U.S. SWORDFISH FISHERIES IN THE NORTH PACIFIC OCEAN[1]

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Abstract

This working paper presents catch, effort and catch-per-unit-effort information on U.S. fisheries for swordfish in the North Pacific Ocean. The major gear types employed by U.S. fisheries were harpoon, drift gill net, and longline. The oldest of the fisheries was the California harpoon fishery which dates back to the early 1900's. The California drift gillnet fishery began in the early 1980's and was the dominant fishery for swordfish throughout that decade. The gillnet fishery was succeeded by the longline fishery in 1990. The longline fishery continues to be the largest U.S. fishery for swordfish in the North Pacific Ocean. This report summarizes historical trends and recent developments of effort, catch, and CPUE for each of these fisheries.

INTRODUCTION

The United States is a major harvesting and consuming nation for swordfish (*Xiphias gladius*). U.S. fisheries in the Atlantic Ocean, Gulf of Mexico, and Pacific Ocean harvested 1,970 metric tons (mt) in 2021 (NMFS, Office of Science and Technology, 2022). Of this total, 766 mt (39%) were taken by the U.S. fisheries for swordfish in the North Pacific Ocean. This report summarizes historical trends and recent developments for these fisheries.

1. FISHERIES AND CATCHES

U.S. swordfish fisheries in the North Pacific Ocean was categorized by the major gear types employed (harpoon, drift gill net, and longline). Harpoon fishing for swordfish in California is the oldest of the three, dating back to the early 1900's (Coan et al., 1998). This fishery primarily supplied the local market for swordfish until the late 1970s. Harpoon catch peaked at 1,699 mt in 1978, subsided to a more typical level the following year, gradually decreased to a record low level in 2012 and 2015 and has remained low with 7 mt caught in 2021 (Fig. 1). The California drift gill net fishery began in 1980 and became the largest U.S. swordfish fishery in the North Pacific Ocean the following year. Catch by this fishery peaked at 2,990 mt in 1985 then trended down to a record low 13 mt in 2021. Since 2014, the U.S. west coast harpoon and gillnet fisheries targeting swordfish have been modifying their gear and using "deep-set buoy gear" to maximize economic benefits while minimizing non-target

catch. In 2021, 19 vessels participated in the buoy gear fishery and caught 49 mt of swordfish in the eastern Pacific Ocean. Shallow-set longline fishing for swordfish in Hawaii began in 1988 and grew rapidly. The shallow-set fishery, along with incidental catches of swordfish by the deep-set longline fishery for tunas, became the largest U.S. fishery in the North Pacific Ocean for swordfish by 1990 with catches peaking at 5,936 mt in 1993. Longline catches of swordfish decreased in the following years but it still is the largest U.S. fishery for swordfish in the North Pacific Ocean with catch at 690 mt in 2021. Some shallow-set longline vessels migrate between Hawaii and west coast states depending on the seasonality of swordfish and fishing conditions.

California Harpoon Fishery

The California harpoon fishery targeting swordfish began in the early 1900s, with catch recorded since 1918. Participation in the harpoon fishery was highest up through the mid-1980s and decreased slowly thereafter (Fig 2). There were 11 vessels fishing in 2021, down from 15 vessels in 2020**.**

The fishing area typically ranges from San Diego to Point Conception. Most fishing effort occurs within the southern California Bight. The fishery usually begins in June in waters off San Diego, peaks in July or August, and ends November.

Harpoon catch of swordfish varied substantially up through the mid-1980s, peaking at 1,699 mt in 1978. Swordfish landings by the California harpoon fishery declined in subsequent years. The swordfish catch was at record lows between 2012 and 2015 and was 7 mt in 2021 (Table 1).

Harpoon catch-per-unit-effort (CPUE) is calculated from logbook data and measured as number of fish per day. One important factor in the harpoon fishery is the use (or lack thereof) of spotter aircraft. Swordfish CPUE for vessels using spotter aircraft was about four times that of vessels that had no aircraft assistance. Aircraft were not used from 1980 through 1983. In general, the trend for swordfish CPUE with and without aircraft assistance was similar (Fig. 3). Both nominal CPUE time series had a high degree of variability with no clear trend. Harpoon swordfish CPUEs were at record lows in 2013 then increased the following three years. There was no CPUE for vessels with aircraft assistance in 2021 while CPUE for operations without aircraft assistance was 1.2 fish in 2021.

California Drift Gill Net Fishery

The California large-mesh drift gill net fishery began in the late 1970s. Swordfish, common thresher shark (*Alopias vulpinus*) and shortfin mako shark (*Isurus oxyrinchus*) were the targeted species (Hanan et al., 1993). The gill net fishery is seasonal with fishing activity beginning in the latter part of one year continuing into the following year. Swordfish catch by this fishery was initially low, but increased in the early 1980s when regulations were changed to allow for a greater level of catch. The number of active drift gill net vessels peaked at 220 during 1985-1986 then decreased gradually to a record low 6 vessels in 2020-2021 (Fig. 4).

Drift gill net fishing effort is concentrated in the Southern California Bight (waters from Point Conception to Mexico), but can extend beyond San Francisco to Oregon. The fishing effort occurs within the 200 mile U.S. EEZ. The drift gill net fishery begins in May and lasts about 10 months with peak swordfish catches in October and November.

Swordfish catch by the drift gill net fishery increased from 160 mt in 1980 to 2,990 mt in 1985. Since then, swordfish catches fluctuated on a decreasing trend to a record low 13 mt in 2021 (Table 1).

