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# PLENARY 09

*21st Meeting of the*
*International Scientific Committee for Tuna*
*and Tuna-Like Species in the North Pacific Ocean*
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# National Report of U.S.A.
# (U.S.A. Fisheries and Research on Tuna and Tuna-like Fisheries in the North Pacific Ocean)[1]

NOAA, National Marine Fisheries Service
United States

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1 Prepared for the Twenty-first Meeting of the International Scientific Committee on Tuna and Tuna-like Species in the North Pacific Ocean (ISC), 14-19 July 2021. Document not to be cited without permission of the author.

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## SUMMARY

Various U.S.A. fishing fleets harvest tuna and tuna-like species in the North Pacific Ocean (NPO) from coastal waters of North America to the archipelagoes of Hawaii, Guam and the Commonwealth of the Northern Mariana Islands (CNMI) and American Samoa in the central and western Pacific Ocean (WCPO). Small-scale gillnet, harpoon, tropical pole-and-line, troll, and handline fleets operate primarily in coastal waters, whereas large-scale purse seine, albacore troll, and longline fleets, which account for most of the tuna catches, operate both within the U.S.A. Exclusive Economic Zones and on the high seas. Thousands of small-scale troll and handline vessels operate in waters around the tropical Pacific Islands; however, these fleets account for only a minor fraction of the total tuna catch.

The National Oceanic and Atmospheric Administration (NOAA) Fisheries continued to conduct research in 2020 on Pacific tunas and associated species at its Southwest and Pacific Islands Fisheries Science Centers and also in collaboration with scientists from other organizations.

Fishery monitoring and socio-economic research was conducted on tunas, billfishes, and bycatch species in U.S.A. Pacific coastal and high-seas fisheries. As in previous years, fishery monitoring and angler effort information were compiled in 2020, and economic performance indicators in the Hawaii longline and small-boat fisheries were assessed.

Stock assessment research on tuna and tuna-like species was conducted primarily through collaboration with participating scientists of the International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC) and international Regional Fisheries Management Organizations (RFMOs).

NOAA Fisheries successfully completed biological and oceanographic research on tunas, billfishes, and sharks. Reported research includes: natal origin of Pacific bluefin tuna, foraging studies of swordfish and pelagic sharks, shark post-release survival rates, effects of hook type on shortfin mako, quantification of swordfish density distribution, effects of catch rate composition on assessment of protected area impacts, environmental predictors of tuna recruitment, and an update to the 2019 Western and Central North Pacific Ocean Striped Marlin Stock Assessment.


## 1. INTRODUCTION

Various U.S.A. fleets harvest tuna and tuna-like species in the North Pacific Ocean. Large-scale purse seine, albacore troll, and longline fisheries operate both in coastal waters and on the high seas. Small-scale coastal purse seine, gillnet, harpoon, troll, handline and recreational hook and line fisheries, as well as commercial and recreational troll and hook and line fisheries, usually operate in coastal waters. Overall, the range of U.S.A. fisheries in the North Pacific Ocean is extensive, from coastal waters of North America to Guam and the Commonwealth of the Northern Mariana Islands (CNMI) and American Samoa in the western Pacific Ocean and from the equatorial region to the upper reaches of the North Pacific Transition Zone.

In the U.S.A., the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries or federal agency) shares monitoring responsibilities for tunas and billfishes with partner fisheries agencies in the states of California, Oregon, Washington, Hawaii, and territories of American Samoa, Guam, and the CNMI. NOAA's West Coast Regional Office (WCRO) and the Southwest Fisheries Science Center (SWFSC) in California, and the Pacific Islands Regional Office (PIRO) and the Pacific Islands Fisheries Science Center (PIFSC) in Hawaii conduct federal monitoring. NOAA Fisheries monitors the landings and sales records, federally-mandated logbook statistics on fishing effort and catch, observer data, and biological sampling data. In California, Washington, and Oregon, landings receipts are collected by state agencies and maintained in the Pacific Fisheries Information Network (PacFIN) system (http://pacfin.psmfc.org/). Some state agencies also collect logbook and size-composition data. In the WCPO, monitoring by partner agencies also involves market sampling and surveys of fishing activity and catch and is coordinated by the Western Pacific Fishery Information Network (WPacFIN) system (http:// http://www.pifsc.noaa.gov/wpacfin/), a federally funded program managed by the PIFSC. The SWFSC, WCRO, PIFSC, and PIRO share management of data on U.S.A. Pacific fisheries for tuna and tuna-like species.

This report provides information on the number of active vessels by fleet and their catches of tunas and billfishes in the NPO based on the data available through 15 March 2021. Data for 2020 are considered preliminary and are subject to change. Although the report is focused on tunas and billfishes, many of the fisheries' catch includes catch of other pelagic fish important to the fishing fleets and local economies; catch data for these species are not included in this report but are included in the ISC data submissions.

NOAA Fisheries also conducts scientific research programs in support of marine resource conservation and management both domestically and internationally. These studies include stock assessments, biological and oceanographic studies, socio-economic analysis, and more. This report includes highlights of recent and ongoing scientific work by NOAA Fisheries of relevance to the ISC.

## 2. FISHERIES

### 2.1. Purse Seine

Currently, the U.S.A. purse seine fishery consists of two separate fleets, one composed of large purse-seine vessels that operate in the WCPO, and a small coastal purse-seine fleet that operates in the eastern Pacific Ocean (EPO). Figure 1 shows the spatial distribution of the U.S.A. Western Pacific purse-seine fishery. Historically, the purse-seine fishery started in the EPO in the mid- 1900s and most catch came from that ocean area until 1993 when vessels moved to the WCPO in response to dolphin conservation measures in the EPO. Vessels also moved to the WCPO because fishing access was granted by the South Pacific Tuna Treaty (SPTT) in 1987. The WCPO fleet operates mainly in areas between 10°N and 10°S latitude and 130°E and 150°W longitude, with the majority of the fishing effort south of the equator. The EPO fleet operates off the coast of Southern California. The number of unique U.S.A. purse-seine vessels (WCPO and EPO) fishing north of the equator decreased from a high of 74 in 1988 to 11 in 2006 (Table 1) then increased to 46 in 2009. In 2020, there were 35 purse-seine vessels fishing in the North Pacific. Prior to 1995, the fleet fished mainly on free-swimming schools of tunas in the WCPO and on schools associated with dolphins in the EPO. Since 1995, most catches have been made on fish aggregation devices and other floating objects in the WCPO. The California-based EPO purse-seine fishery targets mostly small coastal pelagics, such as sardine, mackerel and squid, and targets tunas opportunistically. Larger vessels from the WCPO occasionally fish in the EPO.

The Inter-American Tropical Tuna Commission (IATTC) monitors the purse-seine fleets fishing in the EPO. U.S.A. purse-seine vessels fishing in the WCPO have been monitored by NOAA Fisheries under the SPTT since 1988. Logbook and landings data are submitted as a requirement of the Treaty (100% coverage). Landings are sampled for species and size composition as vessels land their catches in American Samoa by NOAA Fisheries personnel and by SPC samplers in other ports (coverage approximately 1-2% of landings). The Forum Fisheries Agency (SPTT Treaty Manager) places observers on 100% of the vessel trips. In the EPO, logbooks are submitted by vessel operators to NOAA Fisheries or the IATTC, and landings are obtained for each vessel trip from canneries or fish buyers. IATTC observers are placed on all large purse-seine vessels in the EPO.

### 2.2. Longline

The U.S.A. longline fishery targeting tunas and tuna-like species in the NPO is made up of the Hawaii-based fleet, the California-based fleet, and the American Samoa-permitted fleet in the NPO. Vessels operated freely in an overlapping area managed by two domestic management regimes until 2000 when domestic regulations placed restrictions on moving between the two domestic management regimes. The Hawaii-based component of the U.S.A. longline fishery currently comprises a majority of the vessels, fishing effort, and catch.

Regulatory restrictions, due to interactions with endangered sea turtles, curtailed Hawaii-based longline effort for swordfish (*Xiphias gladius*) in 2000 and 2001 followed by a prohibition altogether in 2002 and 2003, during which the Hawaii-based longline fishery targeted tunas exclusively. The Hawaii-based fishery for swordfish (shallow-set longline) was reopened in April 2004 under a new set of regulations to reduce sea turtle interactions. The year 2005 was the first complete year in which the Hawaii-based longline fishery was allowed to target swordfish.

In the following year, the shallow-set longline fishery reached the annual interaction limit of 17 loggerhead sea turtles (*Caretta caretta*) and the fishery was closed on 20 March 2006. The majority of vessels that targeted swordfish converted to deep-set longline and targeted tunas for the remainder of the year. The Hawaii-based shallow-set longline fishery also closed on 18 November 2011 as a result of reaching the annual interaction limit of 16 leatherback turtles. In the Hawaii-based shallow-set longline fishery in 2012, the interaction limits for leatherback (*Dermochelys coriacea*) and loggerhead sea turtles were increased for the Hawaii shallow-set longline fishery to 26 and 34, respectively. Leatherback and loggerhead sea turtle interactions have been less than their respective limits since the levels were revised, though the fishery was closed in both 2019 and 2020 due to a court order that lowered the turtle-take limits back to the 2011 levels (17 loggerhead turtles annually) and the shallow set fishery reached the revised loggerhead turtle take limit.

The number of vessels in the California-based fishery has always been low compared to the Hawaii-based fishery, and composed mainly of vessels that target swordfish. Most vessels with landings to California also participated in the Hawaii-based fishery. The California-based shallow-set longline fishery for swordfish was closed in 2004, resulting in relocation of most of those vessels back to Hawaii. Less than three West Coast permitted vessels fished between 2005 and 2018 using deep-set longline to target tunas. In 2020, three vessels participated under the West Coast permit. Additionally, twelve Hawaii-permitted vessels reported landings in California in 2020.

