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NOAA, National Marine Fisheries Service

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U.S.A. Fisheries and Research on Tuna and Tuna-like Species in the North Pacific Ocean

NOAA, National Marine Fisheries Service

Executive 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 pole-and-line, and longline fleets, which account for most of the tuna catches, operate both within 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 2016 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 2016, 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. These research efforts provided empirical information to quantify fish movements, habitat preferences, post-release survival, feeding habits, and age and growth as well as economic impacts. Reported information includes: longline economics, climate change impacts, cooperative research methods, migration patterns, age validation, population model data conflict resolution methods, research on natural mortality, age-based movement research, stock assessment package review, Pacific bluefin tuna (PBF) distribution and diet studies.

I. 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 2017. Data for 2016 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.

II. Fisheries

A. 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). 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 and outside the exclusive economic zone (EEZ) of Mexico, off Baja 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 2016, there were 42 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 (coverage 100%). 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.

B. 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-based fleet. 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 March 20, 2006. The majority of vessels that targeted swordfish converted to deep-set longline and targeted tunas for the remainder of the year. 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.

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. Only one California-based vessel fished between 2005 and 2015 using deep-set longline to target tunas. Additionally, up to eight Hawaii-permitted vessels landed swordfish caught with shallow-set longline gear to the West Coast 2016.

In the North Pacific, the longline fishery extended from outside the U.S.A. West Coast EEZ to 175°W longitude and from the equator to almost 40°N latitude in 2015 (Figures 1 and 2). The total number of vessels participating in the longline fishery increased from 36 in 1985 to a high of 141 vessels in 1991 (Table 1). Since then, the number of vessels has varied from 17 to 140 with approximately 141 vessels participating in 2016. 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. 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 2013-2016 (Table 2). Bigeye tuna (*Thunnus obesus*) dominates the tuna catch with landings over 4,000 t during the past fourteen years. The 2016 bigeye tuna catch was 8,260 t. Swordfish has been the dominant component of the billfish catch since 1990 and reached a peak of 5,936 t in 1993 before decreasing to 1,185 t in 2004. The U.S.A. 2016 swordfish catch by longline was 1,092 t.

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 vessel 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%. 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 3-5).

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. These data are included in Figures 3-5 along with the Hawaii fleet length data. NOAA Fisheries has placed observers on all California-based 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).

C. 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 (Figures 6 and 7). Fishing usually starts in May or June and ends in October or November. In 2016, 571vessels participated in the fishery, down from 625 in 2014 (Table 1).

The troll and pole-and-line fishery catches almost exclusively albacore with minor incidental catches of skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), and bluefin (*Thunnus orientalis*) tunas, 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 2015 and 2016, 11,558 t and 10,686 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. NOAA Fisheries and various state fisheries agencies monitor the fleet's landings through sales receipts (fish tickets) and landings reported in logbooks.

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 punds) and 90 cm (32 pounds). A single dominant size mode is evident in samples collected in 2016, centered at 7 pounds (68 cm)
Weight distribution of the catch for 2016 is shown in Figure 8. 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.

D. 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 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 confidentiality, no data for the tropical pole-and-line fishery are reported.

E. 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 operates 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 1,818 troll vessels and 420 handline vessels in 2016 (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 when fish were landed for commercial sale. The size distributions of tunas (skipjack and yellowfin) and marlins (striped marlin and blue marlin, *Kajikia audax* and *Makaira nigricans*) caught in the Hawaii fishery in 2015 are summarized in Figures 9 and 10.

The total retained catch from these tropical troll and handline fisheries combined ranged from 1,160 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 2015 followed by bigeye tuna and 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.

F. 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 17 in 2012 (Table 1). Swordfish dominate the catch and peaked in 1985 at 2,990 t. Since then, swordfish catches have fluctuated while decreasing to 62 t in 2010 (Table 2). The estimate of swordfish caught in the drift gillnet fishery for 2106 is 176 t, the highest catch since 2009.

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 the CDFW 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 about 1990; observer coverage is about 20% of effort.

The US fishing industry has been modifying a gear called “deep-set buoy gear” for use in the eastern Pacific Ocean as an alternative to gillnet fishing swordfish and as part of an effort to maximize economic benefits while minimizing non-target catch. Fishermen are testing deep-set buoy gear under an exempted fishing permit from NOAA Fisheries. 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 guide US managers determine if the method can be scaled up to become a viable commercial fishery.

G. 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. Nineteen vessels participated in the fishery in 2106 (Table 1). Trends in swordfish catches have fluctuated from a high of 305 t in 1985 to 5 t in 2012, 2014, and 2015. Catch increased in 2016 to an estimated 25 t (Table 2).

Landings and logbook data for the harpoon fishery are collected by the CDFW with 100% coverage of the fleet. Length measurements were taken by CDFW between 1981 and 1999, covering less than 1% of swordfish landings.

H. 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 SWFSC. Estimates of landings for CPFV and private vessels are obtained through 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 needed. The majority of the highly migratory species (HMS) catch is albacore, yellowfin and Pacific bluefin tuna. The albacore catch by sport vessels was 675 t in 2016 compared to 925 t in 2015.

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 the SWFSC 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 ISC/15/PBFWG-1/03. Catches vary and have ranged from a high of 809 t in 2013 to a low of 6 t in 1988. The 2016 catch was 298 t compared to 382 t in 2015. The spatial distribution of reported logbook fishing effort by the 2016 U.S.A. harpoon, gillnet, and west coast sport fisheries in the North Pacific Ocean are depicted in Figure 11.

III. Research

2012 economic cost earnings of pelagic longline fishing in Hawaii. NOAA reports findings from a cost-earnings study of the Hawaii-based longline fleet (Kalberg and Pan, 2016). Fleet-wide expenditures and revenue are assessed for the 2012 operational calendar year. Captains or owners of 115 of the 126 vessels active at the time of the study voluntarily participated in the face-to-face survey, resulting in a response rate of 91 percent. Results from 2012 were compared with the previous cost-earnings studies of the Hawaii longline fleet that examines the economic profiles of the fleet for 2000 and 2005 operations. Based on survey responses, the average indirect net returns for Hawaii-based longline operations were $72,855 with a direct net cash flow of $56,522 in 2012. Direct net cash flow represents a 233% change over 2005 ($16,955 adjusted value in 2012 dollars), when the last cost-earnings survey was conducted. However, economic performance varied widely in 2012. Not all owners earned a profit in 2012, with nearly one-third of study participants realizing negative net returns for the operating calendar year. In addition, vessel operators exclusively targeting bigeye tuna (deep set) generated relatively higher net returns than vessel operators who pursued only swordfish (shallow set) or a combination of swordfish and bigeye tuna during the fishing year. While vessel operators that targeted swordfish during the year generated relatively higher gross revenues than those who targeted only bigeye tuna, higher operating costs offset these gains. Analysis also indicates that vessel size tended to correlate with gross and net revenue in 2012, in that owners and captains of larger vessels generated more revenue and profit than did captains and owners of smaller vessels.