Drift gill net CPUE was relatively steady from the 1983-1984 season through 2000-2001 and showed much more variation in the following years. The recent trend for gill net CPUE was increasing from 2010-2011, reached a record 11.5 fish per set in 2016-2017 and was 1.97 fish per set in 2020-2021 (Fig. 5)

U.S. Longline Fishery

The fishing vessel *Magic Dragon* came to Hawaii and introduced shallow-set longline techniques for swordfish from Florida in 1988 (Ito et al., 1998). This segment of the longline fishery eventually grew and established Hawaii as a major domestic producer of swordfish. The number of Hawaii-based longline vessels increased rapidly from 37 vessels in 1987 to 141 vessels in 1991 as U.S. longliners from the Gulf of Mexico and the Atlantic swordfish fisheries joined the Hawaii-based longline fishery (Fig. 6). A federal moratorium was implemented in 1991 to limit the number of longline permits at 167 in light of this rapid expansion. Vessel participation never reached the limit. The moratorium on permits was replaced with a limited entry program in 1994 which capped participation in Hawaii's longline fishery at 164 vessels. Vessel activity ranged from 100 to 143 vessels up through 2015, with 141 active longline vessels in 2016. Seventeen U.S. longline vessels went shallow-set longline fishing for swordfish in 2021, up slightly from 14 in 2020.

The U.S. shallow-set longline fishery operating out of Hawaii was heavily regulated in 1999-2001 and prohibited from 2002 through early 2004 due to concerns with sea turtle interactions. Some of these vessels migrated to California to continue fishing for swordfish while other longline fishermen stayed in Hawaii and converted to deep-set longline fishing for tuna. Shallow-set longline fishing from Hawaii was reopened in April 2004 under new regulations promulgated by NOAA Fisheries. The new regulations were enacted to minimize interactions between longline gear and sea turtles included notifying NOAA Fisheries of an intent to deploy shallow-set gear before any such trips, 100 percent observer coverage on shallow-set trips, use only circle hooks and mackerel or mackerel-type bait, begin setting gear one hour after sunset, devices such as a dehooking device and large dip nets to help reduce injuries to sea turtles and a limit of 2,120 shallow sets per year for eligible Hawaii longline limited access permit holders. The limit on the number of shallow sets was removed in 2009. The rules first established a limit on the numbers of interactions between shallow-set longline gear and leatherback (*Dermochelys coriacea*) and loggerhead (*Caretta caretta*) sea turtles. A mandatory fishery closure was enacted when the respective limit for either species was reached. Although shallow-set longline from Hawaii was reopened in March 2004, 2005 was the first complete year this fishery operated under the new guidelines. Since sea turtle interaction limits were implemented, the shallow-set longline fishery closed on four occasions, March 2006 (loggerhead interaction limit), November 2011 (leatherback interaction limit), May 2018 (loggerhead interactions

and Court order) and March 2019 (loggerhead interaction limit). The loggerhead annual interaction limit was changed to a trip limit in September 2020. The shallow-set longline fishery did not reach either turtle interaction limit and remained open in 2020 and 2021.

The U.S. longline fishery in the north Pacific Ocean ranged from 10ºN to 40ºN latitude and from 125ºW to 175ºW longitude in 2021. The total range since 1991 extended from the equator to 50ºN latitude and from 130ºW to 175ºE longitude. Effort by the U.S. longline fishery increased to a record 66.3 million hooks set in 2021. The shallow-set longline fishery, which typically operates in latitudes north of the Hawaiian Islands on the high seas accounted for 1% of the total longline effort. Shallow-set longline effort for swordfish was typically highest during the first half of the year and the area with the highest swordfish catches was between 30º and 35º N latitude (Figure 7).

The preliminary estimate of the 2021 swordfish catch by the U.S. longline fishery in the North Pacific Ocean was 690 mt, up 27% from a thirty year low 543 mt in 2020 (Table 1). The COVID pandemic did adversely impact the shallow-set longline fishery from limited air cargo flights out of Honolulu and depressed mainland market in 2020 but has since recovered in 2021. Longline swordfish catches trended downward from peak catches in the early 1990s as many U.S. longline vessels dedicated more effort to set their gear deep and target bigeye tuna.

There is a substantial difference in nominal CPUE for swordfish (number of fish per 1,000 hooks) depending on targeting practice (Fig. 8). Shallow-set trips specifically target swordfish and had CPUEs about 100 times higher compared to swordfish CPUE on deep-set trips. Shallow-set swordfish CPUE ranged from 8.1 fish in 1995 to 11.9 fish in 1993 between 1991 through 1999 before Court-ordered regulations came into effect for shallow-set longline fishing. Swordfish CPUE on shallow-set trips were not included during 2000-2004 due to those regulatory issues that affected typical fishing patterns and practices. The first complete year in which the U.S. longline fishery operated under the new set of regulations intended to reduce sea turtle interactions was 2005 which shallow-set swordfish CPUE increased to 15.4. The shallow-set swordfish CPUE peaked at 19.1 fish in 2006 because shallow-set longline fishing was closed from March in the height of swordfish season after reaching the interaction limit for loggerhead sea turtle interactions. Swordfish CPUE then declined to 9.3 in 2010, remained relatively steady through 2017 and declined the following four years to a record low 7.0 fish in 2021. Shallow-set longline effort was very low in 2020, therefore quarterly statistics by set type could not be presented to ensure confidentiality of logbook data. Long-term shallow-set swordfish CPUE by quarter was highest in the first quarter and lowest in the third (Figure 9a). The annual mean deep-set swordfish CPUE was 0.1. Deep-set swordfish CPUE was higher during 1991-1995, remained relatively constant from 2000 through 2018 and decreased 2019-2021. The mean quarterly deep-set swordfish CPUE was highest in the second quarter and lowest in the first quarter (Figure 9b).

The mean weight of swordfish in the shallow-set sector was 16.2 kgs higher than swordfish in the deep-set sector in 2021. The weight-frequency distribution for the shallow-set and deep-set swordfish histograms differed with a higher proportion of small swordfish in the deep-set longline weight-frequency histogram. The shallow-set swordfish histogram shows a dominant mode of fish at the 26-50 kg interval while the deep-set histogram has a dominant mode of fish in the 1-25 kg interval (Figures 10a & 10b).

2. DATA SOURCES

Hawaii

Federal longline logbooks have been mandatory for Hawaii-based longline vessels since November 1990. The Federal longline logbook data provide detailed information among the various data sets for the Hawaii-based longline fishery. Logbooks must be maintained by vessel operators and submitted after each trip. Data recorded in the logbooks include: vessel, date, fishing location, effort and gear configuration, catch by species, and interactions with protected species. Coverage of the Federal longline logbook data is estimated to be very close to 100%. The U.S. longline fishery transitioned from paper logbooks to an electronic logbook data collection system from 2018.

