FINAL

ISC/23/PLENARY/09

PLENARY 09

23rd Meeting of the
International Scientific Committee for Tuna
and Tuna-Like Species in the North Pacific Ocean
Kanazawa, Japan
July 12-17, 2023

NATIONAL REPORT OF U.S.A.
(U.S.A. FISHERIES AND RESEARCH ON TUNA AND TUNA-LIKE FISHERIES IN THE NORTH PACIFIC OCEAN)

NOAA, National Marine Fisheries Service
United States

July 2023

Left Blank for Printing

SUMMARY

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 western and central Pacific Ocean (WCPO). Small-scale gillnet, harpoon, 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 Zone and on the high seas. Thousands of small-scale troll and handline vessels operate in waters of the tropical Pacific; however, these fleets account for a small fraction of the total tuna catch.

Several highly migratory species exempted from fishing permit (EFP) fishery programs have been developed in recent years by NOAA Fisheries to evaluate alternative gears and methods to target swordfish and other highly migratory species (HMS) species in the Eastern Pacific Ocean (EPO). NMFS has been prioritizing EFPs in the EPO for alternative fishing gears that will have minimal bycatch are economically viable.

The National Marine Fisheries Service of the National Oceanic and Atmospheric Administration (NOAA - Fisheries) Fisheries actively conducted research in 2022 on Pacific tunas and associated species at its Southwest and Pacific Islands Fisheries Science Centers and also in collaboration with scientists from other organizations. 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.

Fishery monitoring and socio-economic research was also conducted on tunas, billfishes, and bycatch species in the U.S.A. Pacific coastal and high-seas fisheries. As in previous years, fishery monitoring and angler effort information were compiled in 2022, and economic performance indicators in the Hawaii longline and small-boat fisheries were assessed.

NOAA Fisheries successfully completed biological and oceanographic studies on tunas, billfishes, and sharks in 2022, and research on their fisheries and how to improve their stock assessments. Highlighted research includes: the relationship of pelagic predators and anticyclonic eddies, the relationship between tuna and ocean biogeochemistry, the incorporation of uncertainty in biological parameters for stock assessments , the influence of El Niño-Southern Oscillation on tuna longline catch, the evaluation of Pacific bluefin tuna reproduction in the southern California Current, the life history and feeding ecology of Pacific bluefin tuna, and the feeding ecology and diets of albacore tuna and broadbill swordfish.

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, fishery 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/). The State agencies also collect logbook and size-composition data. In the WCPO, monitoring by partner agencies includes market sampling and surveys of fishery activities and catch and is coordinated by the Western Pacific Fishery Information Network (WPacFIN) system (www.pifsc.noaa.gov/wpacfin/), a federally funded program managed by the PIFSC. Together, the SWFSC, WCRO, PIFSC, and PIRO share responsibilities for managing data collected from the 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 2023. The U.S.A fisheries data reported for 2022 are considered preliminary and are subject to change. Although this report focuses on tunas and billfishes, some of the U.S.A fisheries catches other pelagic fish important to the fishing fleets and local economies; catch data for these species are not reported here but are included in the U.S.A data submissions to the ISC for 2022.

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 began in the EPO in the 1950s in the EPO. Most of the purse seine tuna catch came from the EPO until 1993 when many vessels moved to fish in the WCPO in response to dolphin conservation measures in the EPO and to fishing access granted to the U.S.A 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 occurring south of the equator (Figure 1). 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 and 2019 then increased to 46 in 2009. In 2022, there were 23 purse-seine vessels fishing in the North Pacific, up four from 2021. Prior to 1995, the purse seine fleet targeted free-swimming schools of tunas in the WCPO and fished on schools associated with dolphins in the EPO. Since 1995, most catches in the WCPO have been associated with fish aggregation devices and other floating objects. In 2022, a total of 10 California-based purse-seine vessels fished in the EPO and caught 198 t Pacific bluefin tuna, an increase from 3 vessels and 42 t from previous year.

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 must be submitted as a requirement of the SPTT with 100% logbook 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 is about 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 either NOAA Fisheries or the IATTC, and landings data are obtained for each vessel trip from canneries or fish buyers. IATTC fishery observers are required on all large purse-seine vessels in the EPO.

2.2. Longline

The U.S.A. longline fishery targeting tuna and tuna-like species in the NPO includes the Hawaii-based fleet, the California-based fleet, and the American Samoa-permitted fleet operating 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 fishing vessels, effort, and catch.

Regulations to reduce restrictions, due to interactions with endangered sea turtles, curtailed Hawaii-based longline effort for swordfish (*Xiphias gladius*) in the early 2000s. Swordfish fishing effort was reduced in 2000 and 2001 followed by a prohibition on targeting swordfish in 2002 and 2003, during which the Hawaii-based longline fishery targeted tunas exclusively. The Hawaii-based swordfish fishery (a.k.a the shallow-set longline) was reopened in April 2004 under a new set of regulations to reduce sea turtle interactions. In 2005, the Hawaii-based longline fishery was allowed to target swordfish during the entire year.

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 fishing gear 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 both 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 below their respective limits since the levels were revised, although the shallow-set fishery was closed in both 2019 and 2020 under a court order that reduced the turtle interaction limits back to the 2011 levels (17 loggerhead turtles annually) and the shallow set fishery reached the revised loggerhead turtle interaction limit. The sea turtle regulations changed again on September 17, 2020 with the longline fleet limited to 16 annual leatherback turtle interactions and a trip limit of either 2 leatherback or 5 loggerhead sea turtles' interactions was established. Vessels that meet the trip limit are required to immediately stop fishing, retrieve their fishing gear, and return to port.

The number of vessels in the California-based fishery has always been lower than the Hawaii-based fishery, and is composed mainly of vessels that target swordfish. Most vessels with landings in California also participate 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 2022, three vessels participated under the West Coast HMS exempted fishing permit.

In the NPO, 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 2022 (Figures 2 and 3). The total number of vessels participating in the longline fishery increased from 36 in 1985 to a high of 149 in 2019, with 147 vessels participating in 2022. 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.

Catches and species composition in the U.S.A. longline fishery have changed over time in response to fishery and regulatory changes. The majority of the longline catch now consists of tunas and billfishes and annual catches have exceeded 10,000 t since 2013. Bigeye tuna (*Thunnus obesus*) dominates the tuna catch with annual landings totaling over 4,000 t during the past nineteen years. The 2022 bigeye tuna catch was 6374 t. Swordfish was the dominant component of the longline catch from 1990 through 2000 peaking at 5,936 t in 1993 then trending to a low of 543 t in 2020. Swordfish catch was 927 t in 2022.

The Hawaii-based longline fishery is monitored by 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 almost100%. DAR dealer data represent the majority of the fish kept by the longline fishery with individual fish weighed to the nearest pound. Fisheries observers contracted by NOAA Fisheries are also placed on longline vessels to monitor protected species interactions, record vessel operations, and sample multi-species catches. Hawaii-based longline vessels have had an observer coverage rate of approximately 20% for deep-set (tuna-targeting) vessels and 100% for shallow-set (swordfish-targeting) longline trips. 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 6-8).

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 including 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. The 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*). In 2022, 429 vessels participated in the fishery, an increase from 311 vessels from previous year. The albacore catch in 2022 was 8450 t, an increase from 4209 t of albacore caught in 2021 and 7516 t in 2020.

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 high seas continued to drop from about 6.4% in 2021 to about 1.7% in 2022 and the proportion caught in the Canada EEZ slightly decreased from 13.6% in 2021 to 12.3% in 2022. NOAA Fisheries estimated a total of 1412 t of albacore landed in Canada ports in 2022 compared with 719 t the previous year. In 2022, the nominal CPUE was 172 Fish per day, an increase from 114 fish per day in 2021. The spatial distribution of albacore catch and effort for 2022 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 Oregon and Washington. Generally, sizes of albacore caught in the albacore troll and pole-and-line fishery range between 55 cm fork length (3.9 kg) and 90 cm (14.5 kg). In 2022, a total of 21,232 fish were measured, with an average albacore sampling weight of 7.5 kg, compared to 6.7 kg from previous year. Weight distribution of the catch for 2022 is shown in Figure 4. State fishery personnel collect the size data according to sampling instructions provided by NOAA Fisheries, who maintain the database.

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. 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 3450 t in 1988. The highest yellowfin tuna catch for the pole-and-line fishery was 2636 t, recorded in 1993. To protect data confidentiality, no catch data for the tropical pole-and-line fishery have been 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. There were 1707 troll vessels and 432 handline vessels in 2022. 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 tropical troll and handline fishery in 2022 are summarized in Figures 10 and 11.

The total retained catch from these tropical troll and handline fisheries combined ranged from 1160 t in 1992 to 2201 t in 2002 with a total catch of 1480 t in 2022. The majority of the catch consisted of yellowfin and skipjack tuna followed by bigeye and blue marlin in 2022.

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 7 in 2021 and 2022. Swordfish dominate the catch and peaked in 1985 at 2,990 t. Since then, swordfish catches have fluctuated, decreasing to a low of 62 t in 2010. The estimate of swordfish caught in the drift gillnet fishery for 2022 is 29 t, an increase from 14 t in 2021. There was an estimated total of 20 t bluefin tuna caught in the drift gillnet fishery in 2022, a decrease from 55 t in 2021. The large mesh drift gillnet fishery will be terminated within the next a couple of years.