Effects of a hook ring on catch and bycatch in a Mediterranean swordfish longline fishery: small addition with potentially large consequences NOAA Fisheries investigated the effects of a circle hook ring on catch rates of target fish species and bycatch rates of sea turtles, elasmobranchs, and non-commercial fish in a shallow-set Italian swordfish longline fishery (Piovano and Swimmer 2016). Results were compared from 65 sets from six commercial fishing vessels totaling 50,800 hooks in which ringed and non-ringed 16/0 circle hooks with a 10° offset were alternated along the length of the longline. In total, 464 individuals were caught in the 4 years of experiment, with swordfish (*Xiphias gladius*) comprising 83% of the total number of animals captured. Catch rates of targeted swordfish were significantly higher on ringed hooks (CPUEringed hooks = 8.465, CPUEnon-ringed hooks = 6.654). Results indicate that ringed circle hooks captured significantly more small-sized swordfish than non-ringed circle hooks (27.7% vs. 19.5%, respectively). For species with sufficient sample sizes, the odds ratio (OR) of a capture was in favor of ringed hooks; significantly for swordfish (OR = 1.27 95%CI 1.04–1.57), and not significantly for bluefin tuna (*Thunnus thynnus*) (OR = 1.50, 95%CI 0.68–3.42) nor for pelagic stingray (*Pteroplatytrigon violacea*) (OR = 1.13, 95%CI 0.54–2.36). All six loggerhead turtles (*Caretta caretta*) and three of the four blue sharks (*Prionace glauca*) were captured on ringed hooks. Results from this study suggest that the addition of a ring to 16/0 circle hooks confers higher catchability for small-sized commercial swordfish, and does not significantly reduce catch rate of bycatch species and protected species in a Mediterranean shallow pelagic longline fishery. These findings should motivate fisheries managers to consider factors in addition to hook shape when aiming to promote sustainable fishing practices.

Applications of Hawaii longline fishery observer and logbook data for stock assessment and fishery research NOAA Fisheries documents the primary analytical methods used for stock assessment and fishery research that have been applied to the operational and catch data collected from the Hawaii-based pelagic longline fishery by the Pacific Islands Region Observer Program (PIROP) and the National Marine Fisheries Service (NMFS) of NOAA Fisheries (Walsh and

Brodziak, 2016). The primary purpose of this memorandum is to document assessment-related research using the Hawaii longline data and also to provide a basis for the continued application and future improvement of analytical methods by serving as a user's manual. The contents of this report summarize data preparation, evaluation, and stock assessment analysis as conducted throughout two decades (1995-2015). The PIROP data include many operational fishing parameters that provide important information for conducting analyses such as standardizing the observed catch-per-unit-effort (CPUE) of pelagic fishes. The estimates of standardized CPUE using the operational parameters as covariates provide indices of relative stock abundance through time which, in turn, can be used as input information for conducting stock assessments. The PIROP data also provide information needed to measure the consistency of the self-reported logbook data, which comprise a much larger body of less detailed records using graphical and statistical methods of comparison between observer- and self-reported commercial longline data. Thus, the quality and interpretation of the information in the logbook database depends, to some extent, on the observer information.

Climate change impact on carrying capacity and species richness in North Pacific pelagic marine ecosystems NOAA Fisheries investigates impacts of climate change on marine ecosystems, including fisheries, by using output from a suite of 11 earth system models to examine projected changes in two ecosystem-defining variables: temperature and food availability (Woodworth-Jefcoats et al. 2016). In particular, researchers examined projected changes in epipelagic temperature and, as a proxy for food availability, zooplankton density. They find that under RCP8.5, a high business-as-usual greenhouse gas scenario, increasing temperatures may alter the spatial distribution of tuna and billfish species richness across the North Pacific basin. Furthermore, warmer waters and declining zooplankton densities may act together to lower carrying capacity for commercially valuable fish by 2–5% per decade over the 21st century. These changes have the potential to significantly impact the magnitude, composition, and distribution of commercial fish catch across the pelagic North Pacific. Such changes will in turn ultimately impact commercial fisheries' economic value. Fishery managers should anticipate these climate impacts to ensure sustainable fishery yields and livelihoods.

Cooperative Research with the U.S. Surface Albacore Fishery NMFS scientists work with the American Fishermen's Research Foundation (AFRF) and the American Albacore Fishing Association (AAFA) on several monitoring programs and research efforts to improve knowledge of the biology and migration of North Pacific albacore in the waters off the U.S. Pacific coast.

This includes (1) a North Pacific Albacore Size Data Sampling Program. Since 1961, size data have been collected from albacore landings made by the U.S. and Canadian troll fleets at ports along the U.S. Pacific coast by NMFS staff and state fishery personnel. In 2016, fishermen measured 590 fish onboard. The mean size of the measured fish was 70 cm FL; (2) North Pacific Albacore Electronic Logbook program. In 2005, a computer program was developed to allow albacore troll fishermen to enter their logbook data into a computer program rather than complete the traditional paper forms. Since 2006, the program has been used by 5-10 fishermen annually and has received positive feedback on its functionalities and ease of use. In 2013, NMFS staff began developing a new, alternative electronic logbook in PDF format to upgrade the existing version and increase the use of electronic logbooks. Development is nearly complete and testing of the new electronic logbook will begin in 2017; (3) a North Pacific Albacore Archival Tagging program. Staff from NMFS and AFRF collaborate on an archival tagging program established 2001 to study the migration patterns and stock structure of juvenile albacore in the North Pacific. The total number of tags deployed to date is 1043. Tags were not deployed in 2016. During 2016, two tags that were deployed off the coast of Oregon in

2015 were recovered. An analysis of the data from all tags recovered since publication of their first paper on the migrations of juvenile albacore in the North Pacific in 2011 is underway. Recent recoveries include 11 tags, 6 of which were at liberty about 2 years and a seventh that was at liberty for nearly 3 years. NMFS is also working collaboratively on albacore tagging data to understand influences of the environment on albacore thermoregulation, movements, and behavior. Studies include: the inherent properties of the temperature sensors on the tags and establishment of an algorithm to accurately interpret time lags in water and peritoneal temperature changes (Snyder and Franks 2016); the behavior of four juvenile albacore as they simultaneously foraged across a front off the coast of Baja California (Snyder *et al.* In review), and the thermoregulation of juvenile albacore (in prep.); and the environmental conditions that govern the timing of departures and arrivals of juvenile albacore on the eastern Pacific foraging grounds (in prep.).

Blue Shark Electronic Tagging Studies NMFS has been deploying satellite tags on blue sharks since 2002 to examine movements and habitat use in the eastern North Pacific. To date, a total of 100 sharks (51 males and 49 females) have been tagged with some combination of SPOT (n=95) and/or PSAT tags (n=60), with 55 sharks carrying both tag types. The majority of sharks were tagged in the SCB, although 14 sharks were tagged off Baja California Sur, Mexico, and another 12 off southwest Canada. While the sample size is too small to draw conclusions about differences in migration patterns, the two females with longer tracks were far to the south the following summer. Additional tracks will be needed to determine if these patterns are consistent for females and large males for migrations greater than one year, and if so, if they are related to sex or maturity. Data transmitted and recovered from the PSAT tags provide information on vertical and thermal habitat use. Blue sharks occupied waters from 4.4 to 29.8^{o}C, with sea surface temperature ranging from 10.8 to 29.8^{o}C. A manuscript examining geographic and vertical movement patterns is in preparation.

Blue Shark Age Validation Studies Age validation work on blue sharks in the northeast Pacific Ocean culminated in a 2016 publication which demonstrated that blue sharks lay down one vertebral band pair per year. Vertebrae from 26 blue sharks were used to validate 1 growth band per year for blue sharks for sharks of ages 1 to 8 years. Length-frequency modal analysis from 26 years of research and commercial catch data also supported annual band pair deposition in blue sharks (Wells et al. 2016). Annual research surveys provide an opportunity to tag animals with oxytetracycline (OCT). When the shark is recaptured and the vertebrae recovered, the number of bands laid down since the known date of OTC injection can be used to determine band deposition periodicity. Since the beginning of the program in 1997, more than 4000 individuals have been injected with OTC. During the 2016 SWFSC surveys, 3 mako sharks, 1 blue shark, and 141 threshers were injected with OTC and released.