From 1987-2000, market data on longline landings were collected at the Honolulu fish auction by the NMFS. Individual fish weights were obtained from 25%- 90% of fish landed by the Hawaii-based longline fishery and recorded to the nearest half pound. Weights were raised to an estimated whole weight when processing or damage was observed. Sex of fish was not available as most swordfish were landed in processed form (headed, finned, and gutted). The responsibility for collecting market data was transferred to the State of Hawaii, Division Aquatic Resources (DAR) in 2000. Coverage of the DAR market data is estimated to be in excess of 95%.

Data collection by at-sea observers was initiated in 1990 when Hawaii-based longline vessels volunteered to take observers aboard to investigate longline fishery interactions with Hawaiian monk seals (*Monachus schauinslandi*) (Dollar, 1991). A mandatory observer program began in February 1994 (Dollar, 1994) using statistical guidelines to improve the estimates of incidental takes of sea turtles (Dinardo, 1993). Observers covered about 5% of the total longline trips from 1994-1999. Observer coverage was then increased in response to new regulations and has remained at or above 20% for the deep-set tuna sector of the Hawaii-based longline fishery from the latter part of 2000 through 2016. Beginning in 2004, observer coverage on shallow-set trips targeting swordfish was 100%. The observer data are similar to logbooks, although more detailed. The primary purpose for the data collected by the observer program is to assess the fleet-wide impact of longlining on protected and endangered species and these data are also used for stock assessment purposes.

California

There are four types of data on the California-based longline fishery: CDFG landing receipts; CDFG and Federal daily longline logbooks; dockside sampling of swordfish landings collected by the CDFG; and data collected at sea by NMFS observers. Landing receipts have been collected by the CDFG since the start of the fishery in 1991. Daily longline logbook data were first collected by the CDFG on a voluntary basis from 1993 to 1994. Collecting and submitting CDFG longline logbook data (Pacific Offshore) became mandatory in 1995. This system was replaced in 1999 by a NMFS High Seas longline logbook data reporting system in response to Federal requirements under the High Seas Fisheries Compliance Act. Data recorded in the logbooks include: vessel, date, fishing location, effort and gear configuration, numbers of fish caught by species, and number of interactions with protected species. Collection of size samples from longline-caught swordfish began in 1991 in conjunction with drift gill net swordfish sampling (Childers and Halko, 1994) but was discontinued in 2000. NMFS began placing observers on longline vessels from 2001 to investigate interactions with sea turtles and collect detailed catch and effort data. Some size data are also collected by observers.

The California drift gill net fishery is monitored by use of CDFG landing receipts, vessel logbooks, size sampling, and a CDFG and NMFS observer program. Landing receipts have been collected by the CDFG since the fishery's inception in 1980. Drift gill net fishermen are required to collect logbook data on daily operations and catch. Location is recorded in 10 minute squares. CDFG sampled drift gill net swordfish catch for length at local markets beginning in 1981. An observer program to monitor the drift gill net fishery was initiated and maintained by CDFG from 1980 to 1989 and has continued since 1990 under NMFS. The observer program is used to monitor bycatch, especially of marine mammals. The NMFS observer program also collects size samples of swordfish.

The California harpoon fishery is also monitored through landing receipts, vessel logbook, and size sampling by the CDFG. Landings have been collected since the early 1900s through a landings receipt system. A mandatory vessel logbook system for the harpoon fishery started in 1974. These logbooks are completed daily and record catches by location in the CDFG 10-minute square codes. Information on aircraft assistance, sight information: jumping (over the water), underwater or finning (above the water), harpooning success, and areas searched is also included. Size sampling of swordfish landings began in 1981 in conjunction with the drift gill net sampling. The sampling program was discontinued in 2000.

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Table 1.--U.S. North Pacific swordfish catch* (metric tons), 1970-2021.

	FISHERY				
YEAR	Longline [2]	Gillnet	Harpoon	Other	Total
1970	5	---	612	10	627
1971	1	---	99	3	103
1972	0	---	171	4	175
1973	0	---	399	4	403
1974	0	---	406	22	428
1975	0	---	557	13	570
1976	0	---	42	13	55
1977	17	---	318	19	354
1978	9	---	1,699	13	1,721
1979	7	---	329	57	393
1980	5	160	566	62	793
1981	3	461	267	20	751
1982	5	911	156	43	1,115
1983	5	1,321	58	378	1,762
1984	3	2,101	96	678	2,878
1985	2	2,990	305	108	3,405
1986	2	2,069	291	113	2,475
1987	24	1,529	235	35	1,823
1988	24	1,376	198	70	1,668
1989	218	1,243	62	63	1,586
1990	2,437	1,131	64	48	3,680
1991	4,535	944	20	50	5,549
1992	5,762	1,356	75	48	7,241
1993	5,936	1,412	168	165	7,681
1994	3,807	792	157	28	4,784
1995	2,981	771	97	35	3,884
1996	2,848	761	81	20	3,710
1997	3,393	708	84	18	4,203
1998	3,681	931	48	26	4,686
1999	4,329	606	81	36	5,052
2000	4,834	649	90	33	5,606
2001	1,969	375	52	19	2,415
2002	1,524	302	90	3	1,919
2003	1,958	216	107	21	2,302
2004	1,185	182	69	51	1,487
2005	1,622	220	77	10	1,929
2006	1,211	443	71	9	1,734
2007	1,735	490	59	6	2,290
2008	2,014	405	48	25	2,492
2009	1,817	253	50	6	2,125
2010	1,676	62	37	3	1,778
2011	1,623	119	24	5	1,771
2012	1,395	118	5	8	1,525
2013	1,270	95	6	14	1,385
2014	1,665	127	6	13	1,811
2015	1,516	99	5	20	1,640
2016	1,092	173	25	57	1,348
2017	1,618	179	28	51	1,876
2018	1,052	148	10	71	1,281
2019	734	52	11	190	987
2020	543	35	6	128	712
2021	690	13	7	56	766

* Based on estimated whole weight. Dashes indicate no fishery.