Gillnet fishery landings data with 100% coverage have been collected by state agencies in California and Oregon although no landings have occurred in Oregon since 2004). Logbook data for gillnet fisheries are required to be submitted to NOAA Fisheries 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. A total of 4 gillnet vessels were observed in 2022.

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. Trends in swordfish catches have fluctuated from a high of 305 t in 1985 to 5 t in 2012 and 2015. In the last couple years an increasing number of vessels have switched from the harpoon fishery to a deep-set buoy gear fishery. The number of vessels increased to 17 in 2022 compared with 11 vessels fished in 2021. The catch of swordfish in 2022 was 32 t.

Landings data for the harpoon fishery are collected by the CDFW and logbook data are managed by NOAA Fisheries. 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 587 t in 2022, up from 248 in 2021.

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. The size distribution for Pacific bluefin tuna caught by this fishery can be seen in Figure 12. Catches have fluctuated through time and ranged from a high of 809 t in 2013 to a low of 6 t in 1988. The 2022 catch was 1367 t compared to 1248 t in 2021.

3. HIGHLIGHTED RESEARCH

3.1. Anticyclonic eddies aggregate pelagic predators in a subtropical gyre.

In nutrient-poor subtropical gyres—the largest marine biome—the role of eddies in modulating behavior throughout the pelagic predator community remains unknown. Using a large-scale fishery dataset in the North Pacific Subtropical Gyre, Researchers from NOAA fisheries collaborated with the University of Washington and Woods Hole Oceanographic Institute showed a pervasive pattern of increased pelagic predator catch inside anticyclonic eddies relative to cyclones and non-eddy areas. Results in **Argostegui et al. (2022)** indicate that increased mesopelagic prey abundance in anticyclone cores may be attracting diverse predators, forming ecological hotspots where these predators aggregate and exhibit increased abundance. In this energetically quiescent gyre, it is expected that isolated mesoscale features (and the habitat conditions in them) exhibit primacy over peripheral submesoscale dynamics in structuring the foraging opportunities of pelagic predators.

3.2. Influence of El Niño-Southern Oscillation on bigeye and yellowfin tuna longline catch per unit effort in the equatorial Pacific.

The El Niño-Southern Oscillation (ENSO) has a strong effect on the oceanographic conditions in the equatorial Pacific, including bigeye tuna (BET) and yellowfin tuna (YFT) equatorial habitat and fishing grounds. For optimal fisheries management, the effects of environmental variability such as ENSO on the stocks and on the performance of fisheries must be known and predictable. However, besides some model predictions, the effects of ENSO on these two tuna species are not well understood. NOAA researcher Domokos (2023) used statistical relationships to investigate between past ENSO conditions and equatorial fisheries using the Multivariate ENSO Index, sea surface temperature (SST), and catch and effort records from the longline fisheries in the region. Results of this study indicate that El Niño events have both delayed and concurrent positive effects on BET and YFT catch per unit effort (CPUE). The delayed positive ENSO effect on CPUE is hypothesized to be the result of enhanced recruitment acting via different mechanisms in the west than in the east. The concurrent positive effects on CPUE could be due to catchability, abundance, and/or vertical distribution of BET and YFT relative to fishing gear and require further investigation. Further exploration of the mechanisms underlying the results could lead to better predictability of CPUE of these two tuna species.

3.3. Focusing on the front end: A framework for incorporating uncertainty in biological parameters in model ensembles of integrated stock assessments.

An ensemble can be created by randomly drawing values from the likely parameter space using a Monte-Carlo/bootstrap (MCB ensemble) or fixed at either a high, medium, or low value that encapsulates the variability in the parameter and applied in a full factorial grid across the fixed parameters (factorial ensemble). **Ducharme-Barth and Vincent (2022)** presented management advice was presented for MCB ensembles of various sizes and a 243 model factorial ensemble for Southwest Pacific swordfish (*Xiphias gladius)*, and reference points were compared which included model uncertainty only, model and estimation uncertainty, or both uncertainties weighted by sampling importance resampling. Median reference points were significantly different between the two ensemble types with the factorial ensemble having a significantly larger estimate of model uncertainty than the MCB ensemble. Stock assessments with fixed biological parameters can characterize uncertainty in these parameters more efficiently using a MCB ensemble approach. A factorial ensemble approach is appropriate for comparing different model structure assumptions and functional forms of relationships and can be used in combination with a MCB ensemble approach. Incorporation of both model and estimation uncertainty in estimates of reference points is important when providing management advice because including only model uncertainty can lead to biased estimates of the precision of reference points. Further work is needed regarding appropriate weighting of ensembles which incorporate different data sources or have different likelihood weightings.

3.4. Anticipating fluctuations of bigeye tuna in the Pacific Ocean from three-dimensional ocean biogeochemistry

NOAA researchers collaborated with other scientists to use three-dimensional, dynamical reconstructions and forecasts of ocean biogeochemistry to hindcast and assess the capacity to anticipate fluctuations in bigeye tuna (*Thunnus obesus* Lowe) in the Pacific Ocean. **Taboada et al. (2023)** reconstructed spatial patterns in catch per unit effort (CPUE) through the combination of physiological indices capturing both habitat preferences and physiological tolerance limits in bigeye tuna. Their analyses revealed four distinct regimes characterized by changes in distribution and average CPUE of bigeye tuna in the Pacific Ocean. Habitat models accounting for basin-wide fluctuations in the thermal structure and oxygen concentration throughout the water column captured interannual fluctuations in CPUE and regime switches that models based solely on surface information were unable to reproduce. Decade-long forecast experiments further suggested that forecasts of three-dimensional biogeochemical information might enable anticipation of fluctuations in bigeye tuna several years ahead. This study raises concerns about the future impact of ocean warming and deoxygenation and supports incorporating subsurface biogeochemical information into ecological forecasts to implement efficient dynamic management strategies.

3.5. Recent and Historical Data Show no Evidence of Pacific Bluefin Tuna Reproduction in The Southern California Current System

To investigate the possibility the Pacific bluefin tuna are spawning in the California Current system, **Dewar et al. (2022)** collected samples from 36 females (estimated 3–8 years old) between 2015 and 2019. Histological analyses revealed that two of 36 individuals had cortical aveoli and there was no sign of imminent, active, or recent spawning. Further examination of historical ichthyoplankton collections showed no records of larval bluefin tuna, but confirmed the presence of the larvae of other tuna species in waters > 24°C. Fishery-dependent records showed that bluefin tuna are rarely recorded in purse seine catches where surface temperatures exceed 23°C. Additionally, the conditions in the California Current are differ from those in other bluefin tuna spawning grounds. Typically, spawning ground occur in warm oligotrophic waters with larvae being advected to cooler, more nutrient rich waters. This is the opposite of the conditions in the productive south flowing, California Current. This study provided no evidence of bluefin tuna reproduction in the California Current. However, more comprehensive sampling, in particular off southern Baja California where temperatures can exceed 24°C, may be required to confirm the absence of spawning.

3.6. Otolith Geochemistry Reflects Life Histories of Pacific Bluefin Tuna

Mohan et al. (2022) analyzed otolith biominerals of large Pacific bluefin tuna collected from the western, eastern, and south Pacific Ocean for a suite of trace elements across calcified/proteinaceous growth zones to investigate patterns across ontogeny. They analyzed both life-history trans and the otolith edge for difference across regions and elemental signatures. Three element: Ca ratios, Li:Ca, Mg:Ca, and Mn:Ca displayed enrichment in the otolith core, then decreased to low stable levels after age 1–2 years with little change after that point. Factors other than oceanography including temperature, metabolism, diets, likely influenced otolith crystallization, protein content, and elemental incorporation. Although similar patterns were also exhibited for otolith Sr:Ca, Ba:Ca and Zn:Ca in the first year, variability in these elements differed significantly after age-2 and in the otolith edges by capture region, suggesting ocean-specific environmental factors or growth-related physiologies affected otolith mineralization across ontogeny. Results confirm difference in biomineralization across regions and that some elements are more useful than others for examining migratory pathways.

3.7. Pacific Bluefin Tuna, *Thunnus orientalis*, Exhibits a Flexible Feeding Ecology in the Southern California Bight

To examine the foraging ecology of juvenile Pacific bluefin tuna, stomachs from 963 bluefin were collected in the Southern California Bight (SCB) from 2008 to 2016. Using classification and regression tree analysis, **Portner et al. (2022)** observed three periods characterized by distinct prey. In 2008, Pacific bluefin diet was dominated by midwater lanternfishes and enoploteuthid squids. During 2009–2014, PBF consumed diverse fishes, cephalopods, and crustaceans. Only in 2015–2016 did PBF specialize on relatively high energy, surface schooling prey (e.g., anchovy, pelagic red crab). Interestingly, the energetic value of prey was similar in Nodes 2 and 3, while stomachs from 2009-2014 had the smallest sized prey and the highest number of prey. This work demonstrated that Pacific bluefin tuna is an opportunistic predator that can exhibit distinct foraging behaviors to exploit diverse forage. They can forage across the water column on diverse prey types, schooling and non-schooling. Expanding understanding of Pacific bluefin tuna foraging ecology is improving the ability to predict their responses to changes in resource availability as well as potential impacts to the fisheries it supports. This work is continuing to produce results for Pacific bluefin stomachs collected from 2017 to 2022.