Dealing with Data Conflicts in Statistical Inference of Population Assessment Models That Integrate Information from Multiple Diverse Data Sets Contemporary fisheries stock assessments often use multiple diverse data sets. However, models are simplifications of reality and, therefore, misspecified. These misspecified processes result in biased estimates of absolute abundance and abundance trends, which are often evident as “data conflicts.” The appropriate method to deal with data conflicts depends on whether it is caused by random sampling error, process variation, observation model misspecification, or misspecification of the system (dynamics) model.

Diagnostic approaches are urgently needed to evaluate goodness of fit and identify model misspecification. Carvalho et al. (in press) use simulation methods to evaluate the ability of commonly-used and recently-proposed diagnostic tests (residuals analysis, retrospective analysis, the R0 likelihood component profile, the age-structured production model (ASPM), and catch-curve analysis) to detect model misspecification in the observation model process (i.e., the incorrect form for survey selectivity), systems dynamics (i.e., incorrect assumed values for steepness of the stock-recruitment relationship and natural mortality), and incorrect data weighting. Residual analyses were easily the best detector of misspecification of the observation model while the ASPM test was the only good diagnostic for detecting misspecification of system dynamics model.

Maunder and Piner (in press) recommend external estimation of the sampling error variance in likelihood functions, modelling process variation in integrated models, and internal estimation of the standard deviation of the process variation. Maunder and Piner (in press) provide a framework for model development that identifies and corrects model misspecification and illustrate the framework, using simulated data.

Searching for M: Is There More Information About Natural Mortality in Stock Assessments Than We Realize? Sippel *et al.* (in press) use the recently proposed ASPM diagnostic to identify the conditions under which natural mortality (M) might be estimable. The ASPM diagnostic aims to determine if changes in the scale and trend of stock abundance can be explained by catch alone, which is a key indicator of the presence of a production function. They apply the ASPM diagnostic to the same suit of assessments used in the previous simulations to determine if a relationship between ability to estimate M and the presence of a production function can be identified. Our results indicate that the estimation of M will be more difficult when there is no evidence of an elucidated production function than when a production relationship is visually apparent. The lack of an elucidated production function does not mean that M cannot be estimated as part of the integrated assessment model, rather it means that it will likely be driven by age composition, which is reliant on the reliability of recruitment and selection pattern estimates.

Effects of Age-Based Movement on the Estimation of Growth Assuming Random-At-Age or Random-At-Length Data Age determination and estimation of growth are fundamental components of fisheries biology. Growth is most often estimated by fitting a von Bertalanffy growth model (VBGM) to data consisting of age-length pairs collected from fisheries. The statistical methods used to estimate growth usually make one of two assumptions about the data. The most common assumption is random at age, referred to as the traditional method, where each paired observation is representative of the distribution of lengths for a given age. Less common is the assumption of random at length, referred to as the length-conditional method, where each paired sample is representative of the distributions of ages for a given length. Paired samples that are taken from the population with an intervening length-based process, such as length-stratified sampling or random dockside sampling from length-selective gears, can invalidate this assumption. Simulations showed that using the approximate length-conditional method results in unbiased VBGM parameter estimates when the samples are length-stratified while the traditional method results in biased estimates (Piner *et al.* 2016). However, if samples were collected with an intervening age-based process (e.g., movement), the assumption of random at length could be invalidated. Simulations showed that sampling from populations with spatial structure caused by the age-based process of movement can produce bias in the estimation of growth from the length-conditional method assuming random at length (Lee *et al.* 2017). Estimates of the variability in the length-at-age relationship were better estimated with the length-conditional.

A review of stock assessment packages NOAA researchers reviewed sixteen stock assessment packages used to conduct assessments on fish and invertebrate stocks. Stock assessments provide scientific advice in support of fisheries decision making. Ideally, assessments involve fitting population dynamics models to fishery and monitoring data to provide estimates of time-trajectories of biomass and fishing mortality in absolute terms and relative to biological reference points such as B_{MSY} and F_{MSY}, along with measures of uncertainty. Some stock assessments are conducted using software developed for a specific stock or group of stocks. However, increasingly, stock assessments are being conducted using packages developed for application to several taxa and across multiple regions. This study reviews the range of packages used to conduct assessments of fish and invertebrate stocks in the United States because these assessments tend to have common goals, and need to provide similar outputs for decision making. Sixteen packages are considered, five based on surplus production models, one based on a delay-difference model, and the remainder based on age-structured models. Most of the packages are freely available for use by analysts in the US and around the world, have been evaluated using simulations, and can form the basis for forecasts. The packages differ in their ease of use and the types of data inputs they can use. This paper highlights the benefits of stock assessment packages in terms of allowing analysts to explore many assessment configurations and facilitating the peer-review of assessments. It also highlights the disadvantages associated with the use of packages for conducting assessments. Packages with the most options and greatest flexibility are the most difficult to use, and see the greatest development of auxiliary tools to facilitate their use.

Pacific Bluefin Tuna Otolith Microchemistry Studies To understand the temporal and spatial dynamics of Pacific bluefin tuna distribution throughout their life cycle including characterizing connectivity between western Pacific spawning grounds and foraging grounds in the WPO, EPO and SWPO, NOAA Fisheries is conducting collaborative studies with National Research Institute of Far Seas Fisheries in Shizuoka. These studies will focus on using multiple techniques to distinguish among spawning and foraging grounds throughout the Pacific including biogeochemical markers and morphometrics. Goals will be to (1) Identify and track chemical signatures in otoliths from young-of-the-year (age-0) PBF from both spawning grounds over multiple years using trace elements and stable isotopes; (2) Determine relative contribution of both spawning grounds to sub-adults (ages 1-3) collected throughout EPO and WPO and characterize variability over time by examining core signatures. (3) Identify and track chemical signatures at the outer margins of otoliths from Age 3+ fish on the foraging grounds (EPO, WPO) over multiple years. Samples are currently being processed and results should follow shortly.

Pacific Bluefin Tuna Diet Studies NOAA Fisheries is conducting diet studies to understand the foraging ecology of Pacific bluefin tuna in the Southern California bight NOAA collected stomachs 2008 - 2017 from approximately 750 tuna. Working with recreational anglers and sportfishing organizations in Southern California, we are collecting, processing, and identifying stomach contents from bluefin tuna of all available sizes. Goals are to (1) identify interannual and interspecific variation in the forage consumed by bluefin tuna captured in the California current; (2) establish a long term data set with applications to ecosystem based fisheries management and NOAA's Integrated Ecosystem Assessment Program (IEA); (3) explore results with respect to bluefin tuna biology, climate change, egg and larval data series from California Cooperative Fisheries Investigative Studies surveys, and oceanography.