In the North Pacific, the longline fishery extended from 125°W, just outside the U.S.A. West Coast EEZ to 175°W longitude and from 10°N to almost 40°N latitude in 2018 (Figures 2 and 3). The total number of vessels participating in the longline fishery increased from 36 in 1985 to a relative high of 141 vessels in 1991 (Table 1). Since then, the number of vessels has varied from 114 to a record 149 in 2009, 147 vessels participating in 2020. In Hawaii and California, swordfish are generally landed dressed (headed, tailed, and gutted). Tunas and large marlins are landed gilled and gutted while other bony fishes are usually landed whole. a relatively low volume of sharks are landed headed and gutted. In Hawaii, the landed catch biomass is the reported total fish weight by species recorded at the fish auction. Dressed weights are converted to whole weight for reporting of total catches using standard conversion factors.

Catch levels and catch-species composition in the U.S.A. longline fishery have changed over the past years in response to fishery and regulatory changes. The majority of the longline catch now consists of tunas and billfishes and exceeded 10,000 t in 1993, 1999, 2000, 2008, 2011, and 2013-2019 (Table 2). Bigeye tuna (*Thunnus obesus*) dominates the tuna catch with landings over 4,000 t during the past sixteen years. The 2020 bigeye tuna catch was 7,499 t. Swordfish was the dominant component of the billfish catch from 1990 through 2000 peaking at 5,936 t in 1993 then trended lower to 541 t in 2020.

The Hawaii-based longline fishery is monitored by combined sampling efforts of the NOAA Fisheries and the State of Hawaii's Division of Aquatic Resources (DAR). Longline fishermen are required to complete and submit federal longline logbooks for each fishing operation. The logbook data include information on fishing effort, area fished, catch by species and amount, and other details of the fishing operations. Logbook coverage for the Hawaii-based longline fishery is at or near 100% coverage of vessels by trip. The Hawaii DAR also requires fish dealers to submit reports of landings data, and coverage for the longline fishery and the reporting rate for dealers are very close to 100%. DAR dealer data represent the majority of the fish kept by the longline fishery with individual fish weighed to the nearest pound (Figures 4-6). Observers contracted by NOAA Fisheries are also placed on longline vessels to monitor protected species interactions, vessel operations, and multi-species catches. These observers are required by court decree to be aboard Hawaii-based longline vessels at a rate of coverage of no less than 20% for deep-set (tuna-target) vessels and 100% for shallow-set (swordfish-target) vessels. Information on the sizes of fish caught in the Hawaii-based longline fishery indicate that, in general, a higher proportion of smaller tuna and tuna-like fish species are captured in the shallow-set longline fishery compared to the deep-set fishery (Figures 4-6).

The California-based longline fishery is monitored by NOAA Fisheries and the California Department of Fish and Wildlife (CDFW). Data are collected for 100% of longline landings by the CDFW. Logbooks, developed by the fishing industry (similar to the federal logbooks used in Hawaii), were submitted voluntarily to NOAA Fisheries until 1994 when logbooks became mandatory. Landed swordfish were measured for cleithrum to fork length by CDFW port samplers until 1999. NOAA Fisheries has placed observers on all California-based and non-Hawaii permit longline trips since 2002. The observers collect data on fishing location, protected species interactions, fish catch, disposition of catch and bycatch, and size measurements of catch and bycatch (retained catch and discards).

### 2.3. Albacore troll and pole-and-line

The U.S.A. albacore troll and pole-and-line fishery in the NPO started in the early 1900s.

The fishery currently operates in waters between the U.S.A. West Coast and 160°W longitude. Fishing usually starts in June and ends in October or November. In 2020, 401 vessels participated in the fishery, down from 554 in 2019 (Table 1) due to COVID-19.

The troll and pole-and-line fishery catches almost exclusively albacore with minor incidental catches of Pacific bluefin tuna (*Thunnus orientalis*), eastern Pacific bonito (*Sarda chiliensis lineolata*), yellowtail (*Seriola lalandi*), and mahi mahi (*Coryphaena hippurus*). Since 1985, the albacore catch has ranged from a low of 1,845 t in 1991 to a high of 16,962 t in 1996 (Table 2). In 2019 and 2020, 7,766 t and 7,316 t of albacore were caught, respectively.

U.S.A. troll and pole-and-line vessels operating within the U.S.A. EEZ voluntarily submitted logbook records to NOAA Fisheries from 1973 to 1995 when those vessels fishing on the high- seas were required to submit logbooks. In 2005, the Highly Migratory Species Fishery Management Plan required all U.S.A. troll and pole-and-line vessels to submit logbooks to NOAA Fisheries. NOAA Fisheries and various state fisheries agencies monitor the fleet's landings through sales receipts (fish tickets) and landings reported in logbooks.The proportion of US vessel catch in the US EEZ dropped from about 93 % in 2019 to about 78% in 2020 and the proportion caught in the high seas in increased from 2.8% in 2019 to 12.6% in 2020.Spatial distribution of albacore catch and effort for 2020 are shown in Figures 7 and 8, respectively.

Since 1961, a port sampling program has been in place for collecting size data from albacore landings along the U.S.A. Pacific coast. Generally sizes of albacore caught in the albacore troll and pole-and-line fishery range between 55 cm fork length (8.5 pounds) and 90 cm (32 pounds). In 2020, the total of 13,070 fish were measured. Weight distribution of the catch for 2020 is shown in Figure 9. State fishery personnel collect the size data according to sampling instructions provided by NOAA Fisheries, who maintain the database. In recent years, cooperative fishermen have also collected size data on selected fishing trips to augment data collected through the port sampling program.

### 2.4. Tropical pole-and-line

The tropical pole-and-line fishery targets skipjack around the Hawaiian Islands. Hawaii DAR monitors the tropical pole-and-line fishery using Commercial Fish Catch reports submitted by fishers and Commercial Marine Dealer reports submitted by fish dealers. The number of vessels participating declined from a high of 27 in 1985 to a low of one in 2012 (Table 1). Skipjack tuna is usually the largest component of the catch by Hawaii pole-and-line vessels. The highest skipjack tuna catch for this fishery was 3,450 t in 1988 (Table 2). The highest yellowfin tuna catch for the pole-and-line fishery was 2,636 t, recorded in 1993. To protect data confidentiality, no catch data for the tropical pole-and-line fishery are reported for recent years.

## 2.5. Tropical Troll and Tropical Handline

Tropical troll fishing fleets for tuna and tuna-like species operate in Hawaii, Guam, and the CNMI. Tropical handline fishing fleets also operate in Hawaii. The vessels in these fisheries are relatively small coastal vessels (typically around 8 m in length) and primarily make one-day fishing trips in coastal waters. Historically, the number of U.S.A. troll and handline vessels combined ranged from 1,878 in 1988 to 2,502 in 1999, and there were 1,607 troll vessels and 394 handline vessels in 2020 (Table 1). The operations range from recreational, subsistence, and part- time commercial to full-time commercial. The small vessel catches generally are landed fresh and whole, although some catches are gilled and gutted.

Weights of individual fish were obtained from Hawaii DAR dealer data. The size distributions of tunas (skipjack,yellowfin, and bigeye) and marlins (striped marlin and blue marlin, *Kajikia audax* and *Makaira nigricans*, respectively) caught in the Hawaii fishery in 2020 are summarized in Figures 10 and 11.

The total retained catch from these tropical troll and handline fisheries combined ranged from 1,162 t in 1992 to 2,326 t in 2012 (Table 2). The majority of the catch was made up of yellowfin and skipjack tuna in 2020 followed by blue marlin.

The Guam Division of Aquatic and Wildlife Resources (DAWR) monitors the troll fishery using a statistically designed creel survey and commercial landings data. The Guam DAWR, with the assistance of NOAA Fisheries, extrapolated the creel survey data to produce estimates of total catch, fishing effort, and fishermen participation estimates by gear type. Similarly, the Hawaii tropical troll and handline fisheries catch and effort summaries are compiled from Hawaii DAR Commercial Fish Catch reports and Commercial Marine Dealer reports. The CNMI Division of Fish and Wildlife (DFW) monitors the tropical troll fishery in the CNMI region using creel surveys and commercial landings, and with the assistance of NOAA Fisheries, extrapolated the creel survey data to produce estimates of total catch, fishing effort, and fishermen participation estimates by gear type.

## 2.6. Drift Gillnet

The U.S.A. large mesh drift gillnet fishery targets swordfish and common thresher sharks in areas within the EEZ in California waters and historically off the coast of Oregon. Other pelagic sharks, and small amounts of tunas and other pelagic species are also caught in the large mesh drift gillnet fishery. The number of vessels participating in this fishery has steadily decreased from a high of 220 in 1986 to a low of 12 in 2019. Swordfish dominate the catch and peaked in 1985 at 2,990 t. Since then, swordfish catches have fluctuated while decreasing to a low of 62 t in 2010 (Table 2). The estimate of swordfish caught in the drift gillnet fishery for 2020 is 35 mt, a decrease from 52 mt caught in 2019 and the total of 12 vessels participated in 2020, down from 16 in 2019 (Table 1)

Gillnet fishery landings data (100% coverage) are collected by state agencies in California and Oregon (no landings have occurred in Oregon since 2004). Logbook data for gillnet fisheries are required to be submitted to SWFSC for all trips. CDFW collected length data for swordfish landings between 1981 and 1999 from less than 1% of the landings. NOAA Fisheries observers on large mesh drift gillnet vessels have collected data on fishing location, protected species interactions, fish catch, disposition of catch and bycatch, and length since 1990; observer coverage is about 20% of effort.