3.8. Juvenile Albacore Tuna (*Thunnus alalunga*) Foraging Ecology Varies with Environmental Conditions in the California Current Large Marine Ecosystem

Nickels et al. (2023) describes the diets of juvenile North Pacific albacore from three regions in the California Current Large Marine Ecosystem from 2007 to 2019 and uses classification and regression tree analysis to explore environmental drivers of variability. Important prey includes northern anchovy (*Engraulis mordax*), rockfishes (*Sebastes* spp.), boreal clubhook Squid (*Onychoteuthis borealijaponica*), euphausiids (Order: Euphausiidae), and amphipods (Order: Amphipoda), each contributing >5% mean proportional abundance. Most prey items were short lived species or young-of-the-year smaller than 10 cm. Diet variability was related to environmental conditions over the first 6 months of the year (Pacific decadal oscillation, sea surface temperature, and North Pacific Gyre Oscillation) and conditions concurrent with Albacore capture (region and surface nitrate flux). Nickels et al. describes foraging flexibility over regional and annual scales associated with these environmental influences. Continuous, long-term studies offer the opportunity to identify flexibility in Albacore foraging behavior and begin to make a predictive link between environmental conditions early in the year and Albacore foraging during summer and fall.

3.9. Albacore Tuna and Broadbill Swordfish Diets in the State of the California Current Ecosystem Report

Thompson et al. 2022 quantifies the diets of North Pacific albacore tuna and broadbill swordfish to provide insight into how forage varies over time and space, as well as provide a direct metric of forage utilization.

Juvenile albacore tuna were collected off Northern California, Oregon, and Washington during the summer and fall fishing season. Based on preliminary data from 2021, the dominant prey from 2021 were northern anchovy (*Engraulis mordax*), Euphausiids (Order: Euphausiacea), and Pacific saury (*Cololabis saira*). Northern anchovy consumption increased in 2020 and 2021 after a low in 2018-2019. Sardine (*Sardinops sagax*) consumption was also high in 2020 and 2021, well above the long term mean. Rockfish (*Sebastes* spp.) consumption demonstrated an opposing pattern, with consumption declining in 2020 and 2021 after a peak in 2019, coinciding with the northern anchovy low.

Swordfish were collected off Southern and Central California during the commercial drift gillnet season (August 15 through January 31). Stomachs are classified by the year the fishing season began (stomachs from January are assigned to the previous year's fishing season). Swordfish fed mainly on fish and cephalopods. In 2019, the dominant prey was northern anchovy followed by market squid (*Doryteuthis opalescens*). In 2020, slender blacksmelt (*Bathylagus pacificus*) was the most important followed by northern anchovy and market squid. Northern anchovy and market squid were consumed above the long-term mean in 2019-2020, with Northern anchovy well above the mean. Pacific hake (*Merluccius productus*) fell near the mean in both years. The other small pelagics and rockfish were a minor part of swordfish diets across years. Fished species were less important in swordfish diets overall when compared with albacore.

4. NOAA FISHERIES LITERATURE RELEVANT TO ISC FROM THE PAST YEAR

Peer-Reviewed Publications

Andrzejaczek, S., Lucas, T.C.D., Goodman, M.C., Hussey, N.E., Armstrong, A.J., Carlisle, A., Coffey, D.M., Gleiss, A.C., Huveneers, C., Jacoby, D.M., Meekan, M.G., Mourier, J., Peel, L.R., Abrantes, K., Afonso, A.S., Ajemian, M.J., Anderson, B.N., … Curnick, D.J. 2022. Diving into the vertical dimension of elasmobranch movement ecology. Sci. Adv. 8, eabo1754. https://doi.org/10.1126/sciadv.abo1754

Arostegui, M.C., Gaube, P., Woodworth-Jefcoats, P.A., Kobayashi, D.R., Braun, C.D.. 2022. Anticyclonic eddies aggregate pelagic predators in a subtropical gyre. Nature 609, 535-540. https://doi.org/10.1038/s41586-022-05162-6

Chan, H.L. 2023. How climate change and climate variability affected trip distance of a commercial fishery. PLOS Clim 2(2): e0000143. https://doi.org/10.1371/journal.pclm.0000143

Dewar, H., Snodgrass, O., Muhling, B., and Schaefer, K. 2022. Recent and historical data show no evidence of Pacific bluefin tuna reproduction in the southern California Current system. PLoS ONE 17(5): e0269069. https://doi.org/10.1371/journal.pone.0269069

Domokos, R. 2023. Influence of El Niño-Southern Oscillation on bigeye and yellowfin tuna longline catch per unit effort in the equatorial Pacific. Fish. Oceanogr. 1–14. https://doi.org/10.1111/fog.12644

Druon, J. N., Campana, S., Vandeperre, F., Hazin, F.H.V., Bowlby, H., Coelho, R., Queiroz, N., Serena, F., Abascal, F., Damalas, D., Musyl, M., Lopez, J., Block, B., Afonso, P., Dewar, H., Sabarros, P.S., Finucci, B., Zanzi, A., Bach, P., … Travassos, P. 2022. Global-scale environmental niche and habitat of blue shark (*Prionace glauca*) by size and sex: a pivotal step to improving stock management. Front. Mar. Sci. 9:828412. https://doi.org/10.3389/fmars.2022.828412

Ducharme-Barth, N.D. and Vincent, M.T. 2022. Focusing on the front end: A framework for incorporating uncertainty in biological parameters in model ensembles of integrated stock assessments. Fish. Res. Volume 255: 106452. https://doi.org/10.1016/j.fishres.2022.106452

Giddens, J., Kobayashi, D.R., Mukai, G.N.M., Asher, J., Birkeland, C., Fitchett, M., Hixon, M.A., Hutchinson, M., Mundy, B.C., O'Malley, J.M., Sabater, M., Scott, M., Stahl, J., Toonen, R., Trianni, M., Woodworth-Jefcoats, P.A., Wren, J.L.K., and Nelson, M. 2022. Assessing the vulnerability of marine life to climate change in the Pacific Islands region. PLoS One,17(7):e0270930. https://doi.org/10.1371/journal.pone.0270930

Gilmour, M.E., Adams, J., Block, B.A., Caselle, J.E., Friedlander, A.M., Game, E.T., Hazen, E.L., Holmes, N.D., Lafferty, K.D., Maxwell, S.M., McCauley, D.J., Oleson, E.M., Pollock, K., Shaffer, S.A., Wolff, N.H., and Wegmann, A. 2022. Evaluation of MPA designs that protect highly mobile megafauna now and under climate change scenarios. Global Ecol. Conser. Volume 35: e02070. https://doi.org/10.1016/j.gecco.2022.e02070

Jorgensen, S.J., Micheli, F., White, T.D., Van Houtan, K.S., Alfaro-Shigueto, J. Andrzejaczek, S., Arnoldi, N.S., Baum, J.K., Block, B., Britten, G.L., Butner, C., Caballero, S., Cardeñosa, D., Chapple, T.K., Clarke, S., Cortés, E., Dulvy, N.K., Fowler, S., Gallagher, A.J. … Ferretti, F. 2022. Emergent research and priorities for shark and ray conservation. Endanger. Species Res. Vol. 47: 171-203. https://doi.org/10.3354/esr01169

LaFreniere, B. R., Sosa-Nishizaki, O., Herzka, S. Z., Snodgrass, O., Dewar, H., Miller, N., Wells, R.J.D., and Mohan, J. A. 2023. Vertebral Chemistry Distinguishes Nursery Habitats of Juvenile Shortfin Mako in the Eastern North Pacific Ocean. Mar. Coast. Fish. 15(2), e10234. https://doi.org/10.1002/mcf2.10234

McClure, M.M., Haltuch, M. A., Willis-Norton, E., Huff, D. D., Hazen, E. L., Crozier, L. G., Jacox, M.G., Nelson, M.W., Andrews, K.S., Barnett, L.A.K., Berger, A.M., Beyer, S., Bizzarro, J., Boughton, D., Cope, J.M., Carr, M, Dewar, H., Dick, E., Dorval, E., ... Bograd, S. J. 2023. Vulnerability to climate change of managed stocks in the California Current large marine ecosystem. Front. Mar. Sci. 10. https://doi.org/10.3389/fmars.2023.1103767

Mohan, J. A., Dewar, H., Snodgrass, O. E., Miller, N. R., Tanaka, Y., Ohshimo, S., Rooker, J.R., Francis, M., and Wells, R. D. 2022. Otolith geochemistry reflects life histories of Pacific Bluefin Tuna. PLoS ONE, 17(10), e0275899. https://doi.org/10.1371/journal.pone.0275899

Morse, P.E., Stock, M.K., James, K.C., Natanson, L.J., and Stock, S.R. 2022. Shark centra microanatomy and mineral density variation studied with laboratory microComputed Tomography. J Struct Bio. 214: 107831. https://doi.org/10.1016/j.jsb.2022.107831