Figure 1.–Catch by the U.S. swordfish fisheries of the North Pacific Ocean, 1970-2021.

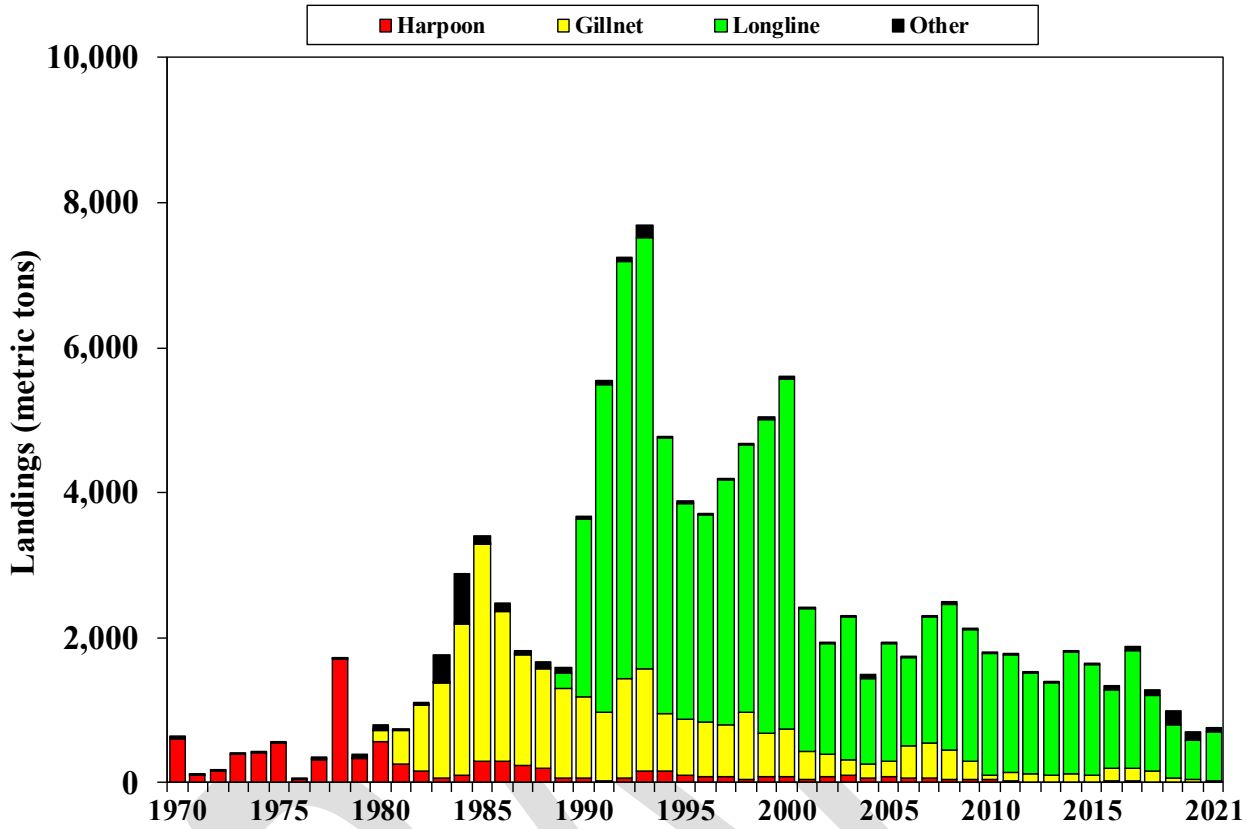


Figure 2.--Number of California harpoon vessels, 1974-2021.

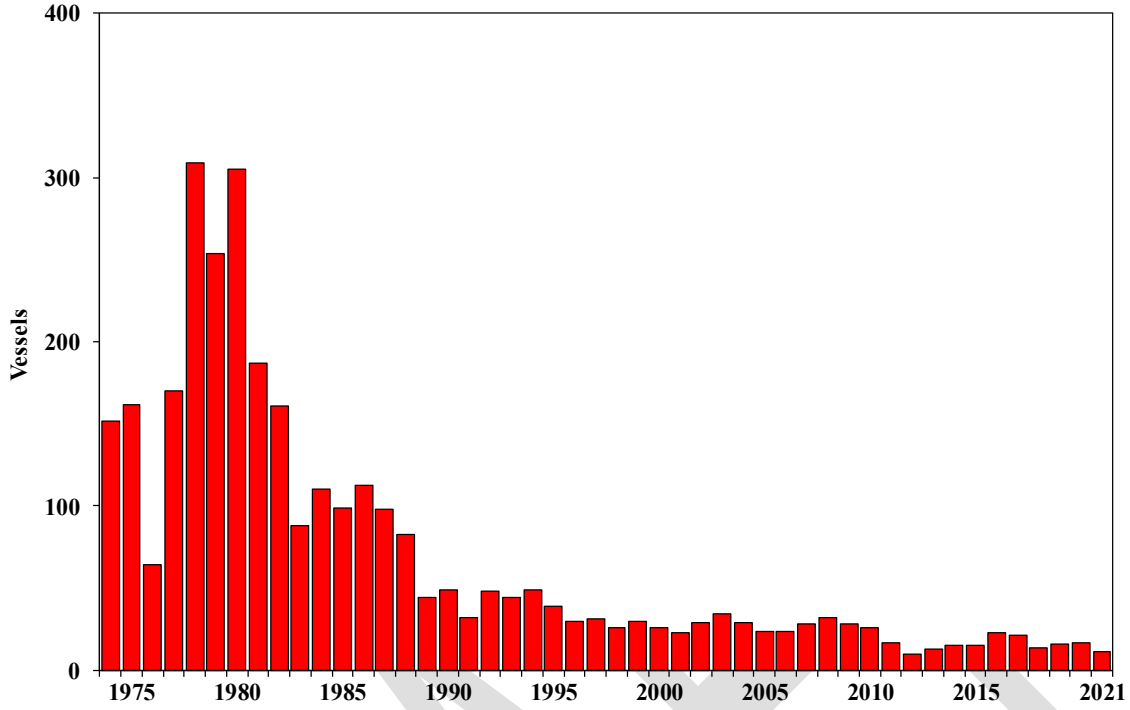


Figure 3.--California harpoon fishery swordfish catch-per-unit-effort (CPUE), 1974-2021.