The U.S.A. fishing industry has been modifying a gear called "deep-set buoy gear" for targeting swordfish in the eastern Pacific Ocean as an alternative to gillnet gear and as part of an effort to maximize economic benefits while minimizing non-target catch. The use of standard (unlinked) buoy gear was officially authorized in 2019. Fishermen were testing deep-set buoy gear under an exempted fishing permit from NOAA Fisheries for the previous 3 years. The deep-set buoy system uses heavy weights to rapidly lower baited hooks to target swordfish between 1,000 and 1,500 feet. The buoy gear's strike detection system alerts fishermen when a fish is on the line and allows for its quick retrieval once hooked. It allows fishermen to avoid unmarketable or federally protected species that reside in shallower waters. Deep-set buoy fishing takes advantage of the fact that different marine species feed at different depths at certain times of the day. Sea turtles, whales, and many fish are most commonly found in warm surface waters known as the upper mixed layer. Other fish, such as swordfish, opah, and bigeye thresher sharks, pursue food resources in deeper waters. The results of the exempted fishing permits gear tests will help U.S.A. fisheries managers determine if the method can be scaled up to become a viable commercial fishery. Currently there is still an Exempted Fishing Permit (EFP) for linked deep-set buoy gear which is an alternative type of deep-set buoy gear that physically links up 10 'gear pieces' that can all still be individually tended.

### 2.7. Harpoon

The harpoon fishery targets swordfish and operates in areas within the EEZ in California waters between 32°N and 34°N latitude. The number of vessels participating in the fishery greatly decreased from 113 in 1986 to 10 in 2012. 17 vessels participated in the fishery in 2020 (Table 1). Among these 17 vessels, 5 vessels participated in harpoon fishery only, the other 12 vessels participated in both buoy fishery and harpoon fishery. In the last couple years there are an increasing number of vessels switched from harpoon fishery to deep-set buoy gear fishery. Trends in swordfish catches have fluctuated from a high of 305 t in 1985 to 5 t in 2012, and

2015. Catch decreased in 2019 and 2020 from 11 mt to 6 mt.

Landings data for the harpoon fishery are collected by the CDFW and logbook data are managed by SWFSC. Length measurements were taken by CDFW between 1981 and 1999, covering less than 1% of swordfish landings.

### 2.8. Sport

Sport (recreational) catch and effort data are available from commercial passenger fishing vessels (CPFVs) and catch data are available from private vessels that target tunas and other pelagic fish. Logbook data for CPFVs are obtained from fisheries agencies in California while CPFV logbook data from vessels fishing out of Oregon and Washington are submitted to NOAA Fisheries.

Estimates of catch for CPFV and private vessels are obtained through logbooks and surveys and maintained in the Recreational Fisheries Information Network (RecFIN) database (http://www.recfin.org/) for California, Oregon, and Washington. Total sport catches of tunas, sharks and billfish are estimated from data obtained from RecFIN and augmented by state and federal logbook data sets where available. The majority of the highly migratory species (HMS) catch is albacore, yellowfin and Pacific bluefin tuna. The albacore catch by sport vessels was 260 t in 2020 compared to 1364 t in 2019.

Sport catches of Pacific bluefin tuna are estimated differently from other species. From 1993 through 2012 the IATTC collected size samples from bluefin landed by CPFVs. In 2013 no sampling occurred and in 2014 NOAA Fisheries began collecting length samples from bluefin landed by CPFVs. A description of the size sampling and the procedure for estimating annual sport catches of Pacific bluefin are provided in working paper: http://isc.fra.go.jp/pdf/ISC20/ISC20_ANNEX11_Stock_Assessment_Report_for_Pacific_Bluefin_Tuna.pdf. Catches vary and have ranged from a high of 809 t in 2013 to a low of 6 t in 1988. The 2020 catch was 651 t compared to 462 t in 2019.

## 3. RESEARCH

### 3.1 Natal Origin of Pacific Bluefin Tuna from the California Current Large Marine Ecosystem

While the general pattern of PBF trans-Pacific migrations has been documented, questions remain about the origin of PBF in the California Current large marine ecosystem (CCLME) and the contribution rates of recruits from the two spawning areas. For this study (Wells et al. 2020) we used natural chemical tags in PBF otoliths to identify natal origin of PBF after their trans-Pacific migration to the California Current. First, we examined chemical signatures of multiple cohorts of age-0 PBF from both the East China Sea and Sea of Japan spawning areas to obtain yearly baseline chemical signatures. Next, core material of the otolith from subadult PBF in the

CCLME was analyzed to estimate the relative contribution of each spawning area. Here, we present the first predictions of the natal origin of PBF in the CCLME using otolith chemistry. Otoliths from 119 age-0 PBF (ca. 30 per year) collected from 2014-2017 were analyzed to establish baseline signatures for each spawning area. Element:Ca ratios in otolith cores of age-0 PBF significantly differed both between ECS and SoJ spawning areas and among years ($p<0.01$). Significant interactions between spawning area and year highlights the necessity of obtaining element:Ca baselines for age-0 PBF each year from both the ECS and SoJ.

The natal core of age-1 fish (40 per year) collected from CCLME were analyzed for assignment to spawning region matched to age-class. Mixed-stock analysis of age-1 PBF collected in the CCLME indicate that migrants from both the ECS and SoJ recruited into the Eastern Pacific Ocean. Contribution rates varied from year to year, with both spawning areas contributing significant numbers of recruits to the CCLME with a minimum value of 20% contribution. Our study provides a four-year assessment sourcing the natal origin of recruits in the Eastern Pacific Ocean using laser ablation with high spatial resolution sampling. Inter-annual variability observed in element:Ca ratios emphasizes the need to have annual baseline samples of age-0 PBF collected from both spawning areas to enable age-class matching. Interestingly, both spawning grounds make a significant contribution to the population of fish in the CCLME, with variability in the relative contribution across years. This insight will improve our ability to examine the environmental forcing mechanisms associated with the westward migrations and recruitment. Results also support the utility of the approach to examine sourcing of PBF and movement dynamics throughout the Pacific Ocean.

### 3.2 Stomach Content Analysis

The primary goals of this research (Preti 2020) were to better understand their foraging ecology of nine top predators that co-occur in the California Current Large Marine Ecosystem (CCLME) [shortfin mako (*Isurus oxyrinchus*), blue (*Prionace glauca*), thresher (*Alopias vulpinus*), bigeye thresher (*Alopias superciliosus*) sharks, broadbill swordfish (*Xiphias gladius*), short-beaked common dolphin (*Delphinus delphis delphis*), Eastern North Pacific long-beaked common dolphin (*Delphinus delphis bairdii*), northern right whale dolphin (*Lissodelphis borealis*), and Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)]. Comparisons among predators provides insights into potential competition, niche overlap, and degrees of diet specialization. Also, given the shifts towards integrated ecosystem assessments and ecosystem management, there is movement away from looking at species in isolation. Consequently, all nine predators are included in this report although the sharks are the main focus. Stomachs for the nine predator species were collected by federal fishery observers aboard large-mesh drift gillnet vessels during years 1990-2014. Stomachs from *D. d. bairdii* and *L. obliquidens* were also obtained from stranded animals. Prey were weighed, counted and identified to the lowest possible taxonomic group. Data analyses included prey accumulation curves and relative indices of importance including the standard metrics Index of relative (IRI) and Geometric index of importance (GII). The % GII is the arithmetic mean between %N, %F and %W of a prey item and it is based on a multivariate approach to vector geometry. Because of its basis in vector geometry, it provides a more precise method for interpreting stomach contents although numeric comparisons among species are complicated. To examine patterns in prey importance, including the impacts of size, regions, season and sea surface temperature, a number of additional analyses were conducted including redundancy analysis (RDA) and generalized additive modelling (GAM).

The stomachs of 2044 predators were analyzed and 1,676 contained prey. For each of the fish species, other than bigeye thresher sharks, more than 150 individuals were examined. Diet composition by number of (individual) prey (as a percentage, %N) was summarized for all predators.

**3.3 Quantitative estimates of post-release survival rates of sharks captured in Pacific tuna longline fisheries reveal handling and discard practices that improve survivorship.**

Shark catch rates are higher in pelagic longline fisheries than in any other fishery, and sharks are typically discarded (bycatch) at sea. The post-release fate of discarded sharks is largely unobserved and could pose a significant source of unquantified mortality that may change stock assessment outcomes and prevent sound conservation and management advice. This NOAA study (Hutchinson et al. 2021) assessed post-release mortality rates of blue (*Prionace glauca*), bigeye thresher (*Alopias superciliosus*), oceanic whitetip (*Carcharhinus longimanus*), silky (*C. falciformis*) and shortfin mako (*Isurus oxyrhincu*s) sharks discarded in the Hawaii deep-set and American Samoa longline fisheries targeting tuna in the central Pacific Ocean. The impacts on survival rates were examined considering species, fishery, fishing gear configuration, handling method, animal condition at capture and at release, and the amount of trailing fishing gear remaining on discarded sharks. Bayesian survival analysis showed that the condition at release (good vs. injured), branchline leader material, and the amount of trailing fishing gear left on the animals were among the factors that had the largest effect on post-release fate—animals captured on monofilament branchline leaders and released in good condition without trailing fishing gear had the highest rates of survival. This study shows that fisher behavior can have a significant impact on pelagic shark post-release mortality. Ensuring that sharks are handled carefully and released with minimal amounts of trailing fishing gear may reduce fishing mortality on shark populations.