Nickels, C. F., Portner, E. J., Snodgrass, O., Muhling, B., and Dewar, H. 2023. Juvenile Albacore Tuna (*Thunnus alalunga*) foraging ecology varies with environmental conditions in the California Current Large Marine Ecosystem. Fish. Oceanogr. https://doi.org/10.1111/fog.12638

Park, J.S., Almer, J.D., James, K.C., Natanson, L.J., and Stock, S.R. 2022. Bioapatite in shark centra studied by wide-angle and by small-angle X-ray scattering. J R Soc Interface. 19: 20220373. https://doi.org/10.1098/rsif.2022.0373

Park, J.S., Chen, H., James, K.C., Natanson, L.J., and Stock, S.R. 2022. Three-dimensional mapping of mineral in intact shark centra with energy dispersive x-ray diffraction. J. Mech. Behav. Biomed. 136: 105506. https://doi.org/10.1016/j.jmbbm.2022.105506

Portner, E.J., Snodgrass, O., and Dewar, H. 2022. Pacific Bluefin Tuna, *Thunnus orientalis*, exhibits a flexible feeding ecology in the Southern California Bight. PLOS ONE 17(8): e0272048. https://doi.org/10.1371/journal.pone.0272048

Scott, M., Cardona, E., Scidmore-Rossing, K., Royer, M, Stahl, J., Hutchinson, M. 2022. What's the catch? Examining optimal longline fishing gear configurations to minimize negative impacts on non-target species. Mar. Policy. Volume 143. https://doi.org/10.1016/j.marpol.2022.105186

Senko, J.F., Peckham, S.H., Aguilar-Ramirez, D., Wang, J.H. 2022. Net illumination reduces fisheries bycatch, maintains catch value, and increases operational efficiency. Curr. Biol. 32:1-8. https://doi.org/10.1016/j.cub.2021.12.050

Suter, J.M., Ames, R.T., Holycross, B., Watson, J.T. 2022. Comparing observed and unobserved fishing characteristics in the drift gillnet fishery for swordfish. Fish. Res. Volume 256:106456. https://doi.org/10.1016/j.fishres.2022.106456

Taboada, F.G., Park, J.Y., Muhling, B.A., Tommasi, D., Tanaka, K.R., Rykaczewski, R.R., Stock, C.A., Sarmiento, J.L. 2023. Anticipating fluctuations of bigeye tuna in the Pacific Ocean from three-dimensional ocean biogeochemistry. J. Appl. Ecol. 60:3, 463-479. https://doi.org/10.1111/1365-2664.14346

Thompson, A.R., Bjorkstedt, E.P., Bograd, S.J., Fisher, J.L., Hazen, E.L., Leising, A., Santora, J.A., Satterthwaite, E.V., Sydeman, W.J., Alksne, M., Auth, T.D., Baumann-Pickering, S., Bowlin, N.M., Burke, B.J., Daly, E.A., Dewar, H., Field, J.C., Garfield, N.T., Giddings, A., … Weber, E.D. 2022. State of the California Current Ecosystem in 2021: Winter is coming? Front. Mar. Sci. 9, 958727. https://doi.org/10.3389/fmars.2022.958727

Technical reports and other publications

Ayers, A., Leong, K., Hospital, J., Tam, C., Morioka, R. 2022. Hawai'i fisher observations data summary and analysis. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-22-27, 23 p. https://doi.org/10.25923/aepb-m302

Ayers, A., Leong, K., Hospital, J., Tam, C., Morioka, R. 2022. Guam & CNMI fisher observations data summary and analysis. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-22-26, 17 p. https://doi.org/10.25923/wmv2-y197

Bigelow, K. 2022. The American Samoa Longline Limited-entry Fishery Annual Report 1 January-31 December 2021. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-22-40, 12 p. https://doi.org/10.25923/peap-vt07

Bigelow, K., Rice, J., Carvalho, F. 2022. Future Stock Projections of Oceanic Whitetip Sharks in the Western and Central Pacific Ocean. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-22-33, 21 p. https://doi.org/10.25923/yng3-gv19

Domokos, R., Wren, J., Woodworth-Jefcoats, P., Rykaczewski, R., Ruzicka, J., Ahrens, R., Barkley, H., Whitney, J., Oleson, E., Kobayashi, D. 2023. 10-year pelagic sampling strategy (2023-2032). Pacific Islands Fisheries Science Center, PIFSC Administrative Report, H-23-03, 46 p. https://doi.org/10.25923/nw52-tn17

Ito, R. 2022. The Hawaii and California-based Pelagic Longline Vessels Annual Report for 1 January-31 December 2021. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-22-41, 19 p. https://doi.org/10.25923/c2sp-8d23

Ma, H,, Matthews, T., Nadon, M., Carvalho, F. 2022. Shore-based and boat-based fishing surveys in Guam, the CNMI, and American Samoa: survey design, expansion algorithm, and a case study. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-126, 115 p. https://doi.org/10.25923/c9hn-5m88

Otsu, M. 2022. New Insights Into Black Marlin Caught Around Hawai'i. Hawaii Fishing News, Volume 47 Number 7: 18-19.

Walsh, W.A. and Brodziak, J. 2022. CPUE Standardization for Whitetip Shark, Carcharhinus longimanus, in the Hawaiian Longline Fishery, during 1994-2019. Pacific Islands Fisheries Science Center, PIFSC Administrative Report, H-22-06, 64 p. https://doi.org/10.25923/07xf-h192

5. FIGURES

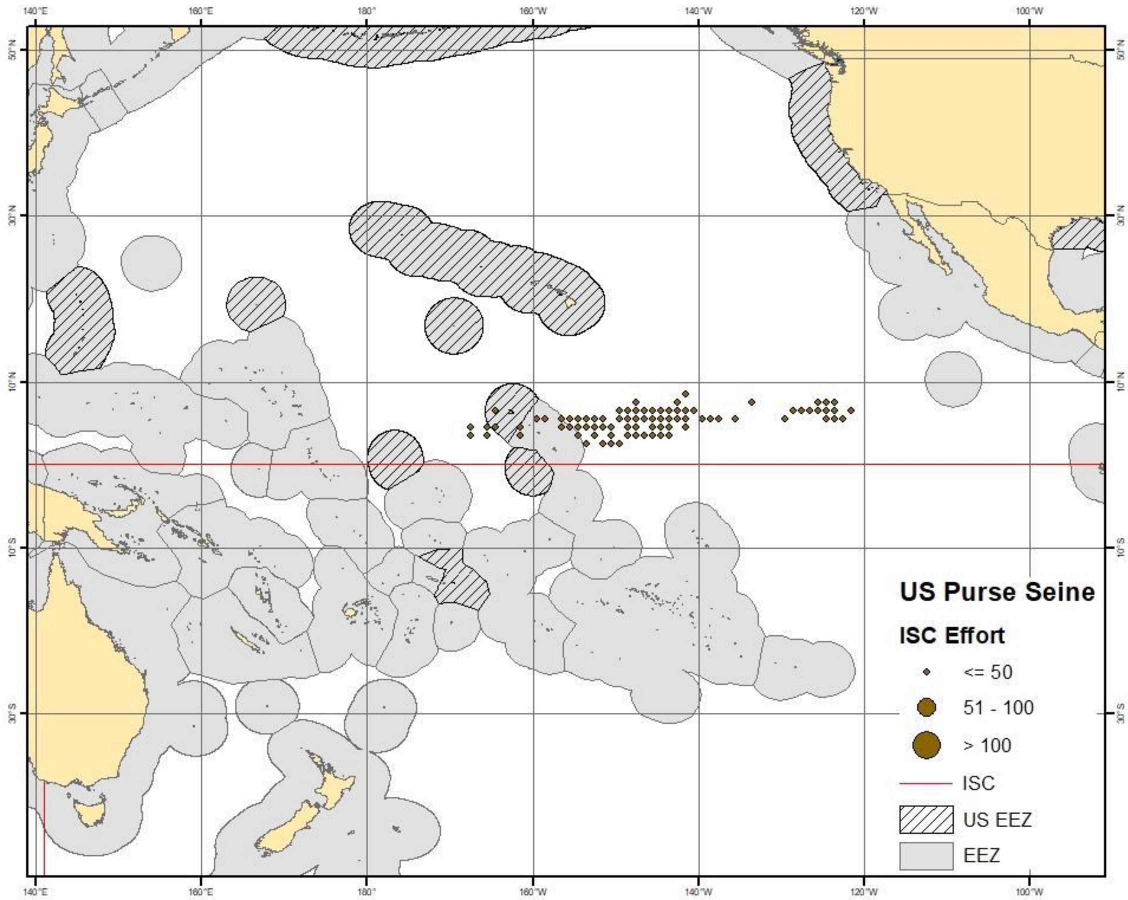

Figure 1. Spatial distribution of reported logbook fishing effort by the 2022 U.S.A Western Pacific purse seine fishery in vessel-days. The size of circles is proportional to the amount of effort. Effort in some areas is not shown in order to preserve data confidentiality.