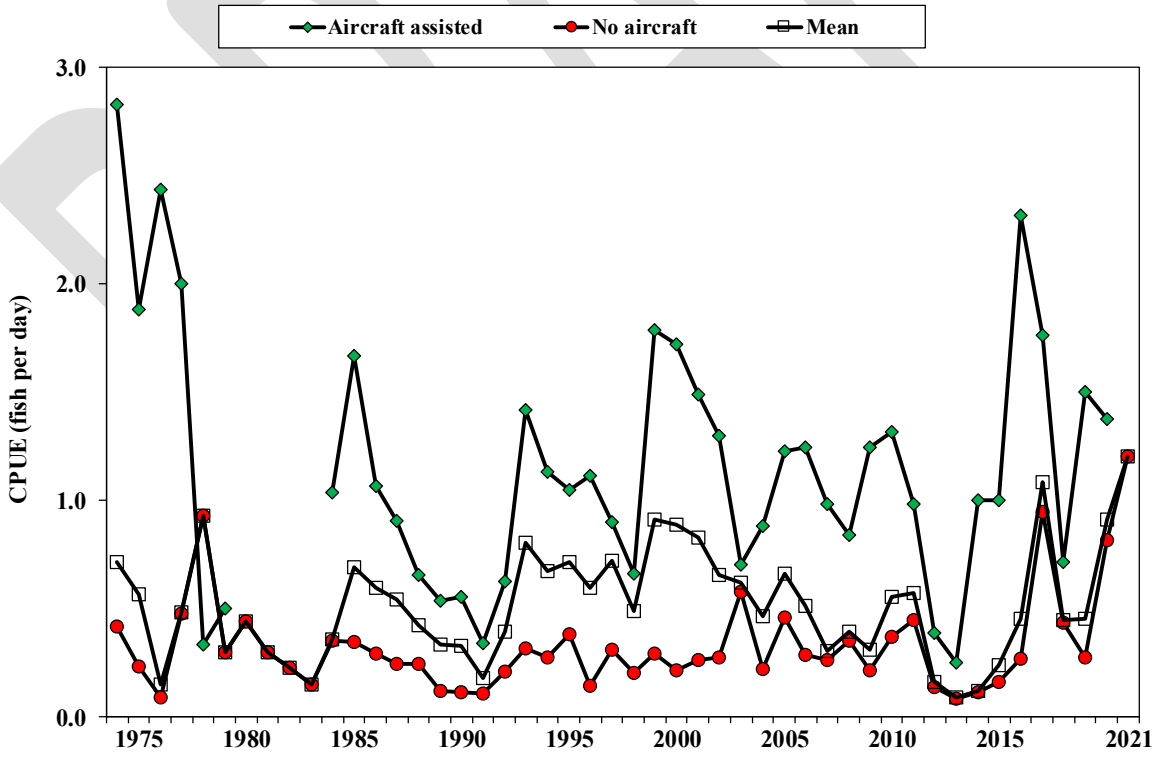


Figure 4.--Number of California drift gill net vessels, 1981-1982 through 2020-2021.

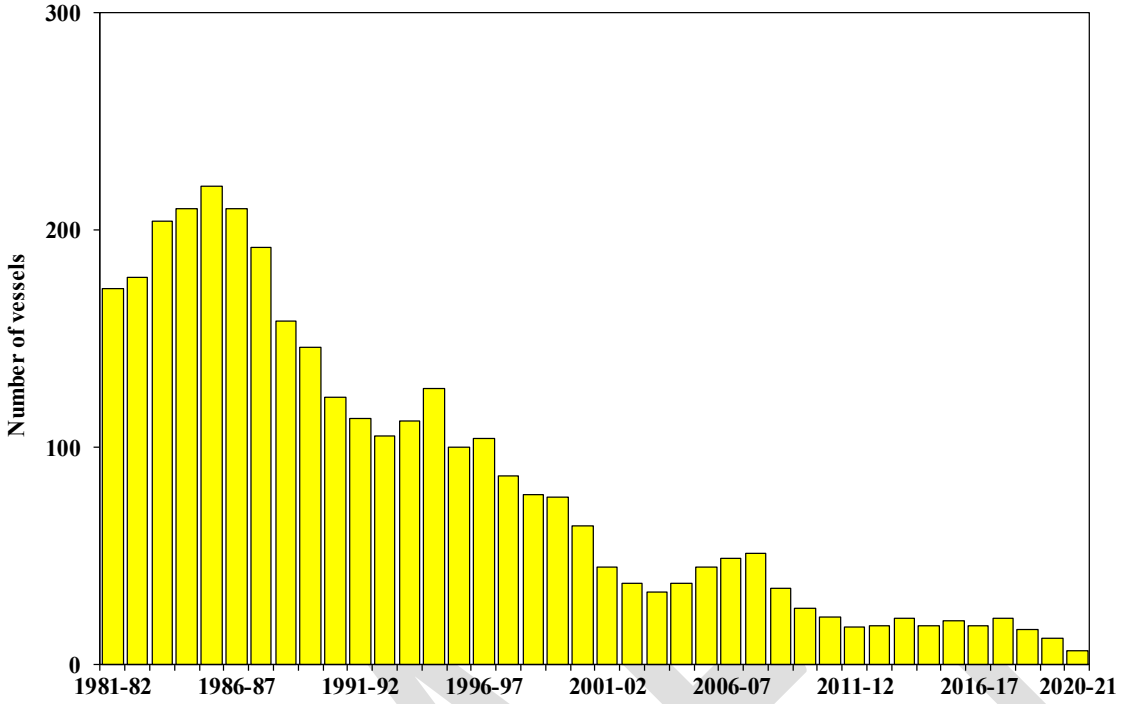


Figure 5.—California drift gill net CPUE, 1981-1982 through 2020-2021.