**3.4 Review on the Effect of Hook Type on the Catchability, Hooking Location, and Post-Capture Mortality of the Shortfin Mako, Isurus oxyrinchus.**

Due to the assessed vulnerability for the North Atlantic shortfin mako (*Isurus oxyrinchus*) there is an identified need to better understand the use of circle hooks as a potential mitigation measure in longline fisheries. NOAA researchers conducted a literature review related to the effect of hook type on the catchability, anatomical hooking location, and post-capture mortality of this species (Keller et al. 2020). This research found twenty-eight papers related to these topics, yet many were limited in interpretation due to small sample sizes and lack of statistical analysis. Catchability results were inconclusive, suggesting no clear trend in catch rates by hook type. The use of circle hooks was shown to either decrease or have no effect on at-haulback mortality. Three papers documented post-release mortality, ranging from 23-31%. The use of circle hooks significantly increased the likelihood of mouth hooking, which is associated with lower rates of post-release mortality. This review suggests minimal differences in catchability of shortfin mako between hook types, but suggests that use of circle hooks likely results in higher post-release survival that may assist population recovery efforts.

**3.5 Quantifying the distribution of swordfish (*Xiphias gladius*) density in the Hawaii-based longline fishery.**

The Hawaii-based longline fishery targeting bigeye tuna and swordfish is the most economically important fishery in Hawaii. Sculley and Brodziak (2020) improved understanding of the distribution of swordfish within this fishery and how it changes in response to environmental conditions is critical for predicting potential climate change impacts to the fishery. The multi-species Vector-Autoregressive Spatio-Temporal (VAST) model was used by NOAA researchers to estimate abundance and density of swordfish within the Hawaii-based longline fishing grounds (Sculley & Brodziak 2020). Swordfish and bigeye tuna catch per unit effort were used in a spatial dynamics factor analysis to help estimate swordfish density in time periods when the swordfish fishery was closed. Although the model was unable to account fully for the significant changes in fishery regulations in 2000, it provided quantified estimates of swordfish density and distribution and information on how those distributions may change in response to environmental variables. Swordfish density center of gravity was found to correlate with the Southern Oscillation Index (SOI) averaged during the swordfish spawning season (April – July), with densities centered further north and east during positive SOI (cooler sea temperatures) and further south and west during negative SOI (warmer sea temperatures).

### 3.6 Catch rate composition affects assessment of protected area impacts.

This NOAA study (Sweeney 2021) examines the sources of discrepancy between previous research that disagreed on fishing impacts in response to the Papahānaumokuākea Marine National Monument expansion. One study found little to no negative impact and another determined 7-9 % reductions in fishing revenues. This new study found catch rate composition to critically affect the underlying trends in data with which models are fit and are likely the source of the conflicting findings. This analysis also suggests that aggregate commercial catch rate is a more robust measure of catch per unit effort (CPUE) for Hawaii's deep-set longline fishery, and recommends a reanalysis of a previous model using this measure.

### 3.7 Toward an environmental predictor of tuna recruitment.

Bigeye tuna are of global economic importance and are the primary target species of Hawaii's most valuable commercial fishery. Due to their high commercial value, bigeye tuna are relatively well studied and routinely assessed. Larval and adult bigeye surveys have been conducted for many years and are supported by ongoing research on their physiology and life history. Yet, modeling stock dynamics and estimating future catch rates remain challenging. This NOAA study (Woodworth-Jefcoats & Wren 2020) demonstrates that an appropriately lagged measure of phytoplankton size is a robust predictor of catch rates in Hawaii's bigeye tuna fishery with a forecast window of four years. This study provides a fishery-independent tool with the potential to improve stock assessments, aid dynamic fisheries management, and allow Hawaii's commercial longline fishing industry to better plan for the future.

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## 5. NOAA FISHERIES LITERATURE RELEVANT TO ISC FROM THE PAST YEAR

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## 6. FIGURES

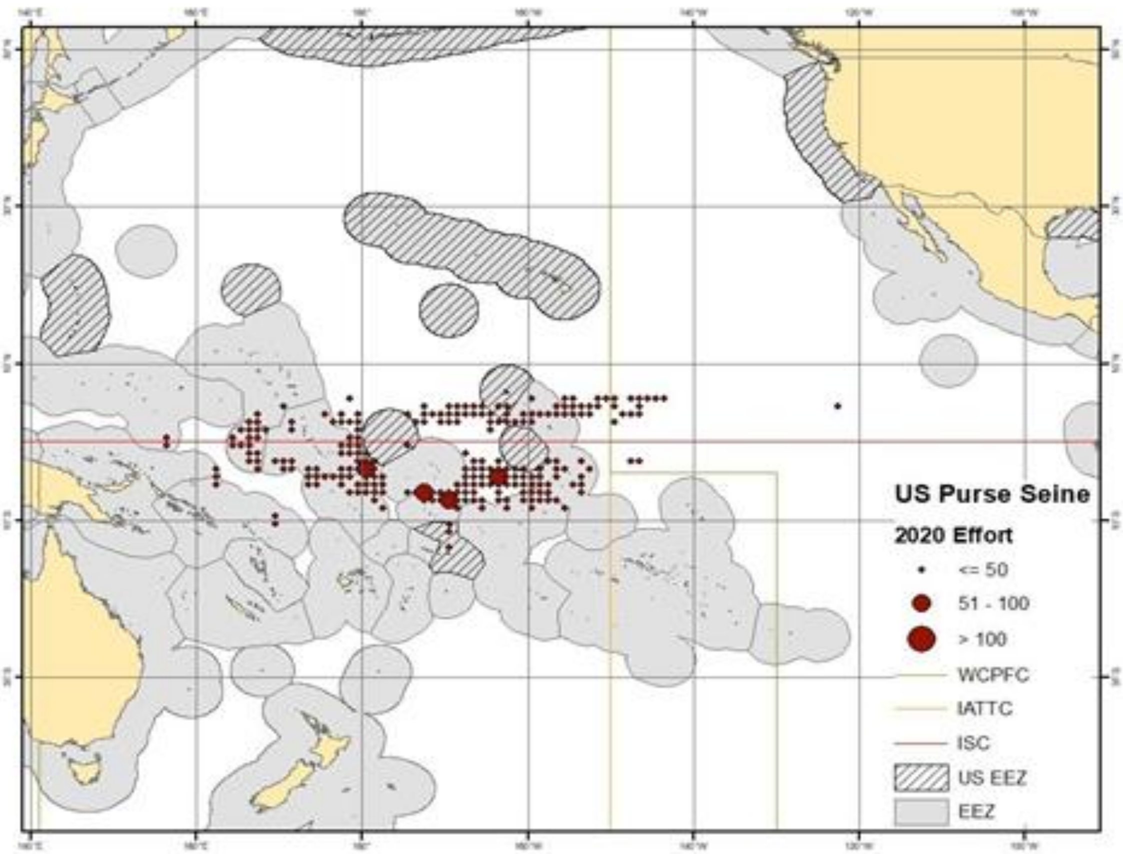



**Figure 1.** Spatial distribution of reported logbook fishing effort by the 2020 U.S. Western Pacific purse seine fishery in vessel-days. The size of circles is proportional to the amount of effort. Effort in some areas is not shown in order to preserve data confidentiality.

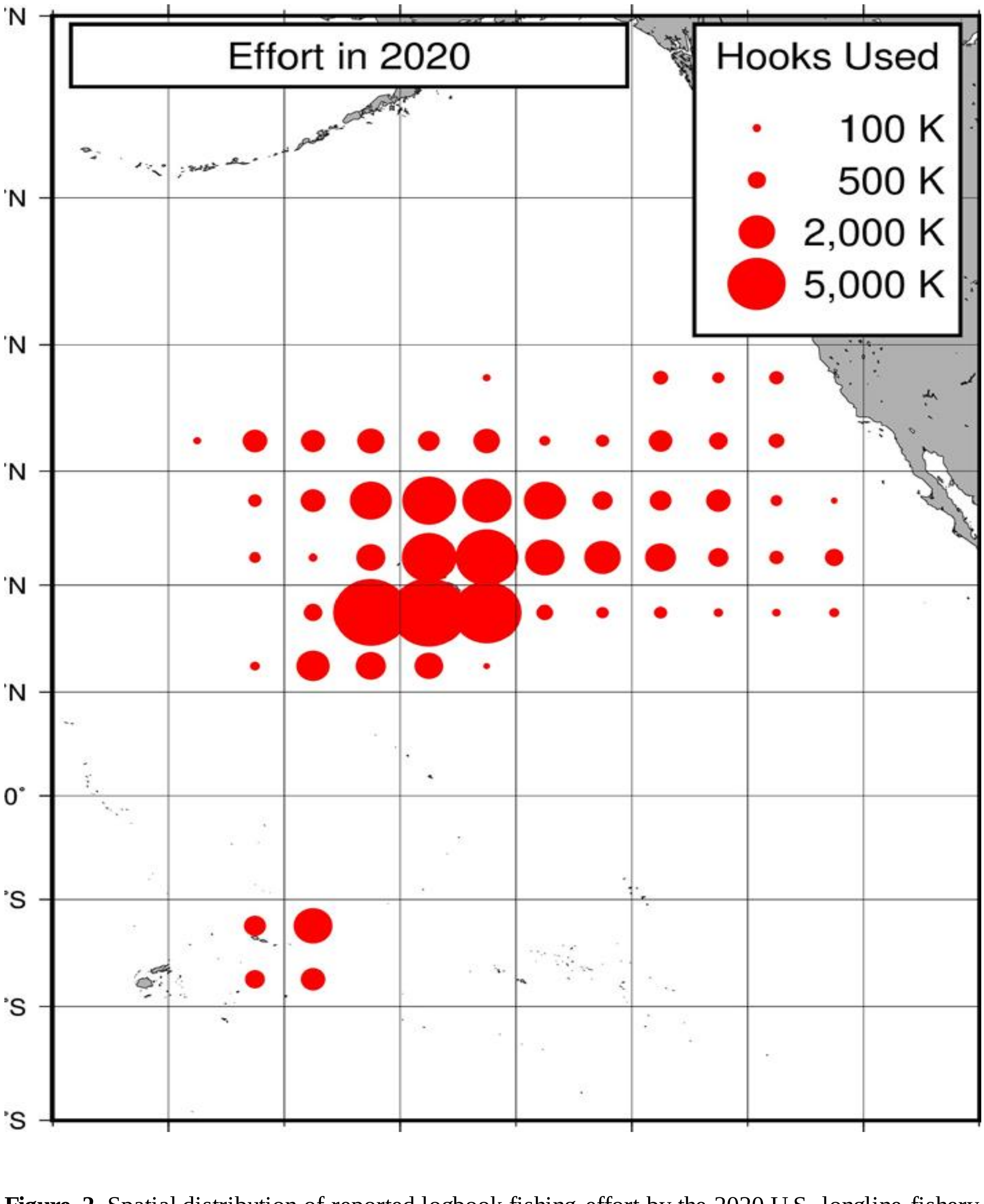



**Figure 2.** Spatial distribution of reported logbook fishing effort by the 2020 U.S. longline fishery in the North Pacific Ocean, in 1,000s of hooks. The size of circles is proportional to the amount of effort. Effort in some areas is not shown in order to preserve data confidentiality.