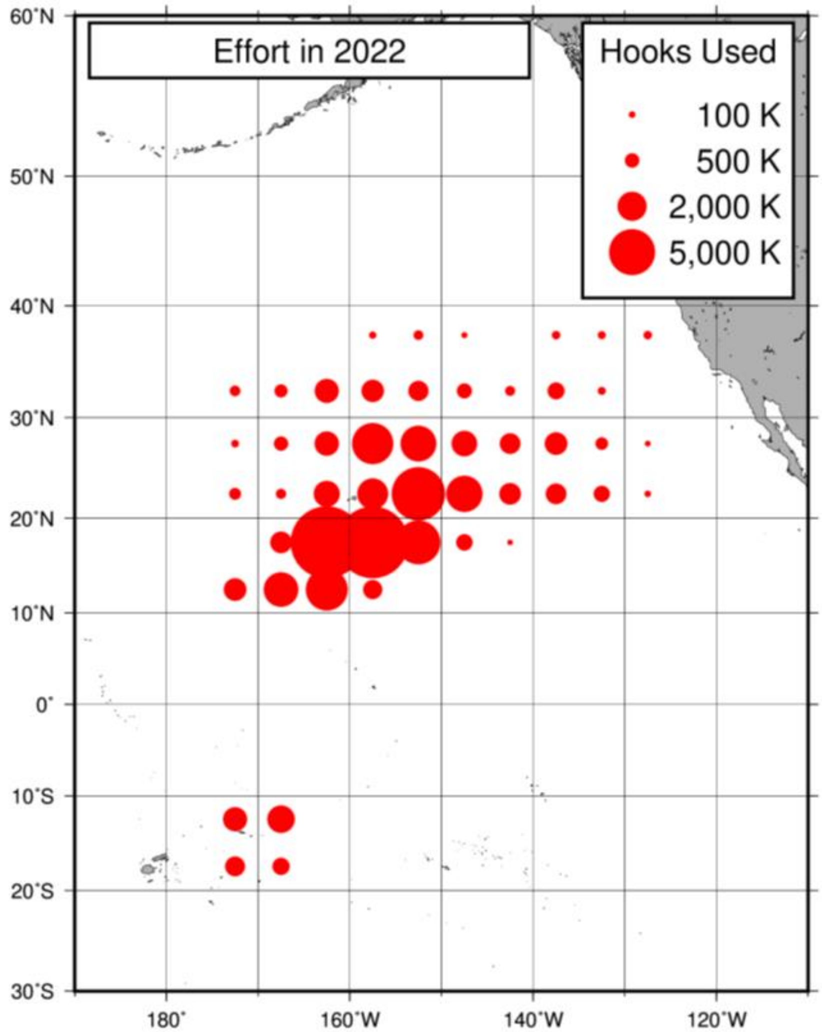

Figure 2. Spatial distribution of reported logbook fishing effort by the 2022 U.S.A longline fishery in the Pacific Ocean, in 1,000s of hooks. The size of circles is proportional to the amount of effort. Effort in some areas is not shown in order to preserve data confidentiality.

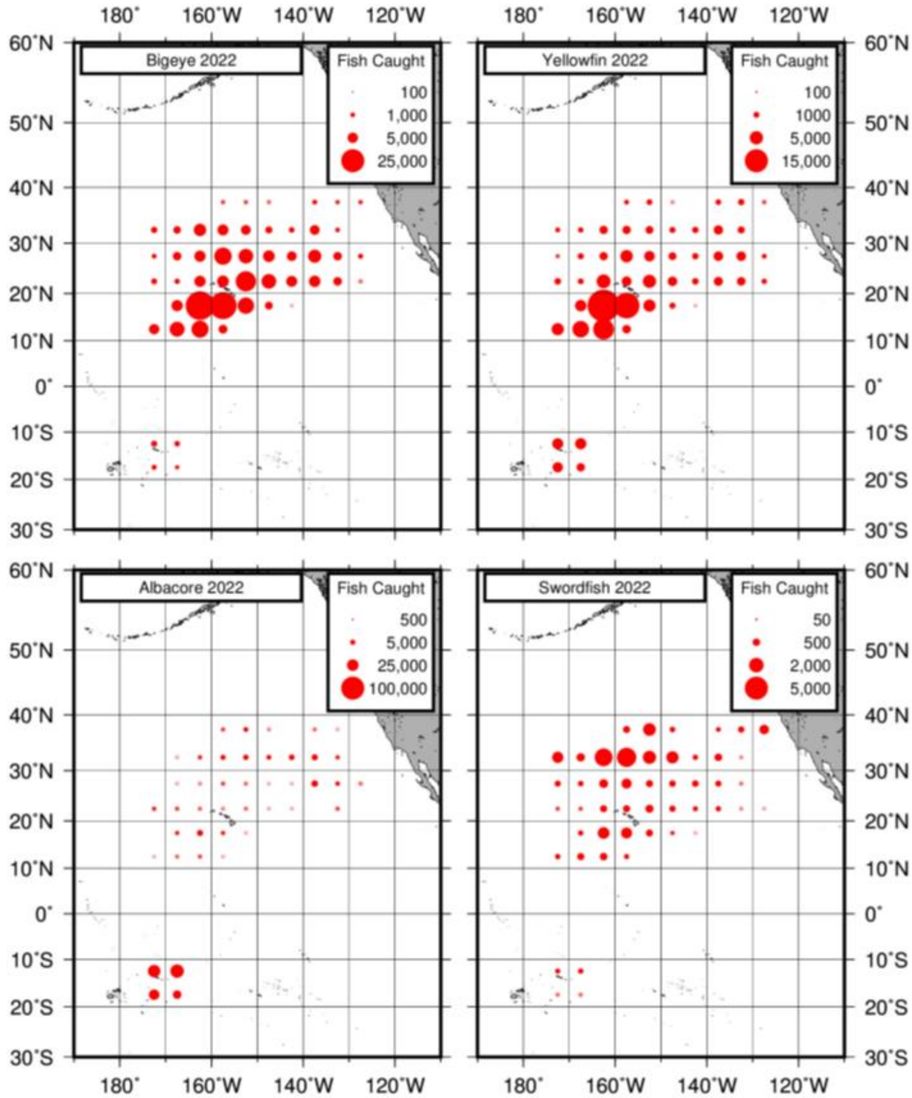

Figure 3. Spatial distribution of reported logbook fishing catch by the U.S.A longline fishery in the Pacific Ocean, in numbers of fish, in 2022 for bigeye tuna (*Thunnus obesus*), albacore tuna (*Thunnus alalunga*), yellowfin tuna (*Thunnus albacares*), and swordfish (*Xiphias gladius*). The size of circles is proportional to the amount of effort. Effort in some areas is not shown in order to preserve data confidentiality.

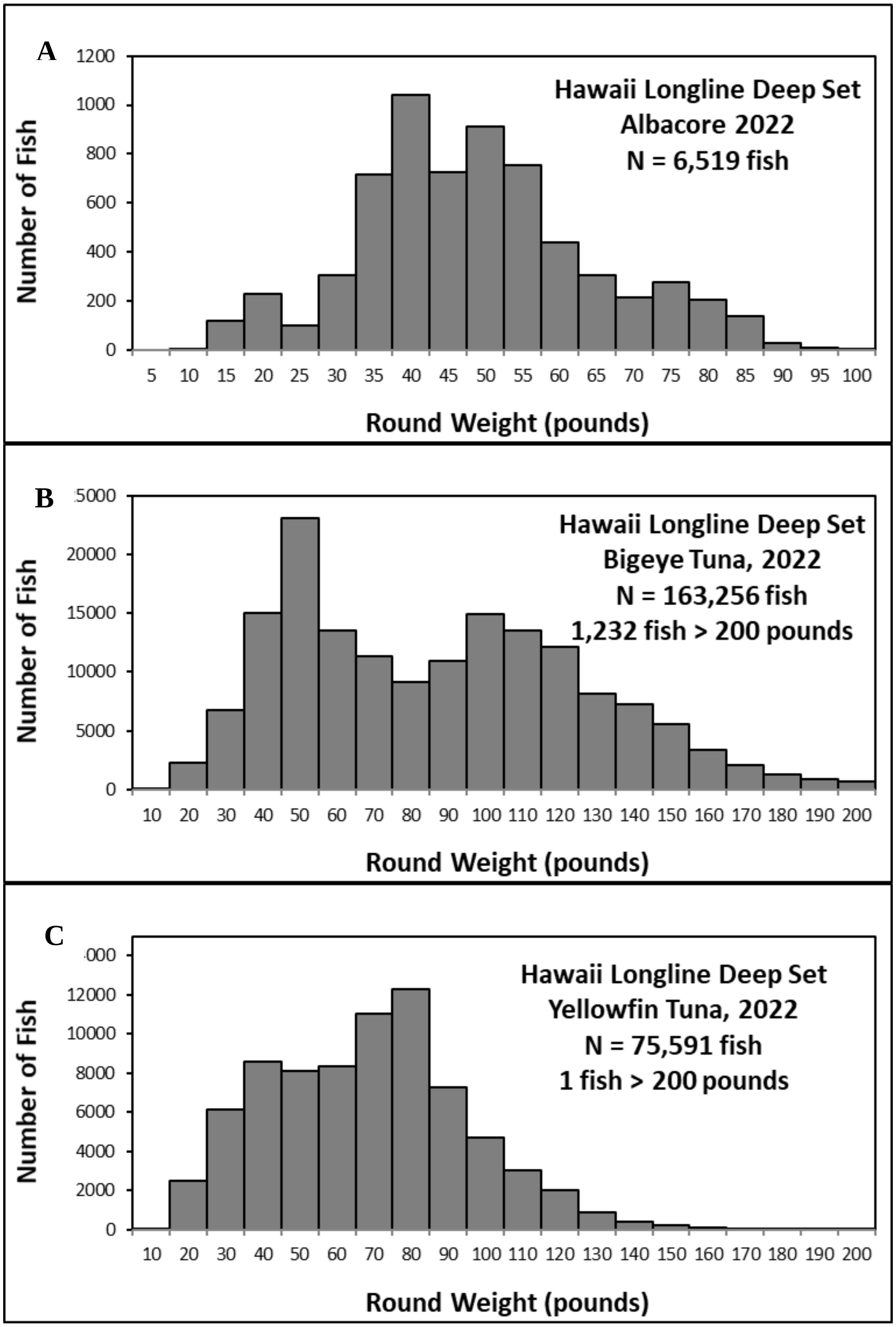

Figure 4. Size distribution of (A) albacore tuna (T*hunnus alalunga*), (B) bigeye tuna (*T. obesus*), and (C) yellowfin tuna (*T. albacares*) caught by the Hawaii-based deep-set longline fishery in the Pacific Ocean, 2022.