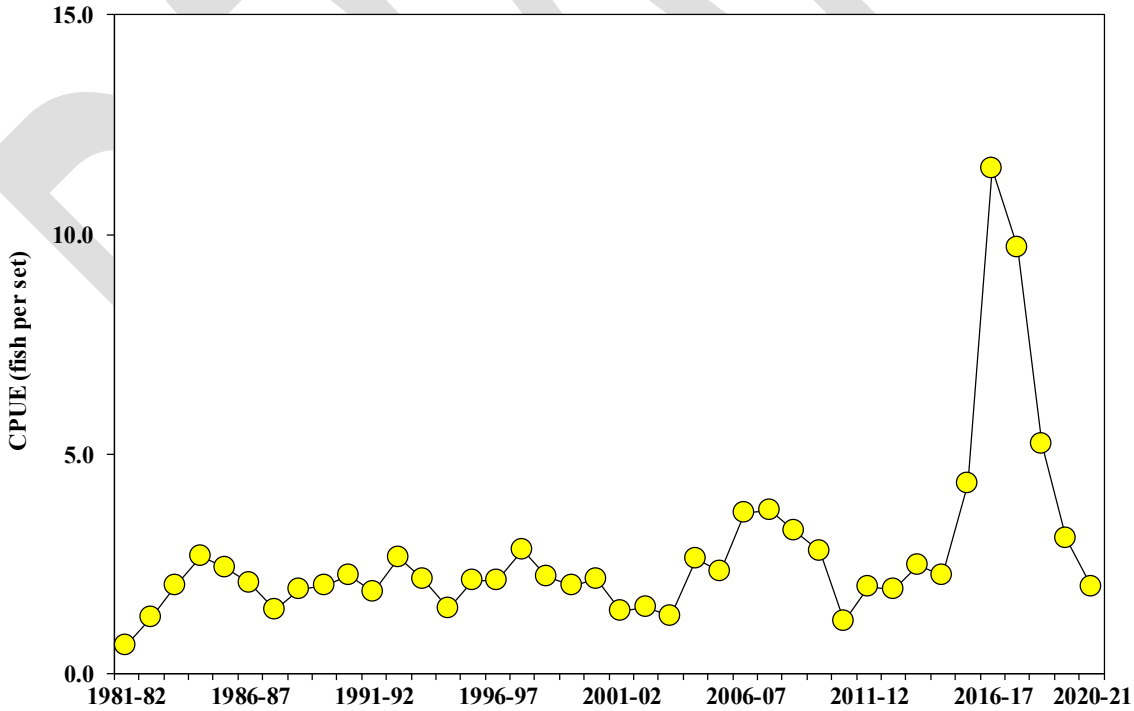


Figure 6.–Number of active U.S. longline vessels in the north Pacific Ocean, 1987-2021.

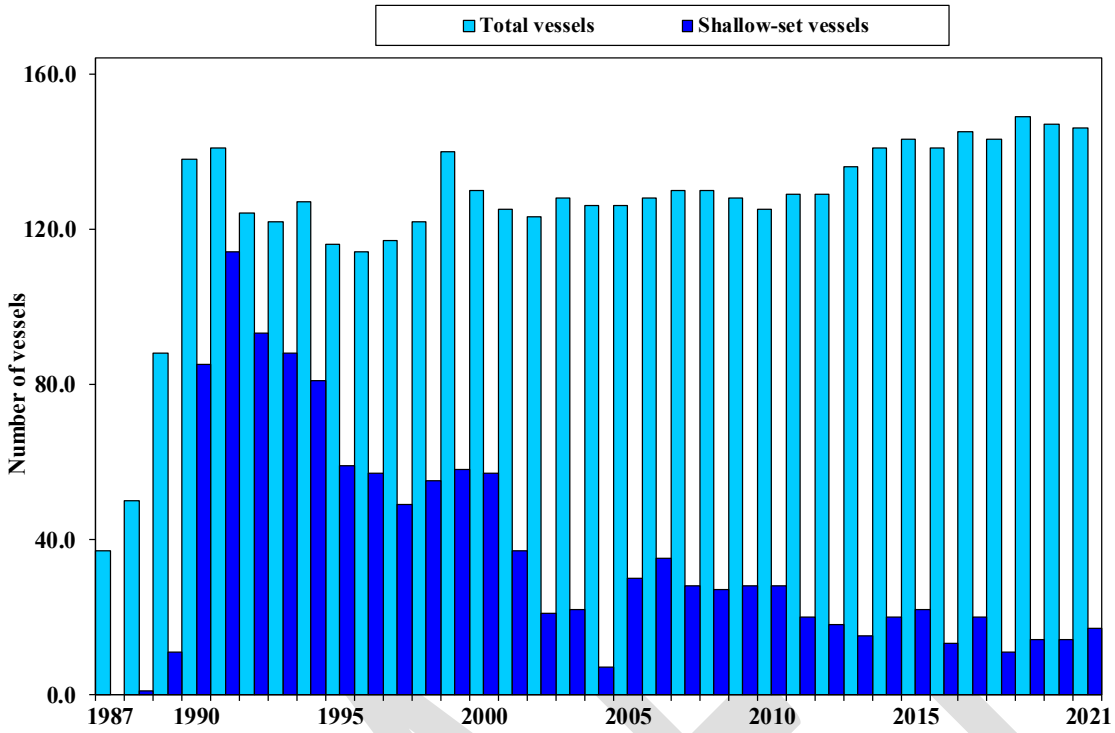


Figure 7.–U.S longline swordfish catch (in numbers) by area, 2021.