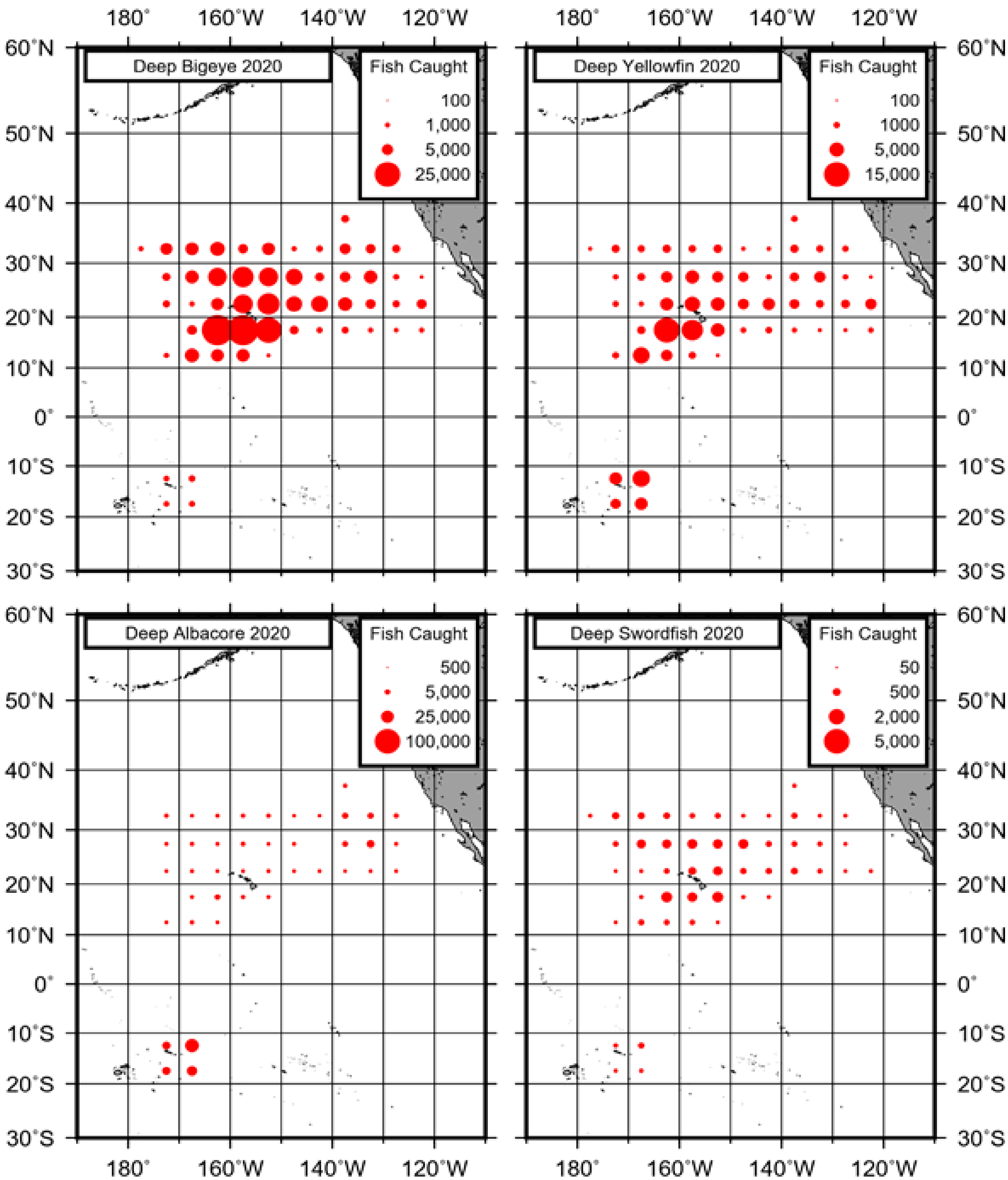



**Figure 3.** Spatial distribution of reported logbook fishing catch by the U.S. longline fishery in the North Pacific Ocean, in numbers of fish, in 2020 for bigeye (*Thunnus obesus*), albacore (*Thunnus alalunga*), yellowfin (*Thunnus albacares*), and swordfish (*Xiphias gladius*). The size of circles is proportional to the amount of effort. Effort in some areas is not shown in order to preserve data confidentiality.

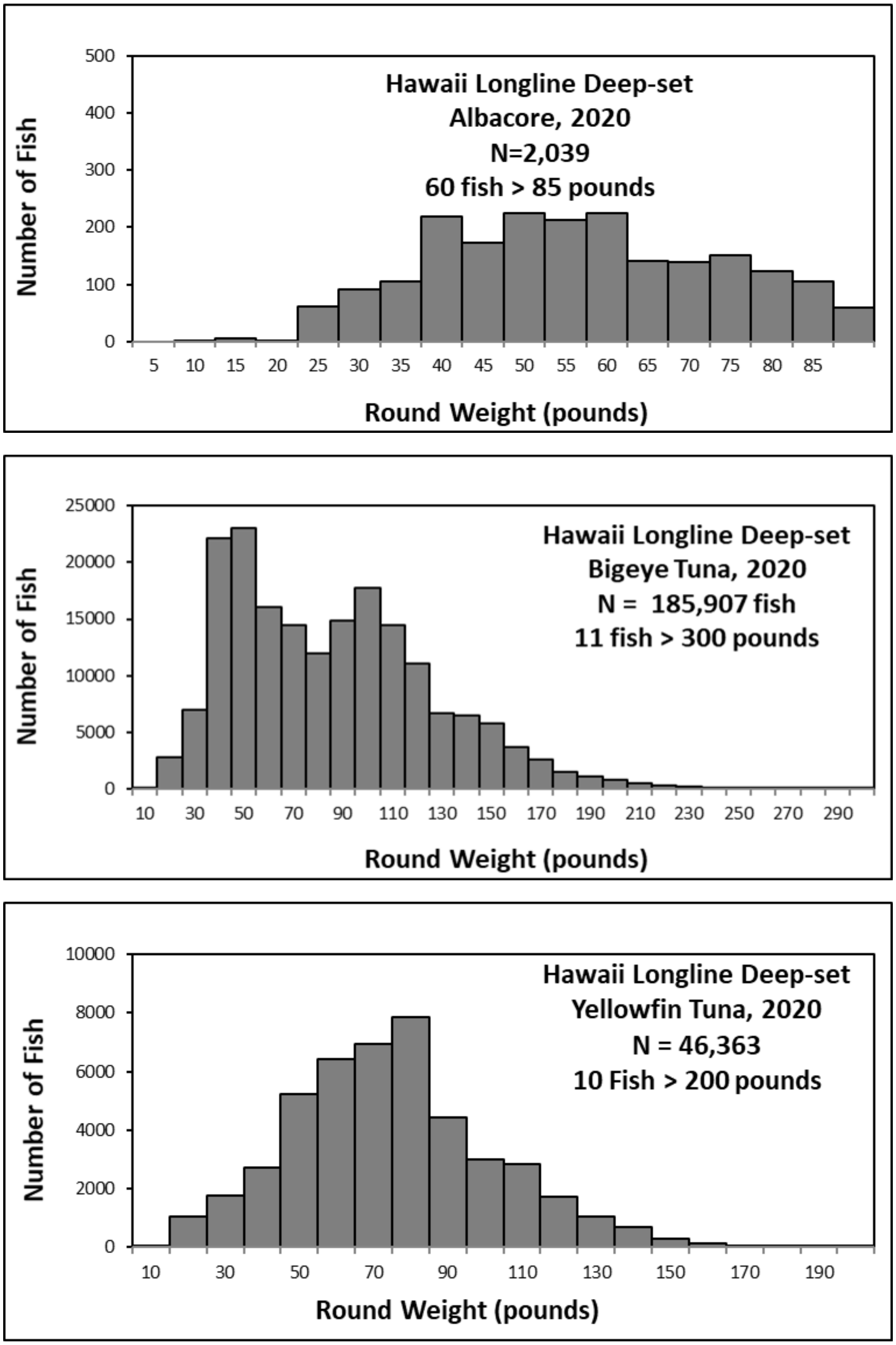



**Figure 4.** Size distribution of (A) albacore (*Thunnus alalunga*), (B) bigeye tuna (*Thunnus obesus*), and (C) yellowfin tuna (*Thunnus albacares*) caught by the Hawaii-based deep-set longline fishery in the north Pacific Ocean, 2020.

