.7 kg)					
Mean	2.98	4.87	3.33	2.58	2.58
S.D.	1.23	1.15	1.21	1.21	0.95
Pups (22.7–44.9 kg)					
Mean	4.67	5.36	5.14	4.28	3.77
S.D.	1.12	1.39	1.12	1.41	1.08
Markers (>44.9 kg)					
Mean	5.34	5.47	5.40	4.94	5.07
S.D.	1.17	1.39	1.19	1.39	1.15

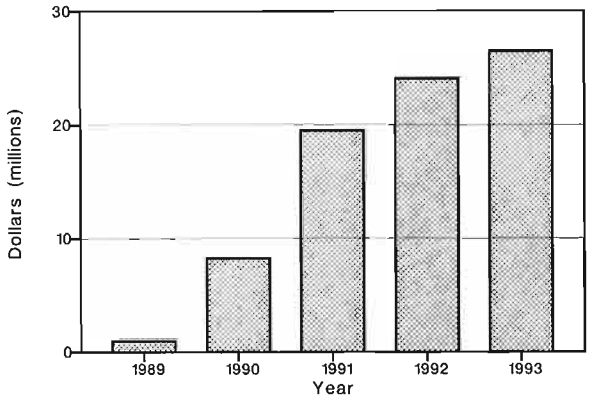

Figure 15
Swordfish ex-vessel revenue from the Hawaii-based longline fishery, 1989–93.

nated interaction incidents with Hawaiian monk seals. The area closure resulted in the loss of several banks where swordfish congregate during the spring months, a loss felt by many of the smaller longline vessels.

Due to uncertainty over the frequency of turtle interaction with longline gear based on logbook reports, the low level of authorized incidental take, and greater than anticipated level of longlining effort, an observer program was initiated.[12] The main objective of the observer program was to document incidental take of sea turtles and to verify logging of interactions by vessel operators. Observers began embarking on longline vessels whose captains volunteered to host them in the last quarter of 1993 (Dollar[11]). A regulation issued by the Secretary of Commerce in January 1994 made it mandatory for all permitted Hawaii-based longline vessels

[12] Endangered Species Act Section 7 Biological Opinion Consultation, conducted by NMFS in 1993.

to give notification 72 hr in advance of departure and to accommodate an observer. The initial authorized level of total turtle take and mortality was modified upward in light of the uncertainty regarding the actual level of incidental take.

The first objective of Amendment 7 to the Fishery Management Plan (FMP) for the Pelagic Fisheries of the Western Pacific Region is to regulate effort ". . . by limiting potential increases in effort in order to minimize the risk of adverse impacts on the longline fishery, other fisheries, the stocks, and protected resources such as sea turtles" (WPRFMC[10]). The limited entry and observer regulations reduce the chance of much higher levels of effort which might affect turtles, allow NMFS to more accurately estimate the impact of longlining on protected sea turtles, and may temporarily dissuade NMFS from imposing conservation measures either under regulations implementing the pelagics FMP, or under the Endangered Species Act based on the earlier authorized level of incidental take of sea turtles.

Conclusions

The Hawaii-based longline fishery for swordfish grew at a rapid pace beginning in 1989 and is now the largest commercial fishery in Hawaii. This growth has raised concern regarding over-utilization of the swordfish stock (WPRFMC[10]). However, the rate at which the fishery has grown in the past 2 yr has slowed in comparison to 1989–91. The number of vessels decreased in both 1992 and 1993. Total fishing effort, in number of sets and hooks, remained about the same during 1991–93 but the effort shifted to outside the EEZ. Swordfish CPUE changed little during 1991–93, but fishermen were making longer trips and fishing farther from Hawaii.

Swordfish landings, ex-vessel revenue, and size of fish have not declined in this new fishery. Indicators presented in this report are helpful in understanding the swordfish in the central Pacific. However, monitoring of the Hawaii-based longline fishery must be continued to see what kind of long-term impact it has on swordfish of the North Pacific.

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