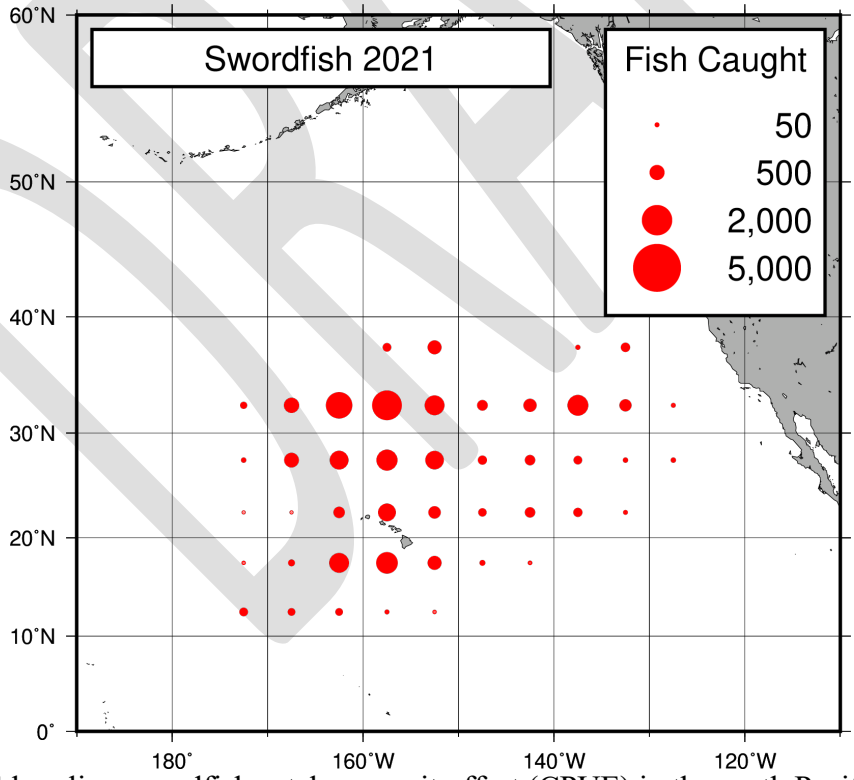


Figure 8.–U.S longline swordfish catch-per-unit-effort (CPUE) in the north Pacific Ocean, 1991-2021.

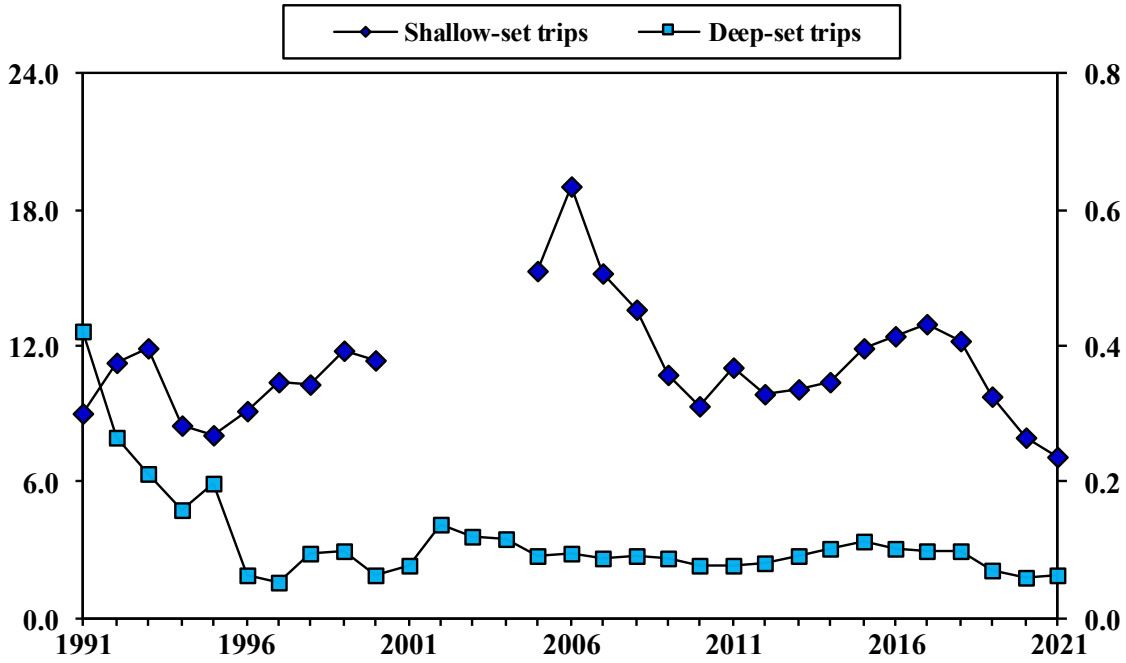
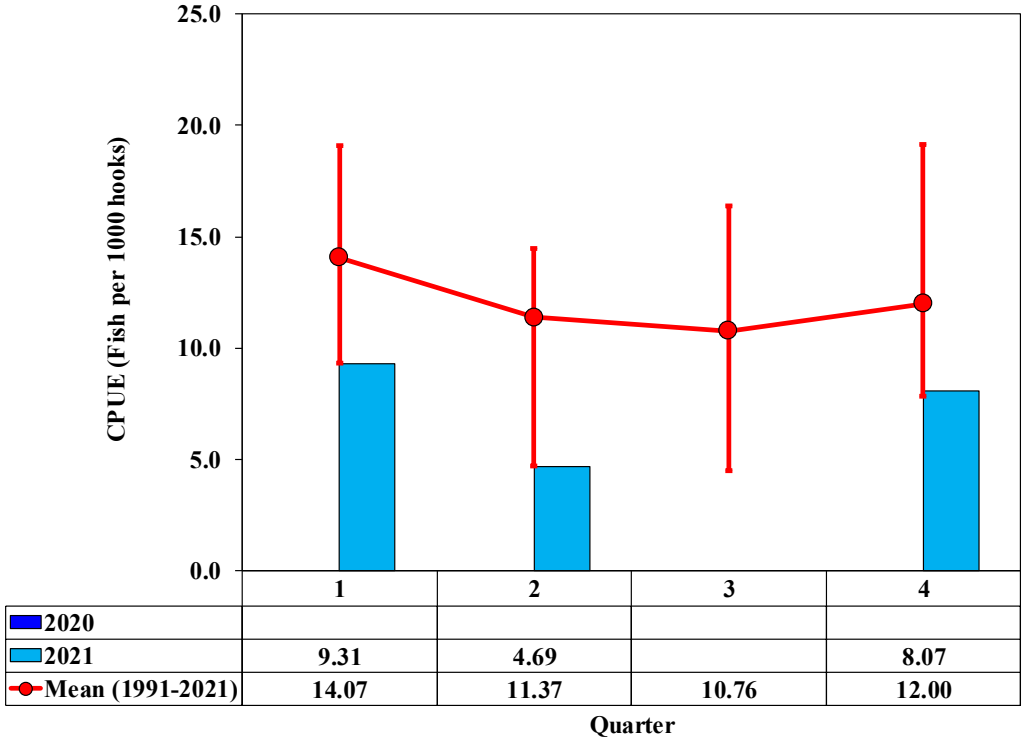
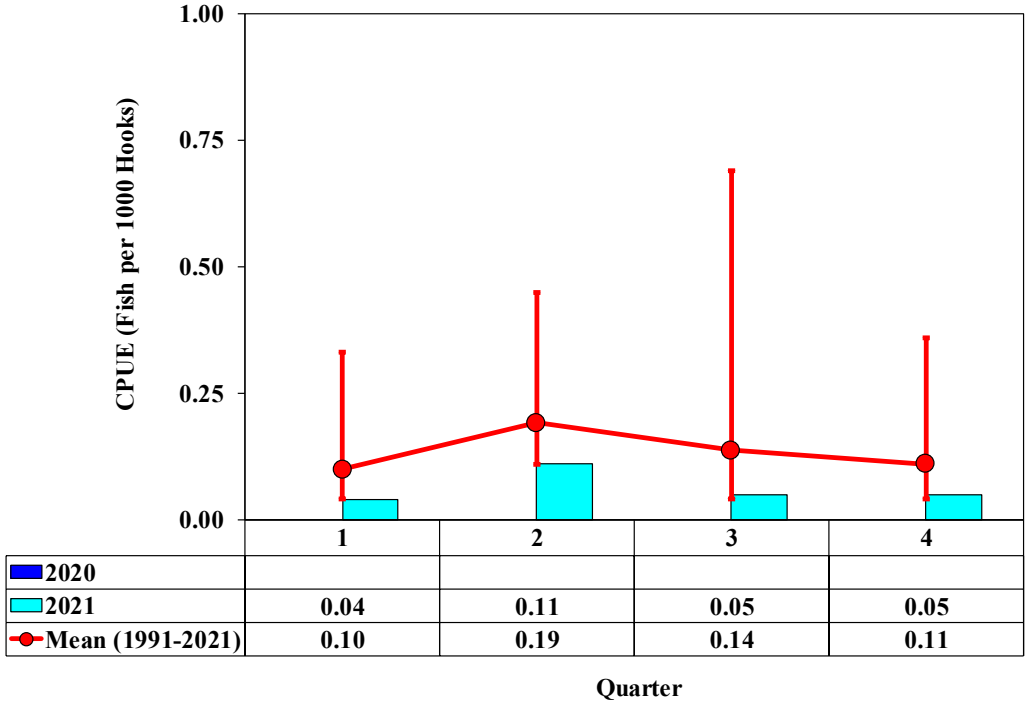