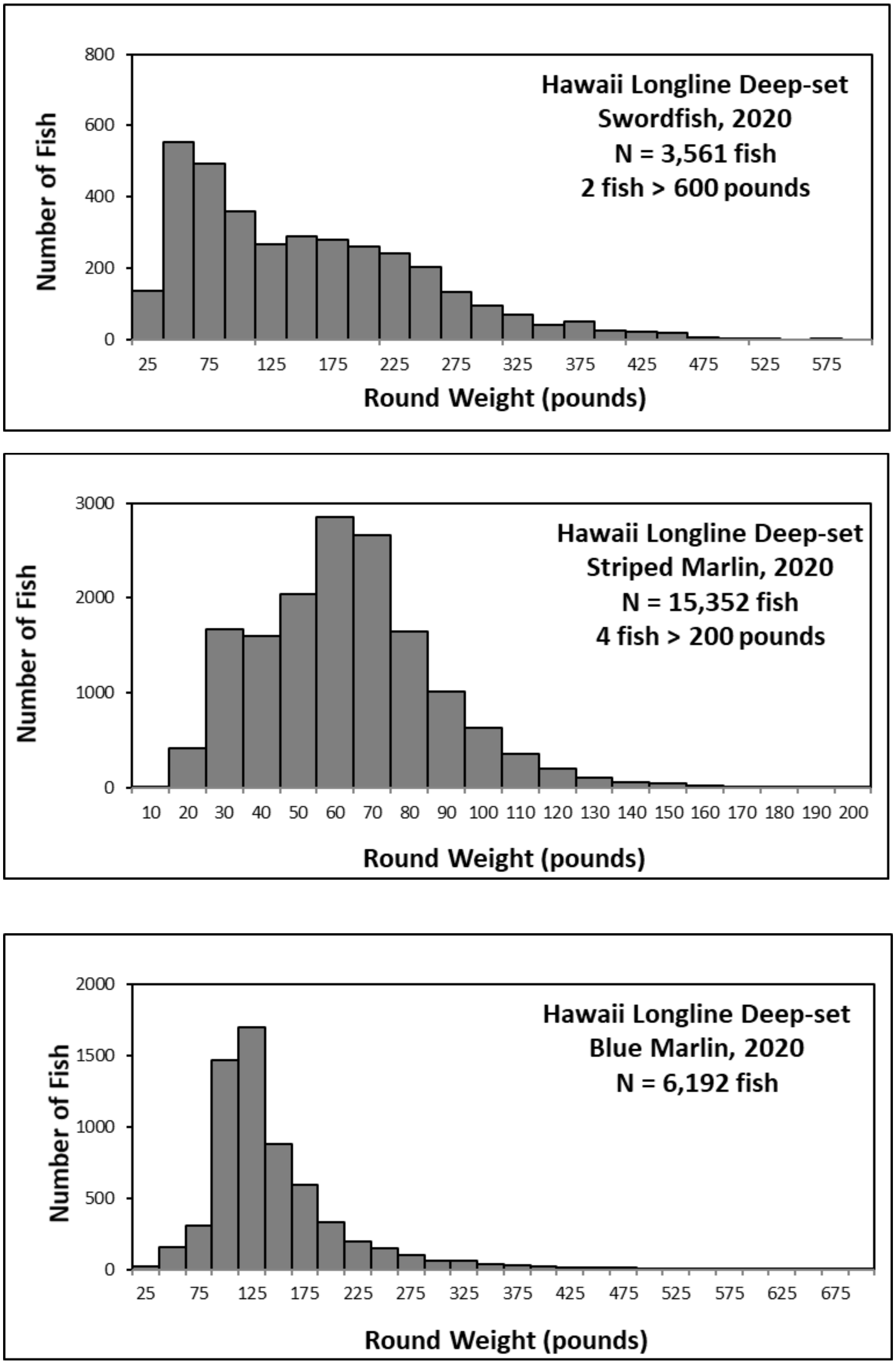
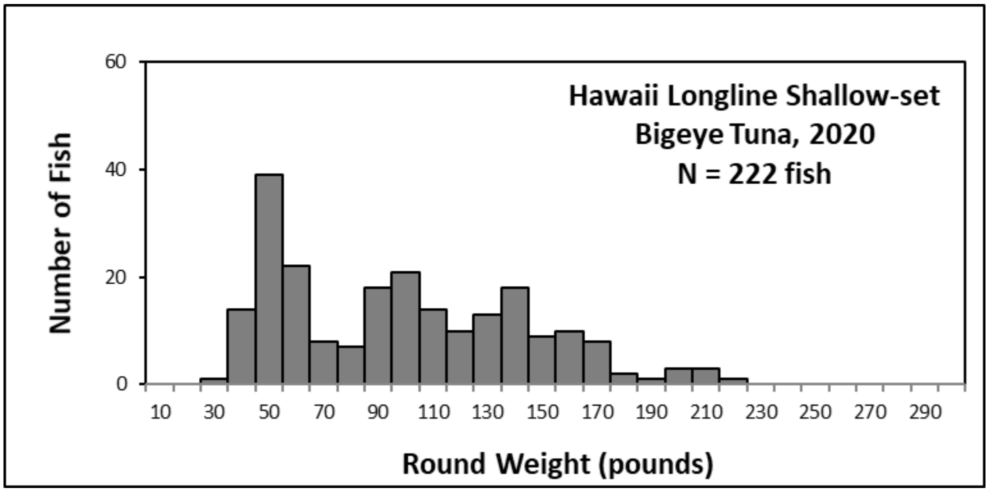



**Figure 5.** Size distribution of (A) swordfish (*Xiphias gladius*), (B) striped marlin (*Tetrapturus audax*), and (C) blue marlin (*Makaira nigricans*) caught by the Hawaii-based deep-set longline fishery in the north Pacific Ocean, 2020.



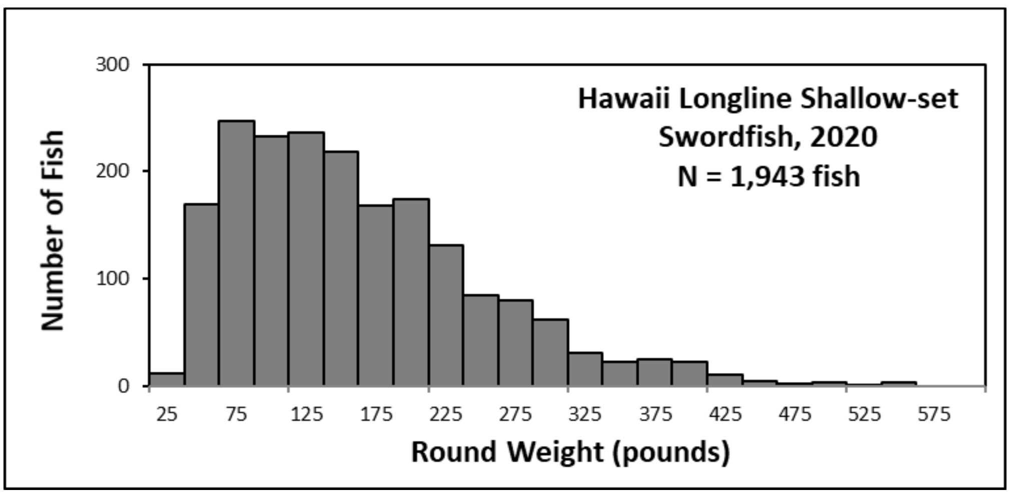




**Figure 6.** Size distribution of (A) bigeye tuna (*Thunnus obesus*), and (B) swordfish (*Xiphias gladius*) caught by the Hawaii-based shallow-set longline fishery in the north Pacific Ocean, 2020.