IV. NOAA Fisheries Literature Relevant to ISC from the Past Year

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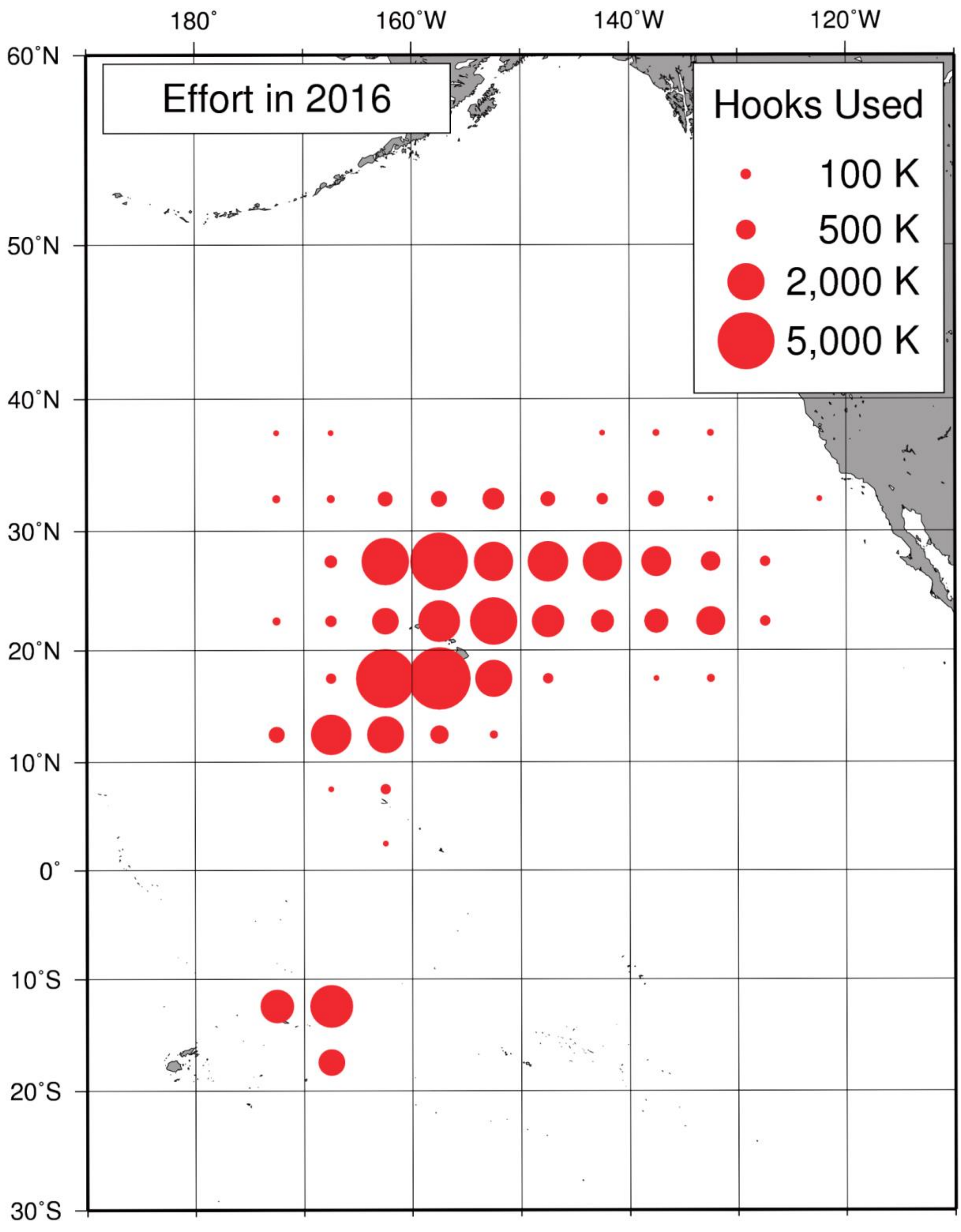


Figure 1. Spatial distribution of reported logbook fishing effort by the 2015 U.S. longline fishery in the Pacific Ocean, in 1,000s of hooks. The size of circles is proportional to the amount of effort.

Effort in some areas is not shown in order to preserve data confidentiality.

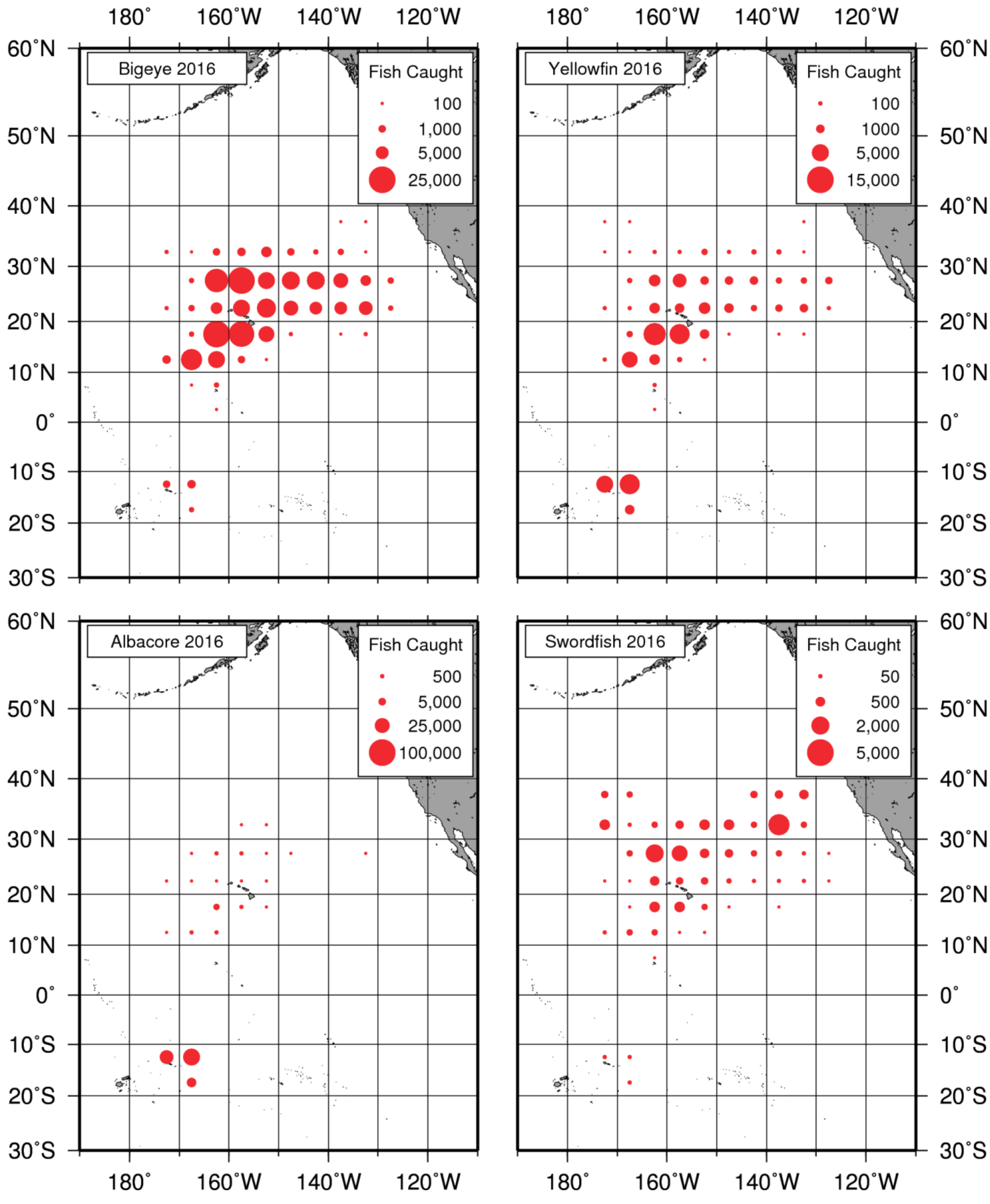


Figure 2. Spatial distribution of reported logbook fishing catch by the U.S. longline fishery in the Pacific Ocean, in numbers of fish, in 2015 for bigeye (*Thunnus obesus*), albacore (*T. alalunga*), yellowfin (*T. albacares*) and swordfish (*Xiphias gladius*). The size of circles is proportional to the amount of catch. Catch in some areas is not shown in order to preserve data confidentiality.