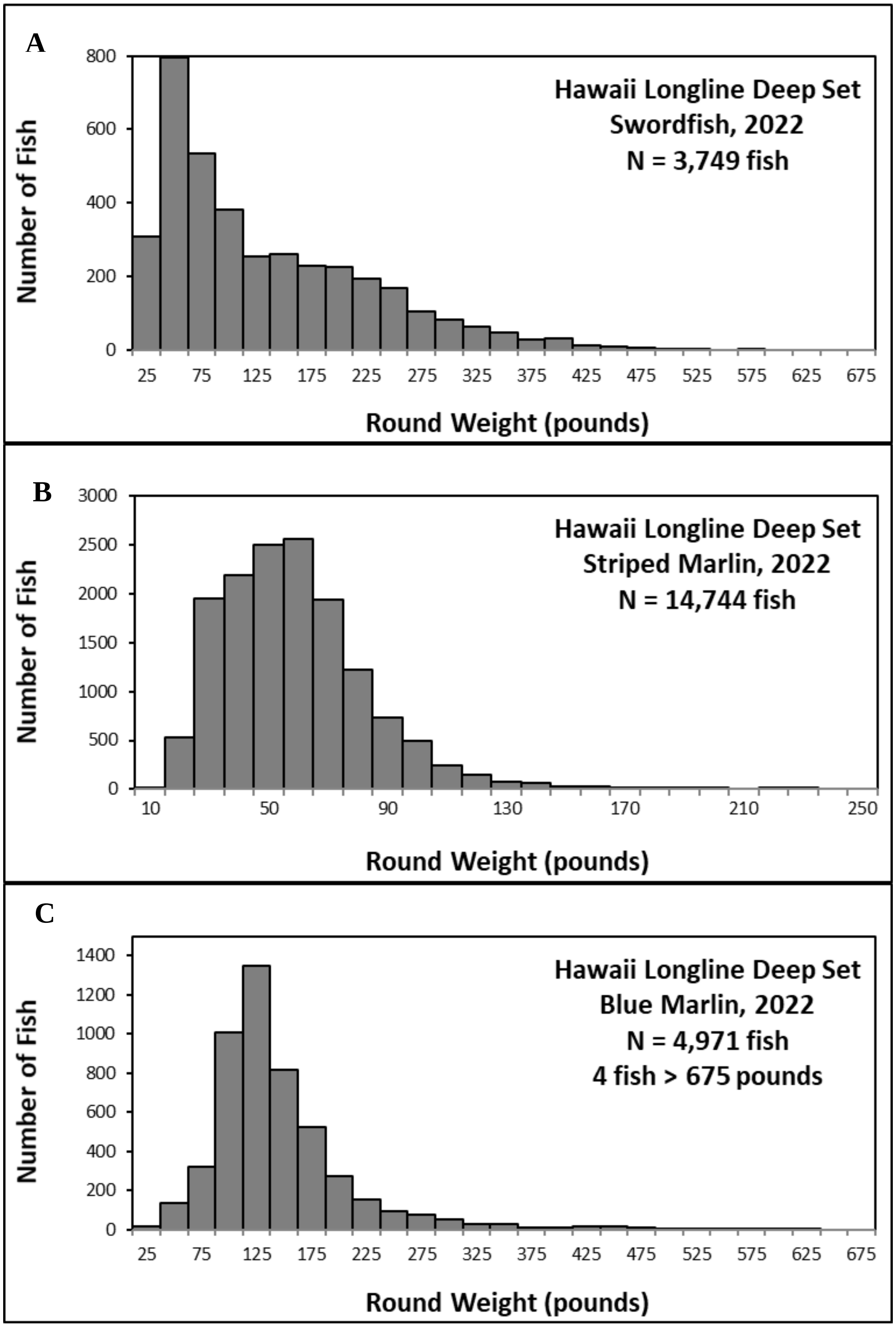

Figure 5. Size distribution of (A) swordfish (*Xiphias gladius*), (B) striped marlin (*Tetrapturus audax*), and (C) blue marlin (*Makaira nigricans*) caught by the Hawaii-based deep-set longline fishery in the Pacific Ocean, 2022.

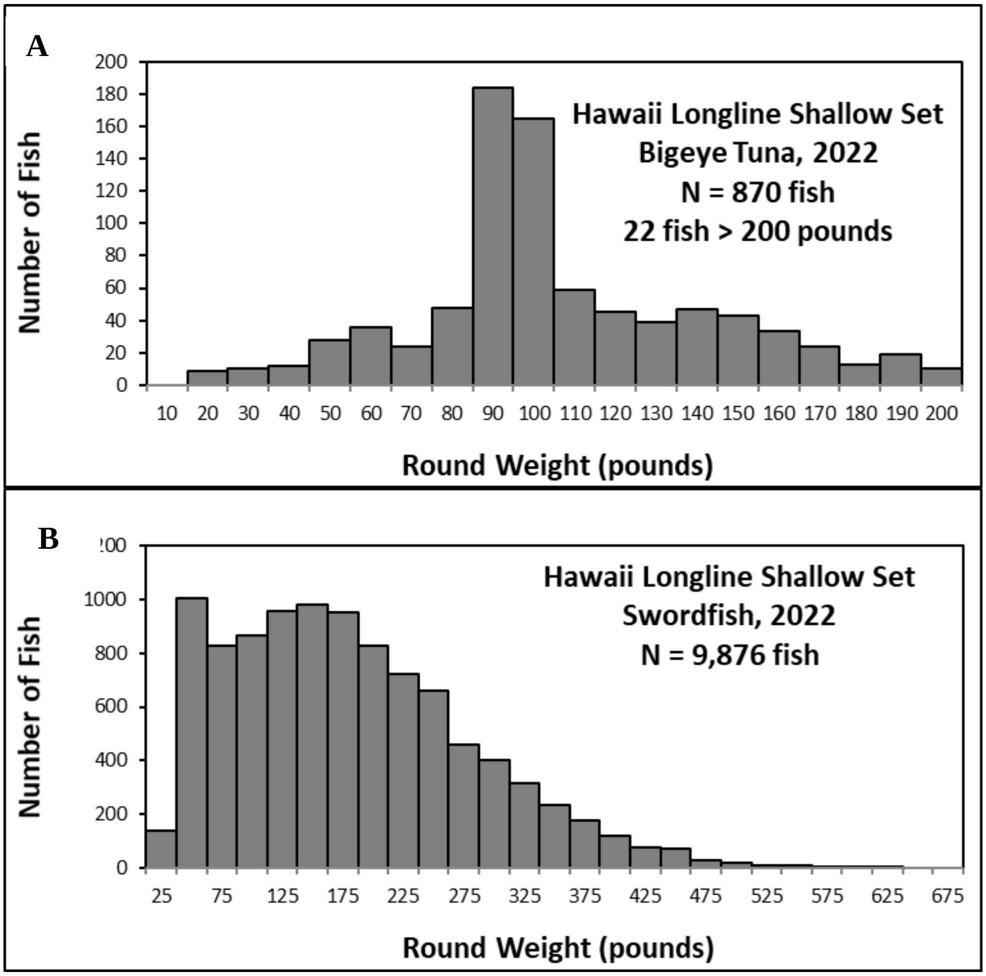

Figure 6. Size distribution of (A) bigeye tuna (*Thunnus obesus*), and (B) swordfish (*Xiphias gladius*) caught by the Hawaii-based shallow-set longline fishery in the Pacific Ocean, 2022.