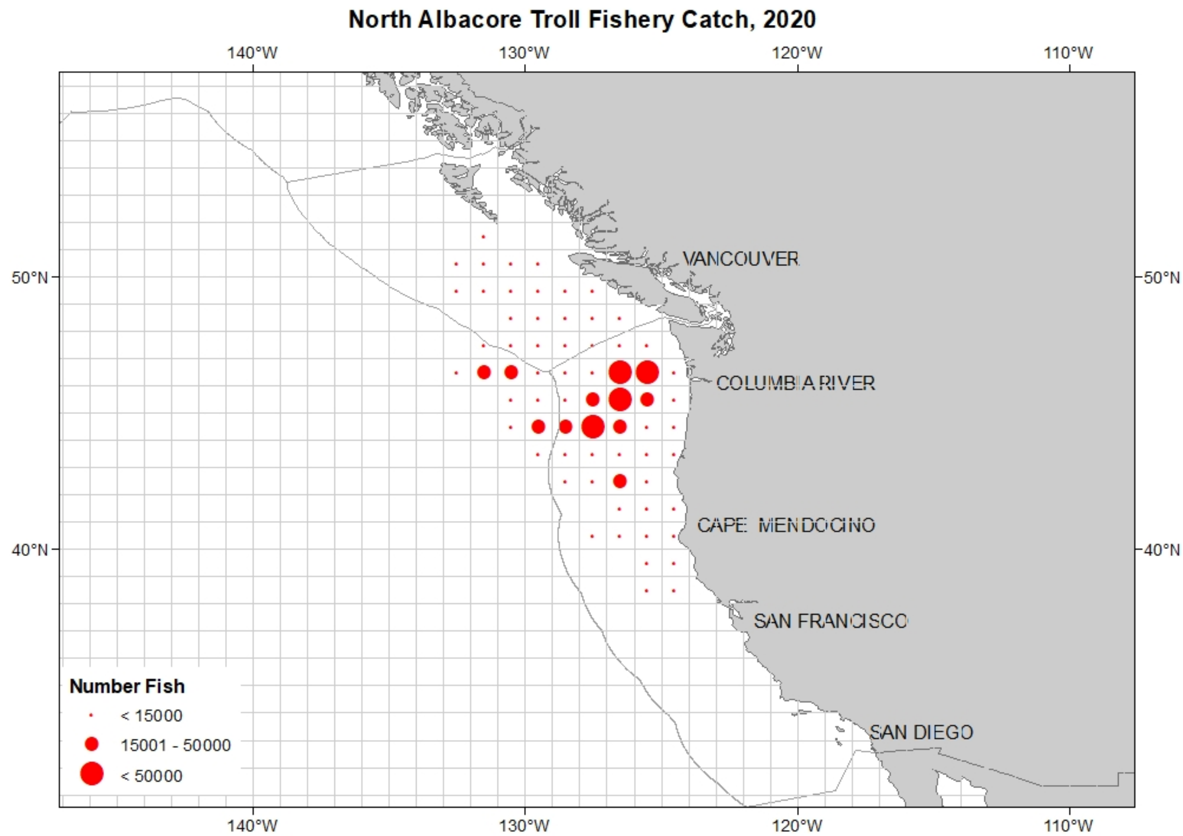



**Figure 7.** Spatial distribution of reported logbook fishing catch by the 2020 U.S. albacore troll and pole-and-line fishery in number of fish. The size of circles is proportional to the amount of catch. Some catch areas are not shown in order to preserve data confidentiality.

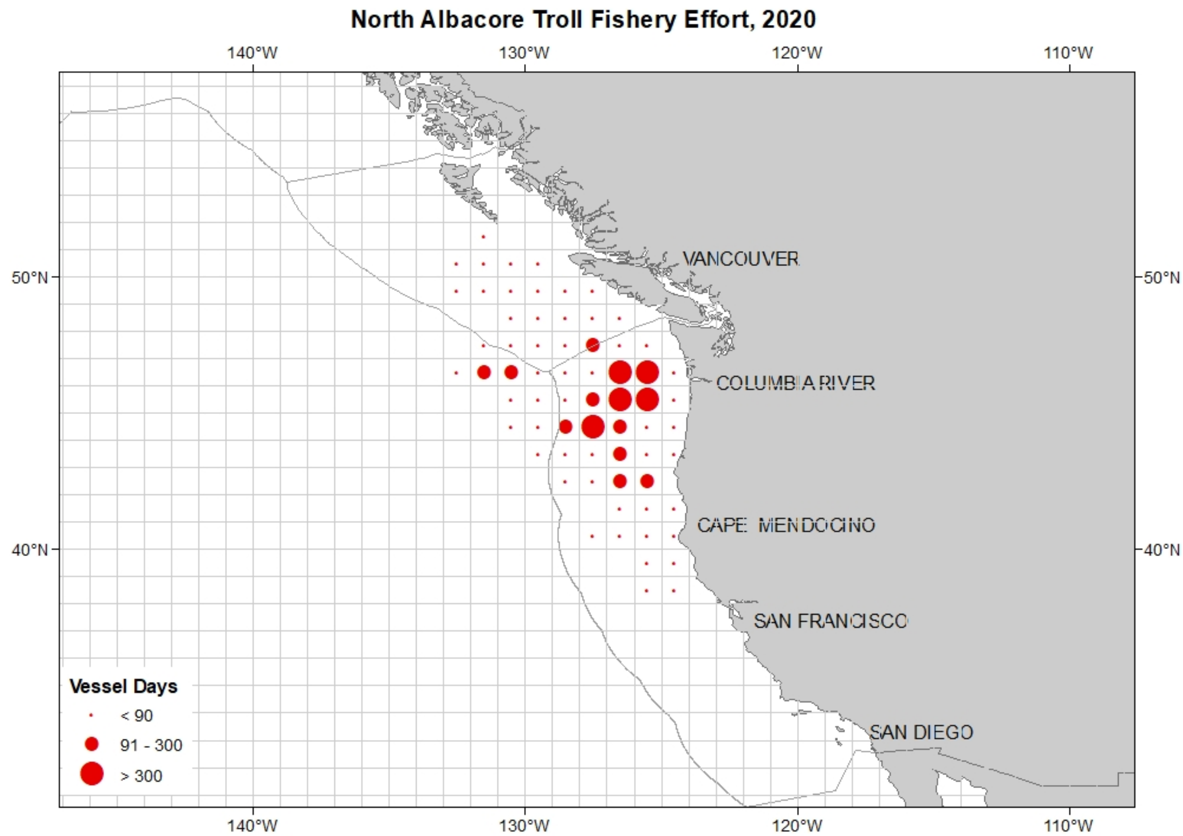



**Figure 8.** Spatial distribution of reported logbook fishing effort by the 2020 U.S. albacore troll and pole-and-line fishery in vessel days. The size of circles is proportional to the amount of effort. Some effort areas are not shown in order to preserve data confidentiality.

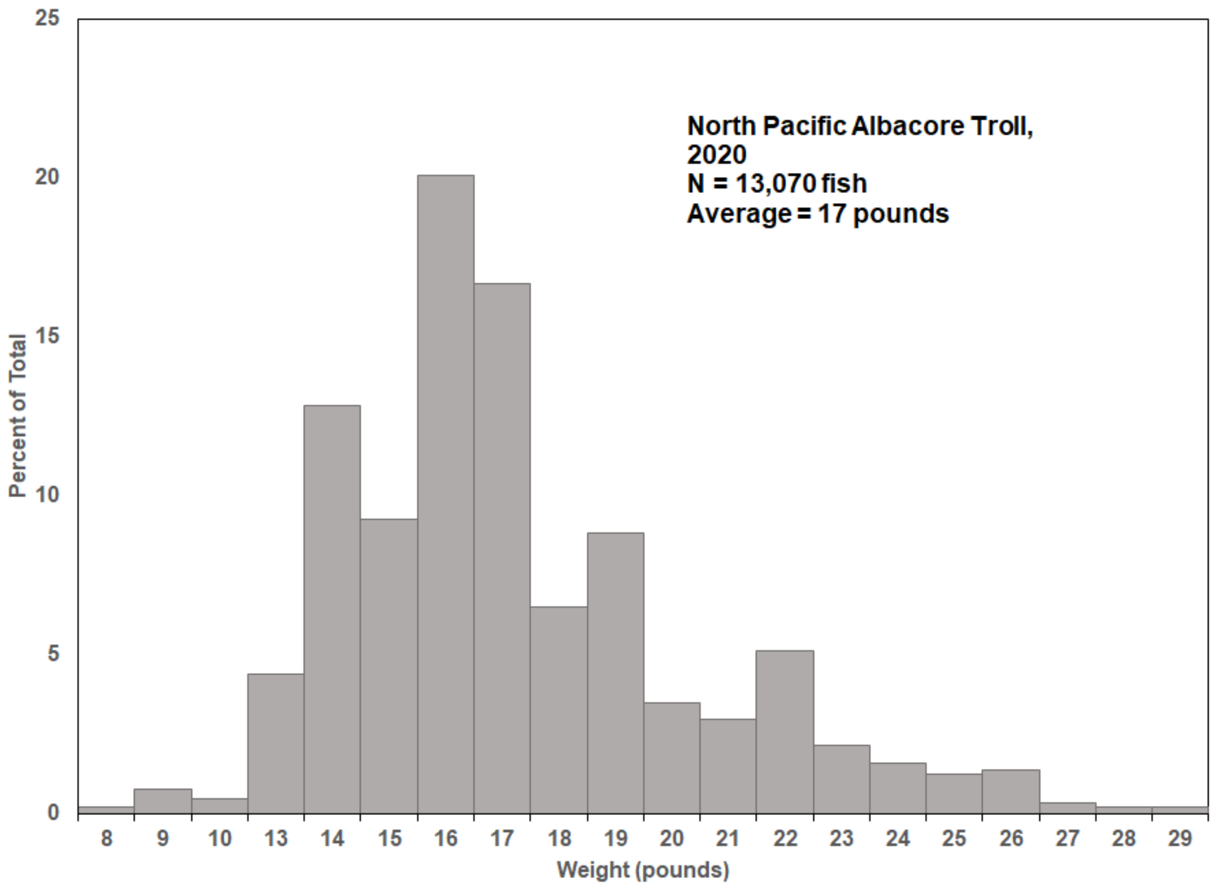



**Figure 9.** Size distribution of albacore (*Thunnus alalunga*) caught by the 2020 U.S. albacore troll and pole-and-line fishery.