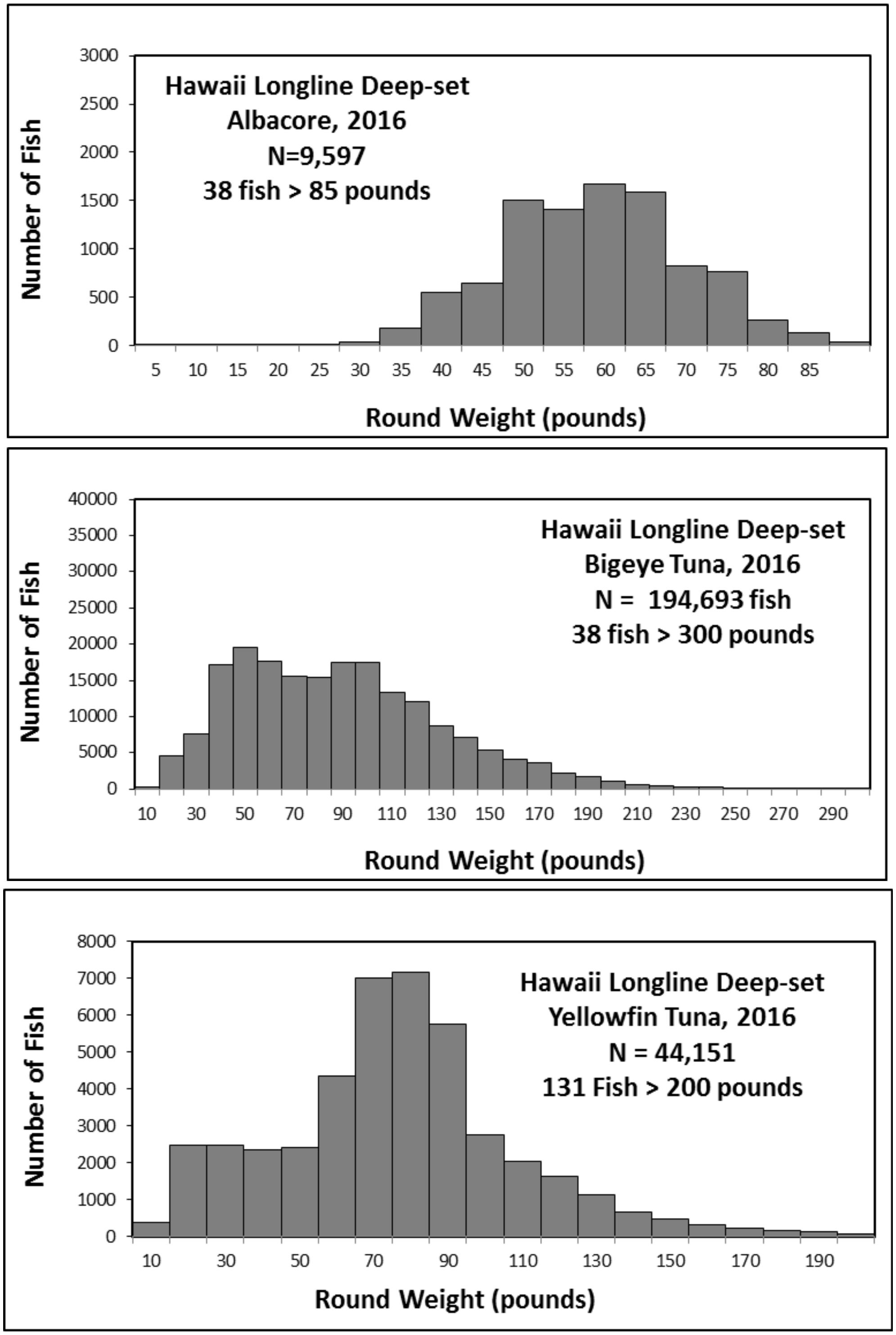


Figure 3. Size distribution of (top) albacore (*Thunnus alalunga*), (middle) bigeye tuna (*Thunnus obesus*), and (bottom) yellowfin tuna (*Thunnus albacares*) caught by the Hawaii-based deep-set longline fishery in the North Pacific Ocean, 2015.

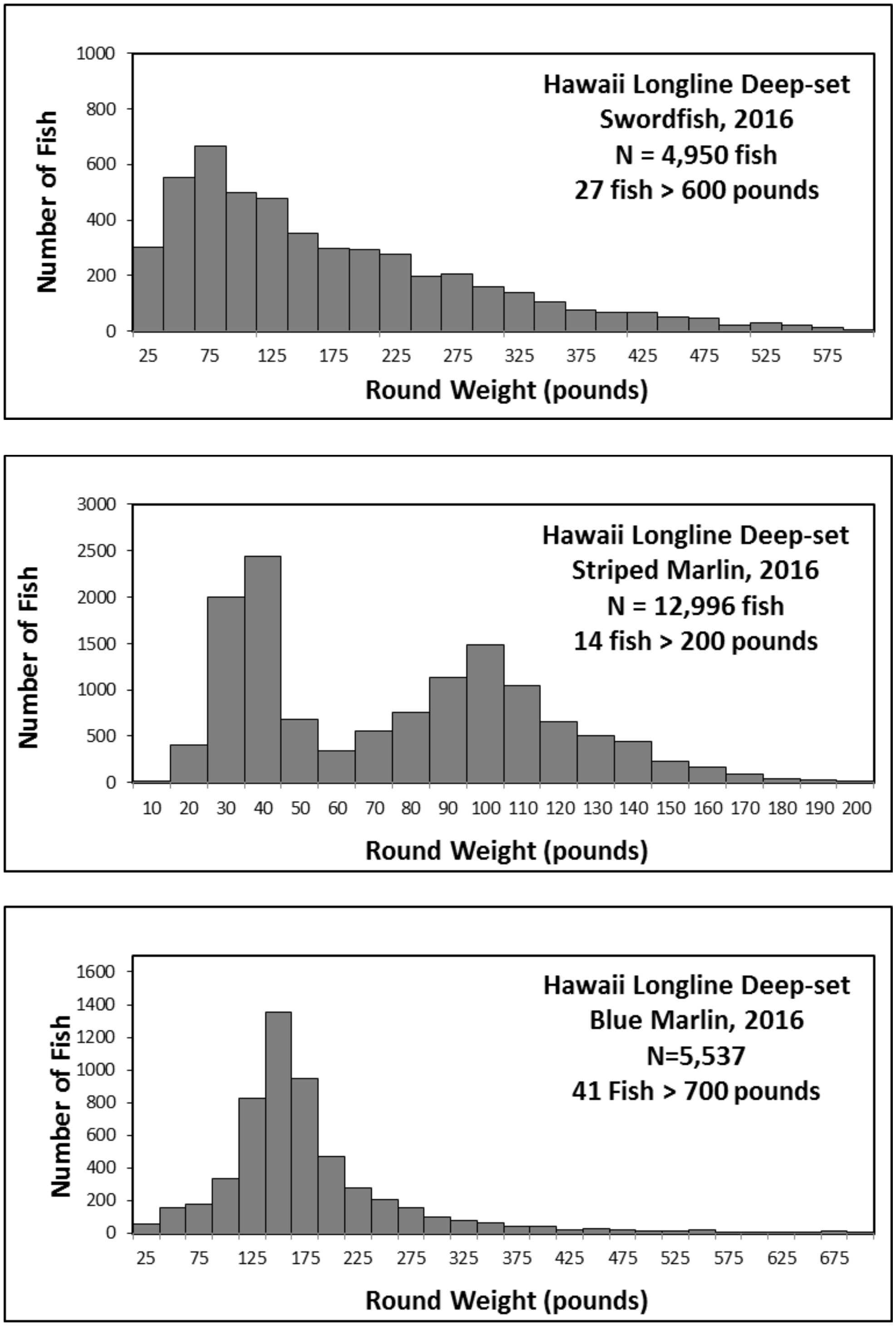
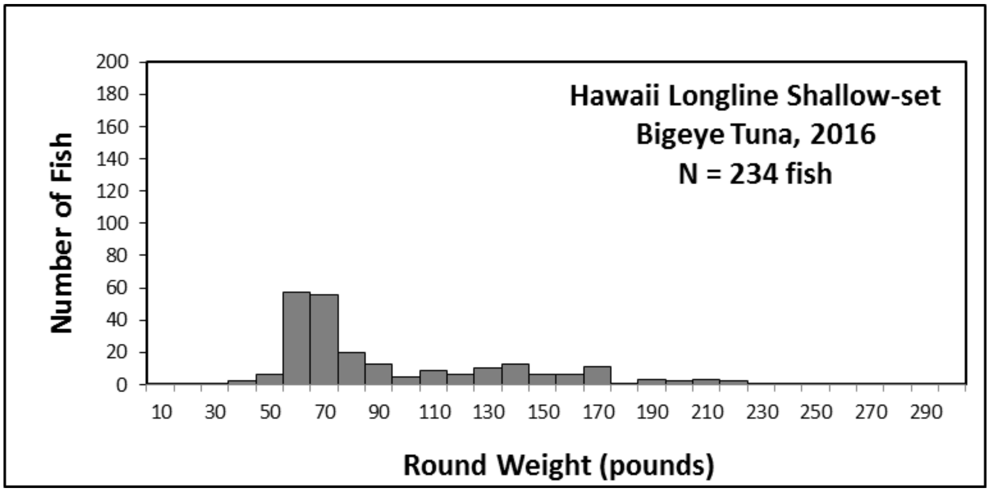