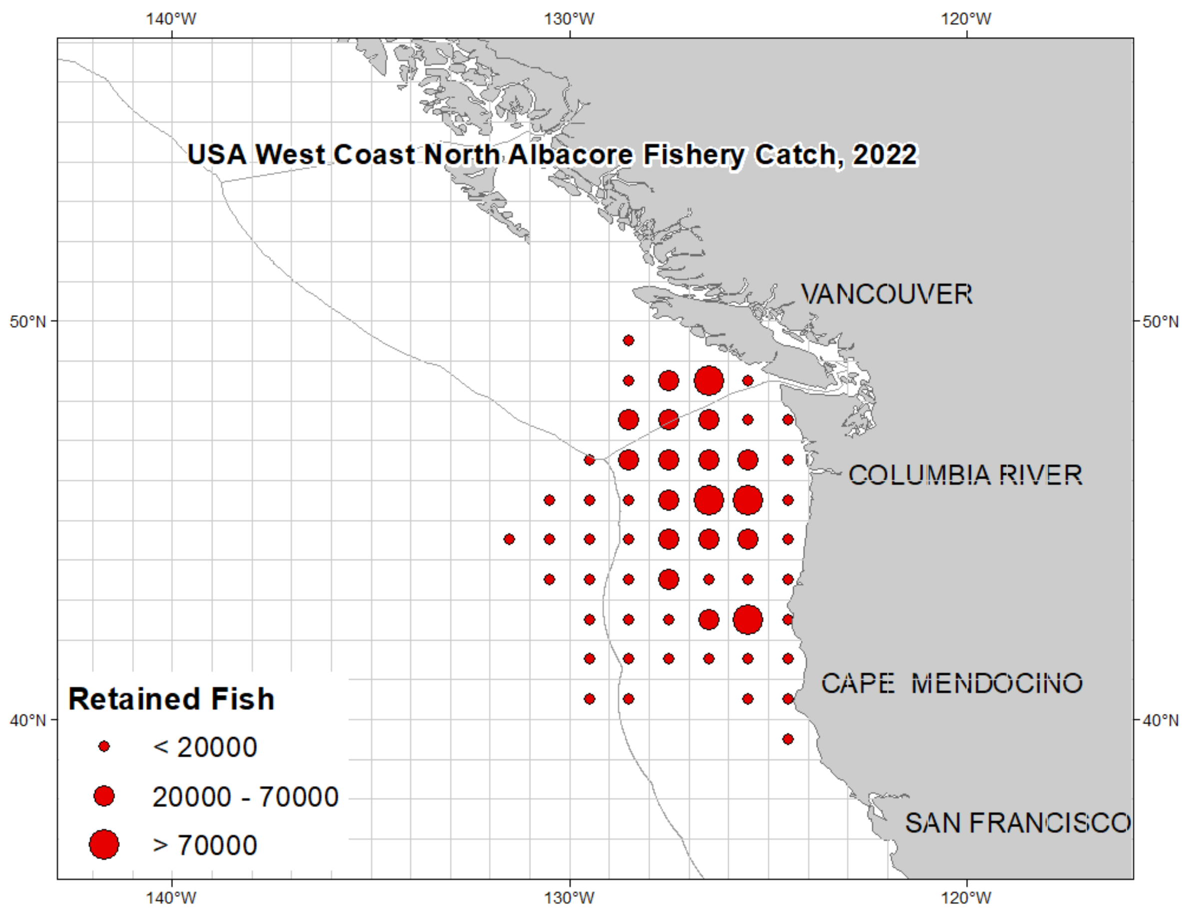

Figure 7. Spatial distribution of reported logbook catch by the 2022 U.S.A albacore troll and pole-and-line fishery in number of fish. The size of circles is proportional to the amount of catch. Some catch areas are not shown in order to preserve data confidentiality.

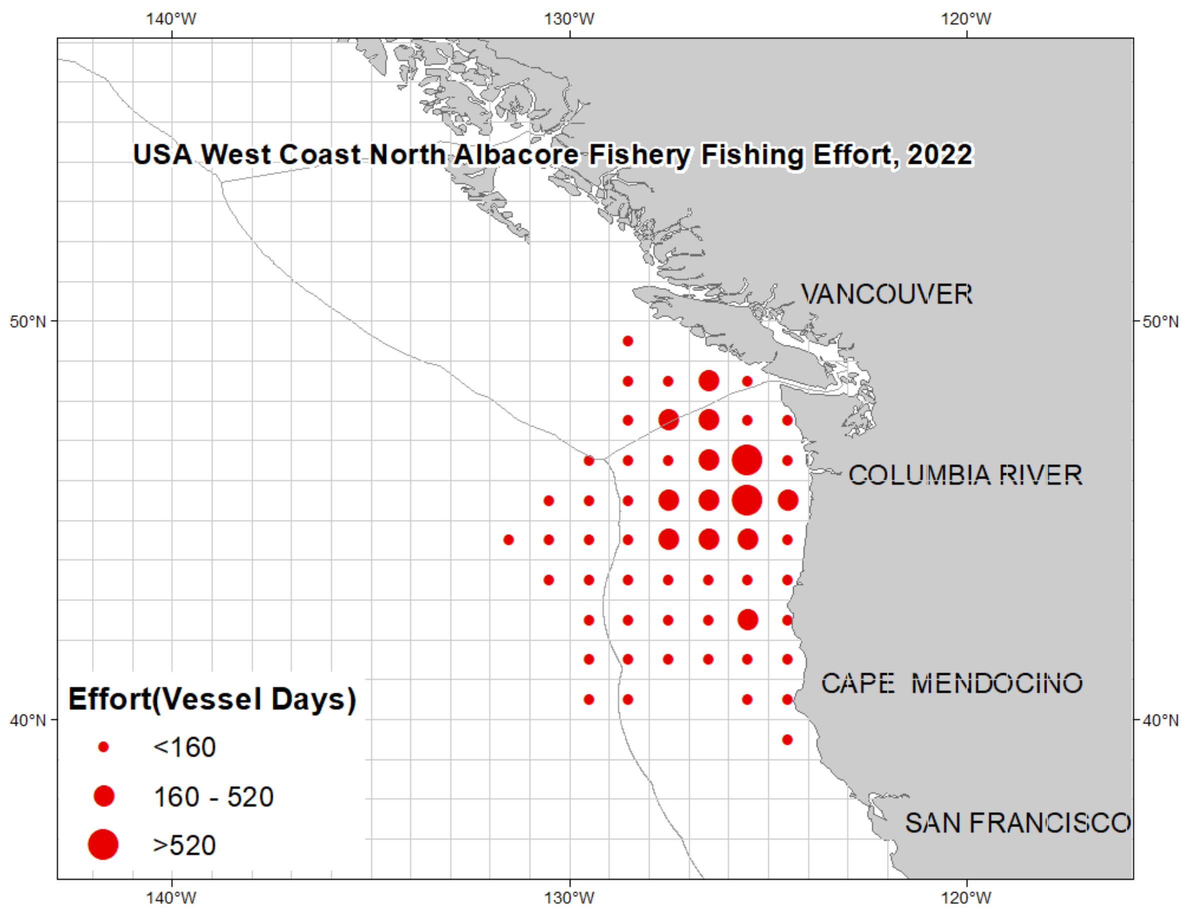

Figure 8. Spatial distribution of reported logbook fishing effort by the 2022 U.S.A albacore troll and pole-and-line fishery in vessel days. The size of circles is proportional to the amount of effort. Some effort areas are not shown in order to preserve data confidentiality.

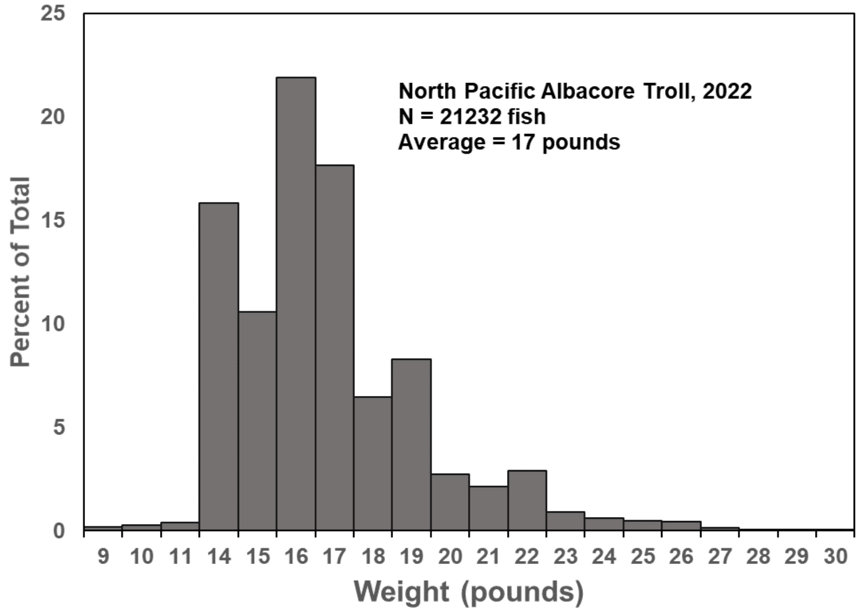

Figure 9. Size distribution of albacore (*Thunnus alalunga*) caught by the 2022 U.S.A albacore troll and pole-and-line fishery.