Shallow-set trips
Deep-set trips
24.0
18.0
12.0
6.0
0.0
0.8
0.6
0.4
0.2
0.0
1991
1996
2001
2006
2011
2016
2021

Figure 9a.–Quarterly U.S. longline shallow-set swordfish CPUE, 1991-2021.



	1	2	3	4
2020				
2021	9.31	4.69		8.07
Mean (1991-2021)	14.07	11.37	10.76	12.00

Figure 9b.–Quarterly U.S. longline deep-set swordfish CPUE, 1991-2021.



	1	2	3	4
2020				
2021	0.04	0.11	0.05	0.05
Mean (1991-2021)	0.10	0.19	0.14	0.11

Figure 10a.–U.S. longline shallow-set swordfish weight-frequency, 2021.

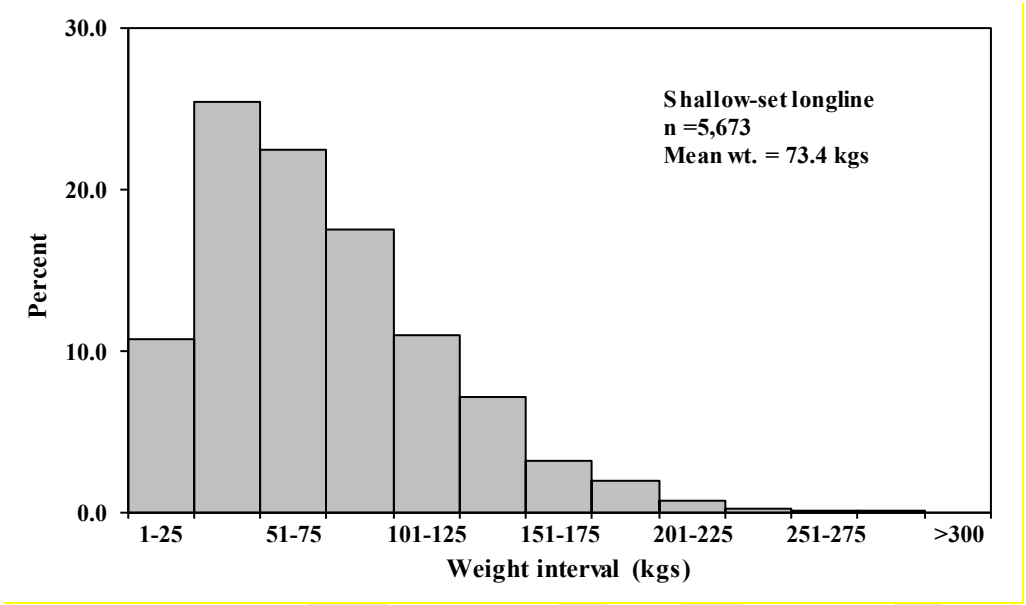


Figure 10b.–U.S. longline deep-set swordfish weight-frequency, 2021.