Figure 4. Size distribution of (top) swordfish (*Xiphias gladius*), (middle) striped marlin (*Kajikia audax*), and (bottom) blue marlin (*Makaira nigricans*) caught by the Hawaii-based deep-set longline fishery in the North Pacific Ocean, 2015.



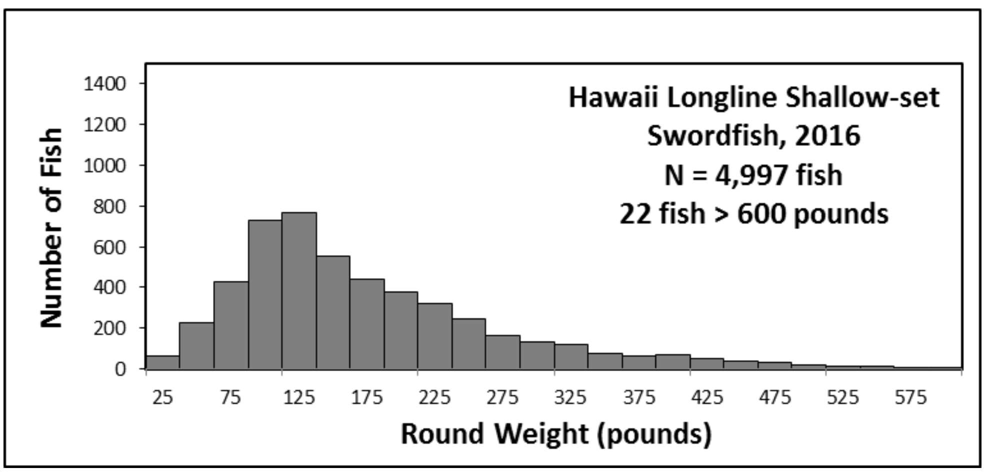


Figure 5. Size distribution of (top) bigeye tuna (*Thunnus obesus*), and (bottom) swordfish (*Xiphias gladius*) caught by the Hawaii-based shallow-set longline fishery in the North Pacific Ocean, 2015.