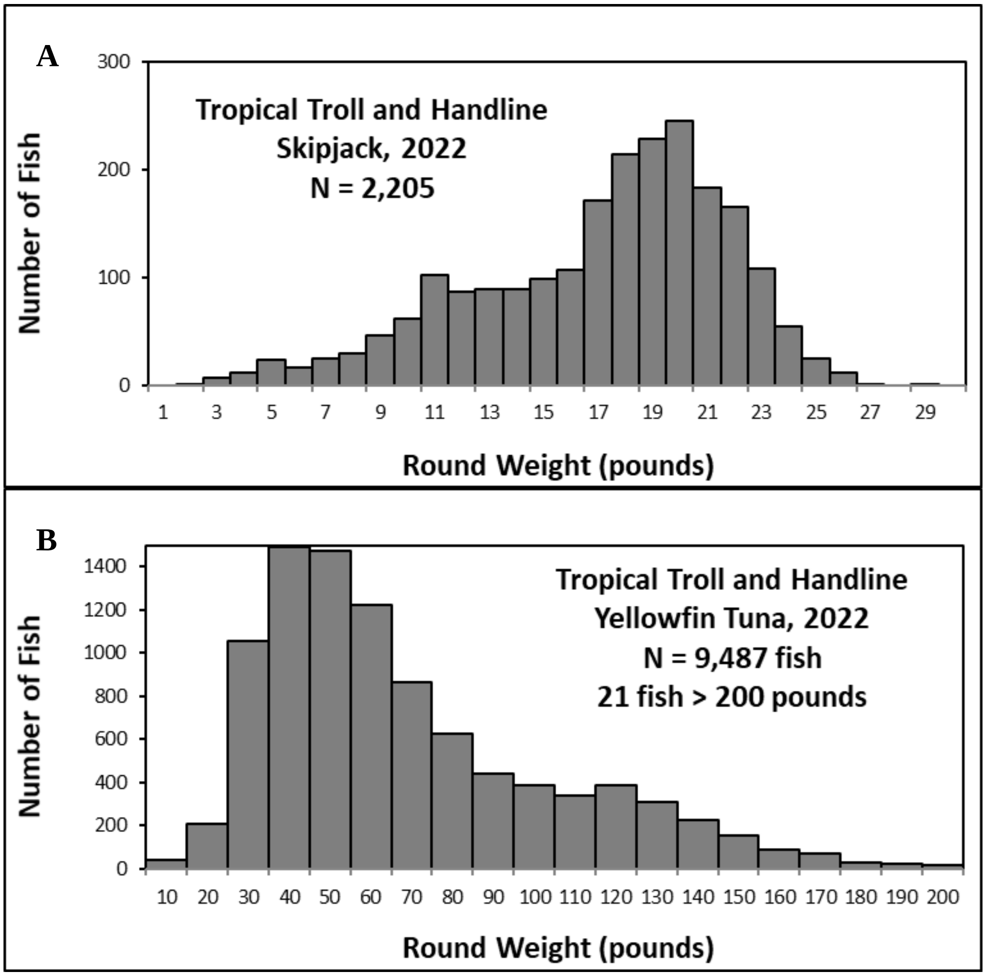

Figure 10. Size distribution of (A) skipjack tuna (*Katsuwonus pelamis*), and (B) yellowfin tuna (*Thunnus albacares*) caught by the Hawaii troll and handline fisheries, 2022

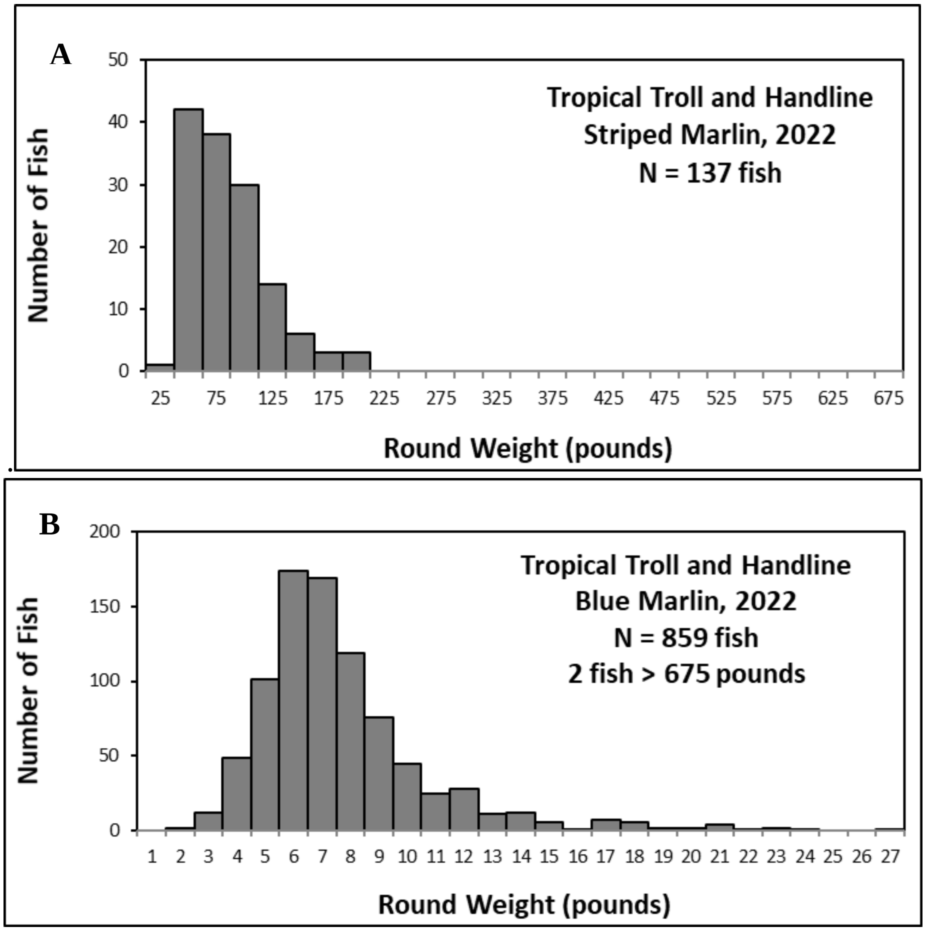

Figure 11. Size distribution of (A) striped marlin (*Tetrapturus audax*) and (B) blue marlin (*Makaira nigricans*) caught by the Hawaii troll and handline fisheries, 2022.

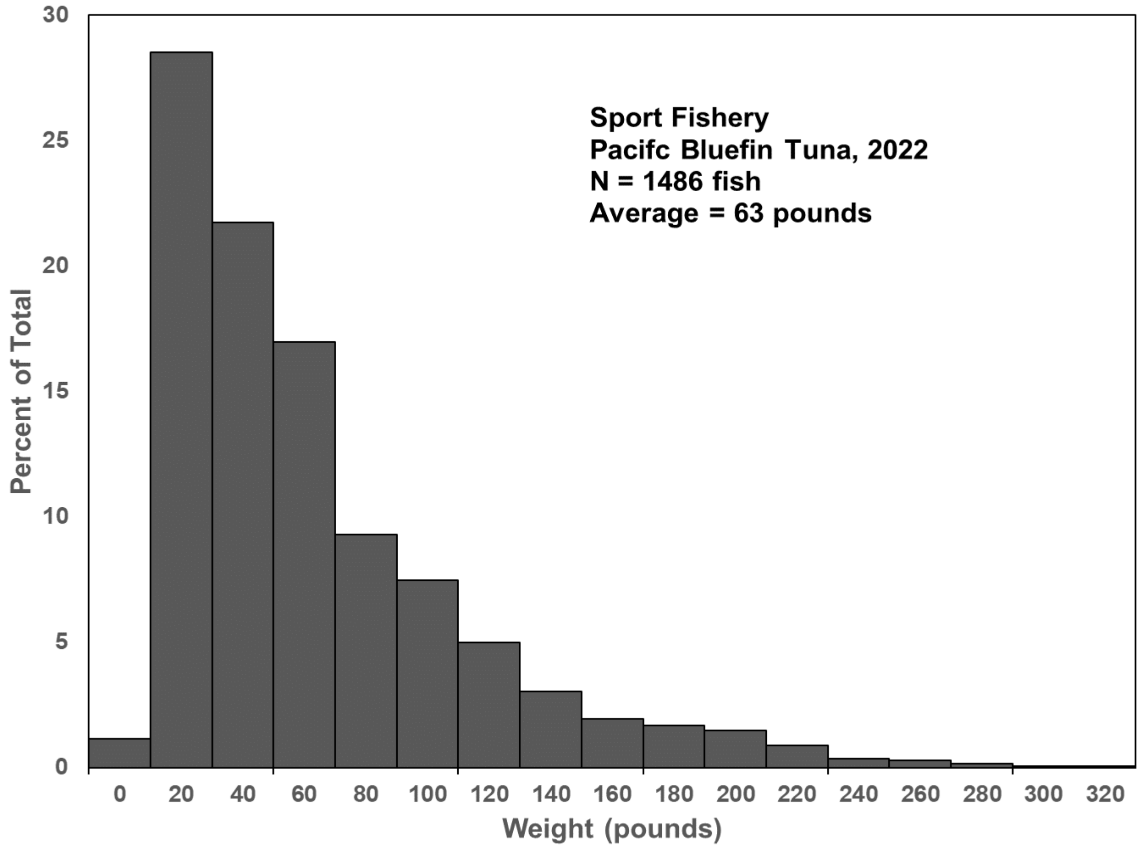

Figure 12. Size distribution of Pacific Bluefin Tuna (*Thunnus orientalis*) caught by the 2022 U.S. West Coast sportfishing industry.