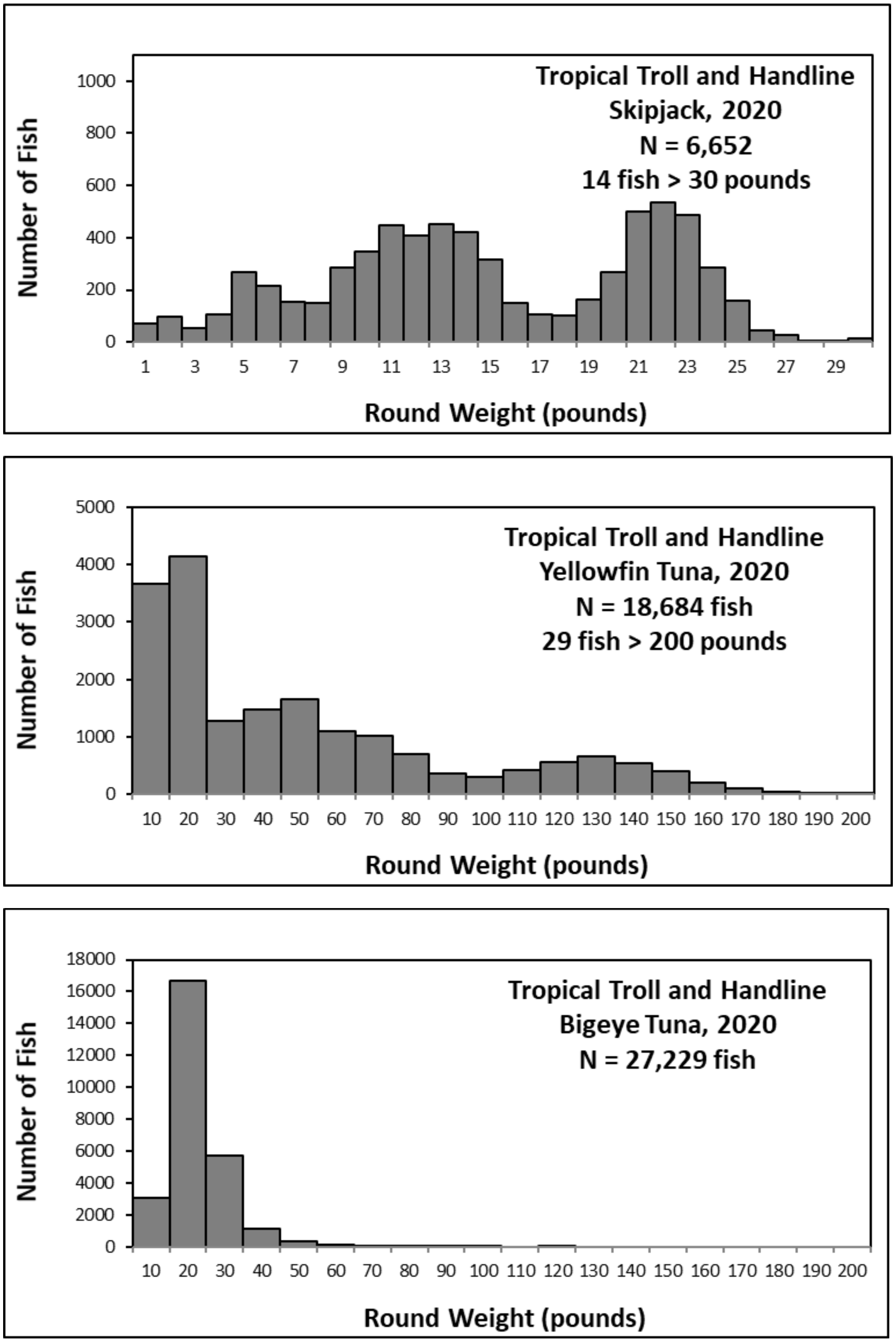



**Figure 10.** Size distribution of (A) skipjack tuna (*Katsuwonus pelamis*), (B) yellowfin tuna (*Thunnus albacares*), and (C) bigeye tuna (*Thunnus obesus*) caught by the Hawaii troll and handline fisheries, 2020.

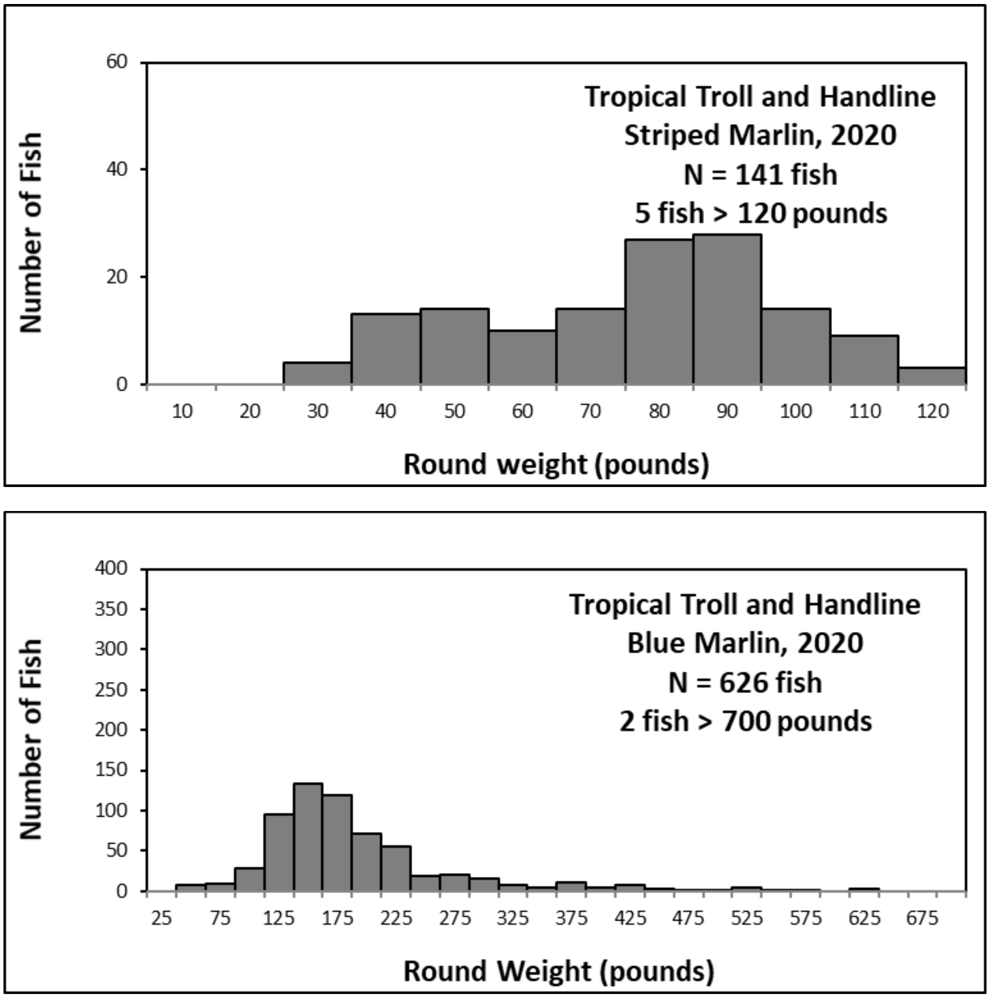



**Figure 11.** Size distribution of (A) striped marlin (*Kajikia audax*) and (B) blue marlin (*Makaira nigricans*) caught by the Hawaii troll and handline fisheries, 2020.

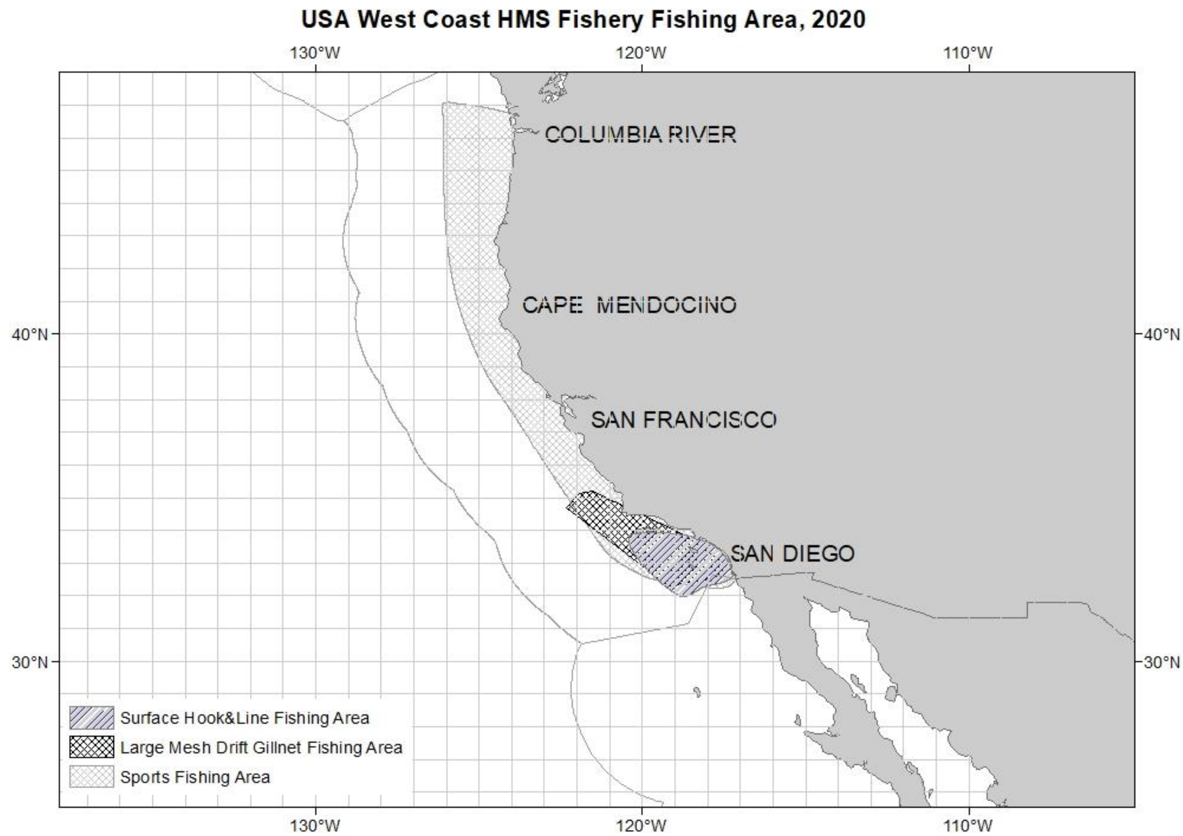



**Figure 13.** Spatial distribution of reported logbook fishing effort by the 2020 U.S. hook and line, Gillnet, and west coast sport fishery in the North Pacific Ocean.