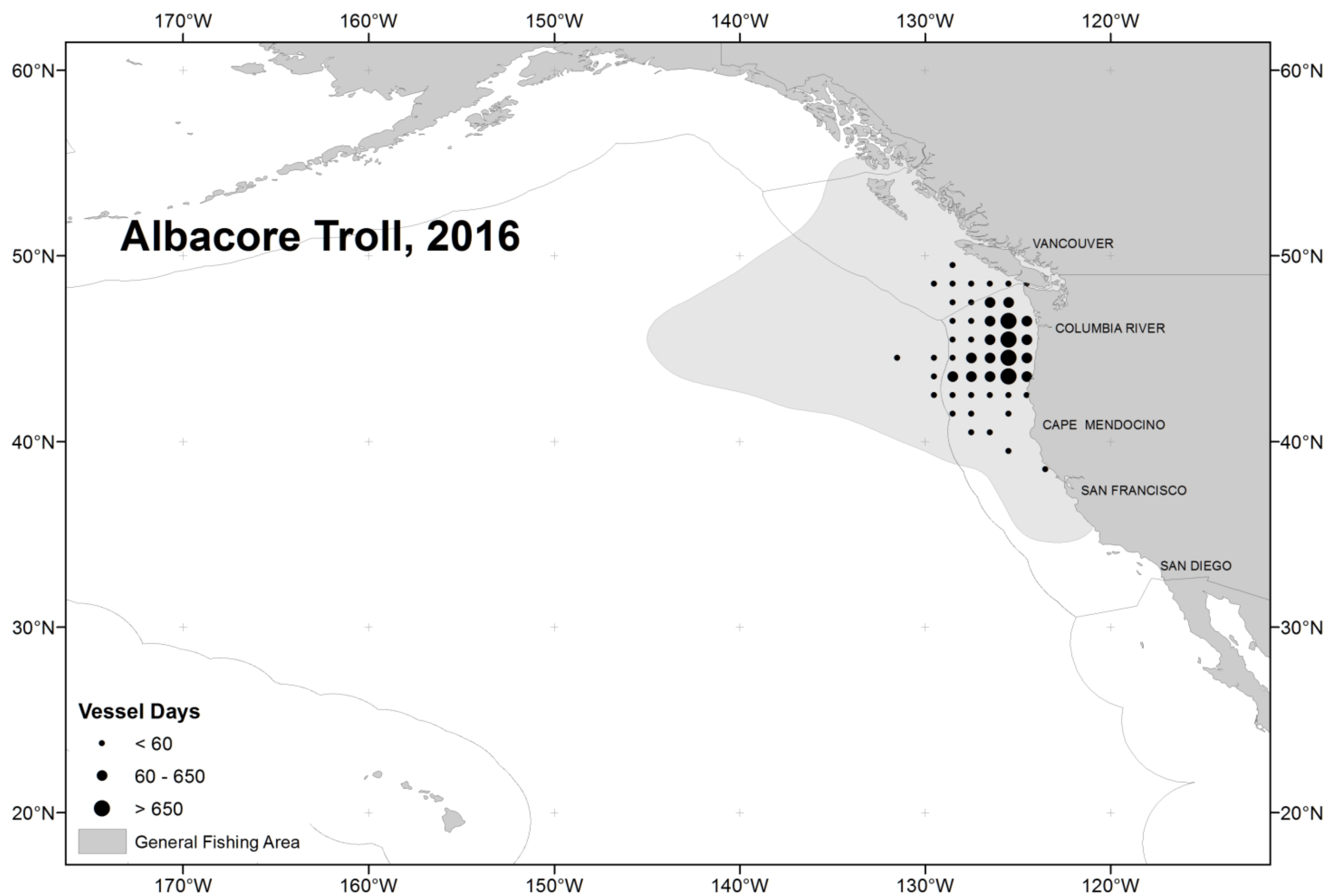

Albacore Troll, 2016
170°W
160°W
150°W
140°W
130°W
120°W
60°N
50°N
40°N
30°N
20°N
VANCOUVER
COLUMBIA RIVER
CAPE MENDOCINO
SAN FRANCISCO
SAN DIEGO
Vessel Days
< 60
60 - 650
> 650
General Fishing Area

Figure 6. Spatial distribution of reported logbook fishing effort by the 2015 U.S. albacore troll and pole-and-line 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.

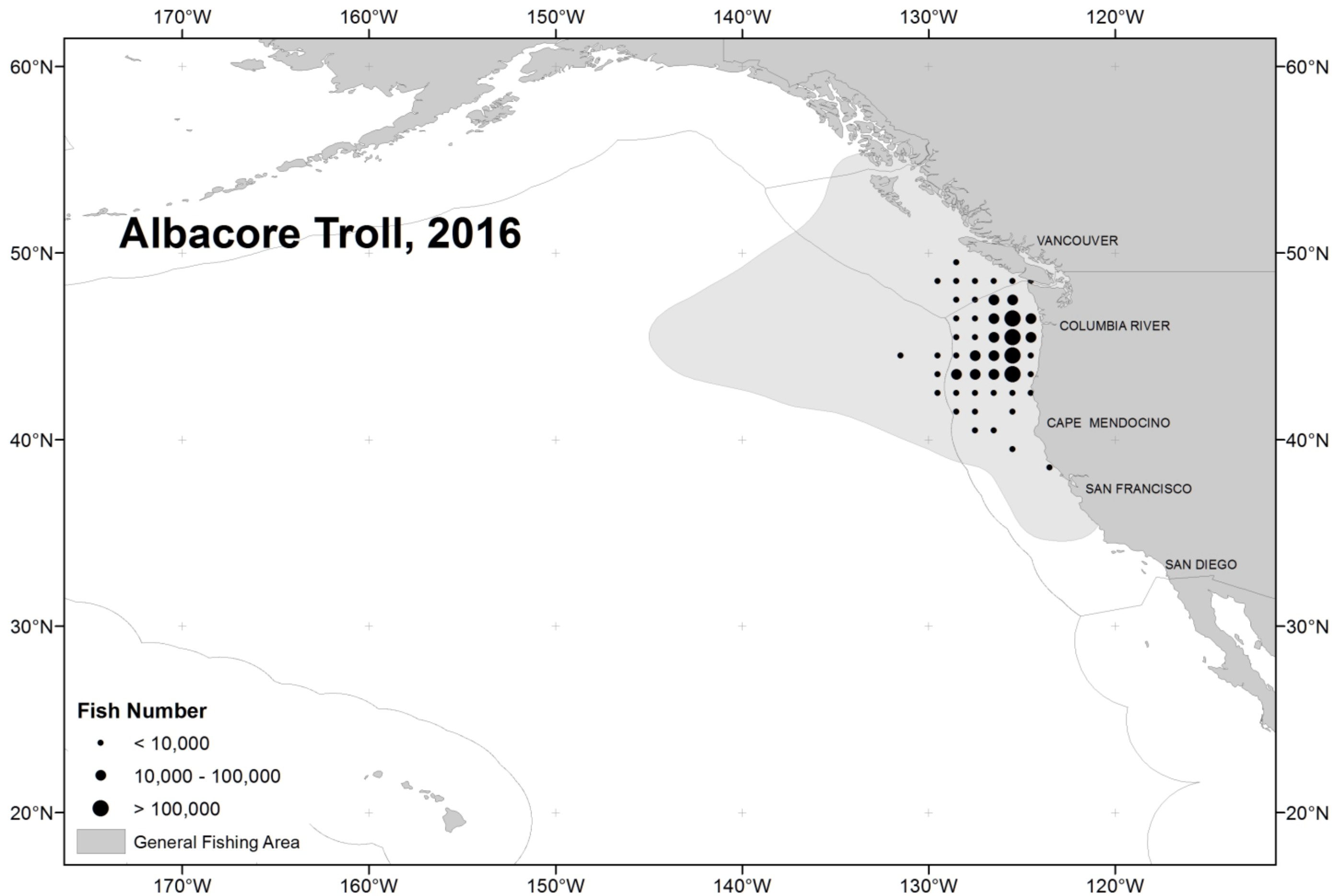

Albacore Troll, 2016
170°W
160°W
150°W
140°W
130°W
120°W
60°N
50°N
40°N
30°N
20°N
VANCOUVER
COLUMBIA RIVER
CAPE MENDOCINO
SAN FRANCISCO
SAN DIEGO
Fish Number
< 10,000
10,000 - 100,000
> 100,000
General Fishing Area

Figure 7. Spatial distribution of reported logbook fishing catch by the 2015 U.S. albacore troll and pole-and-line fishery in number of fish. The size of circles is proportional to the amount of catch. Catch in some areas is not shown in order to preserve data confidentiality.

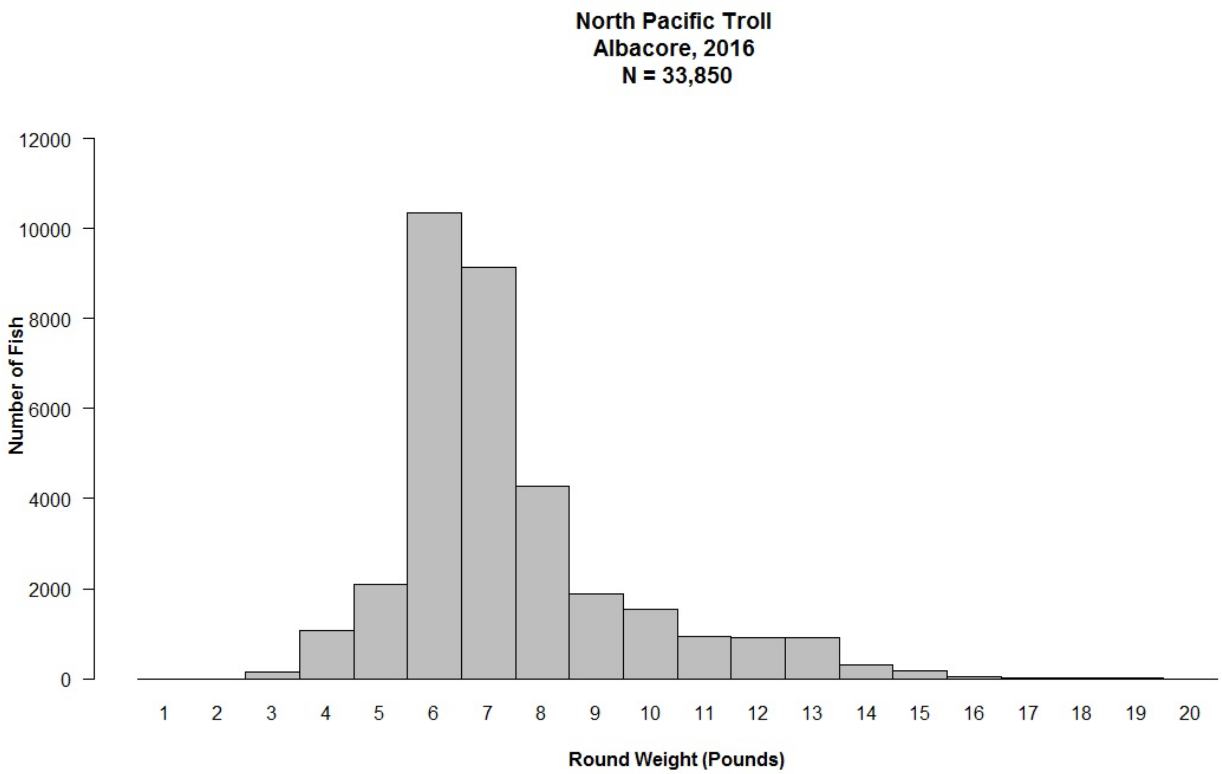


Figure 8. Size distribution of albacore catch by the U.S.A. North Pacific albacore (*Thunnus alalunga*) troll and pole-and-line fishery in 2015.

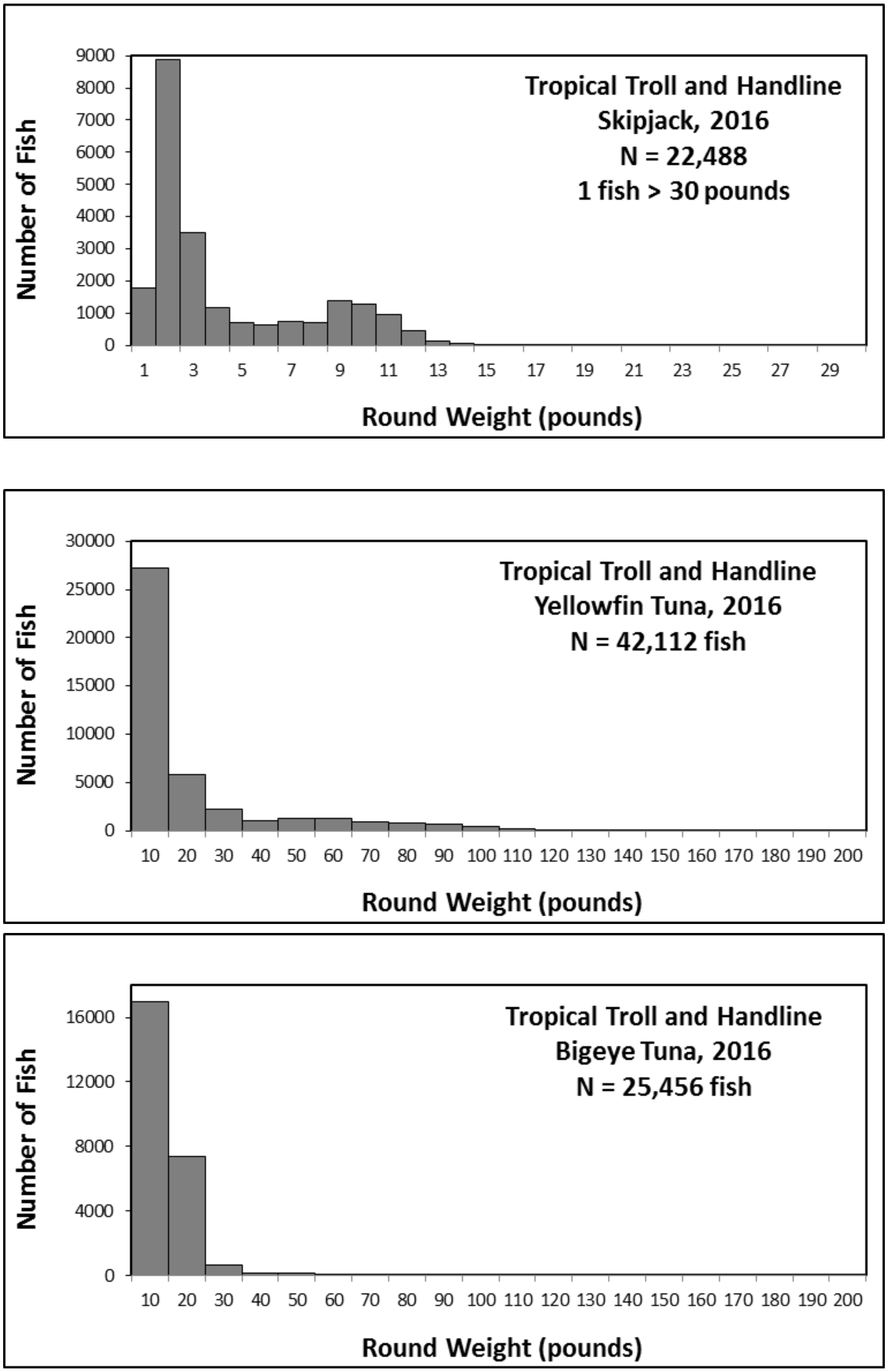
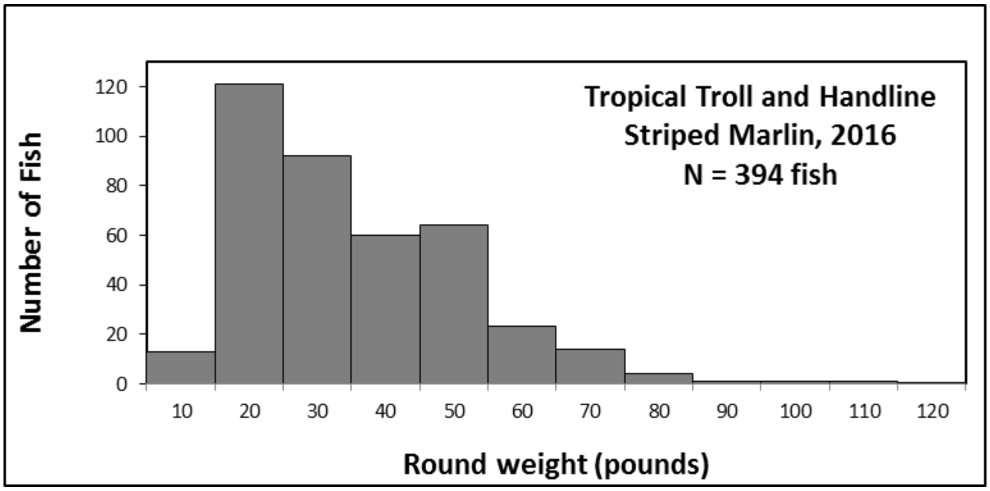


Figure 9. Size distribution of (top) skipjack tuna (*Katsuwonus pelamis*), (middle) yellowfin tuna (*Thunnus albacares*), and (bottom) bigeye tuna (*Thunnus obesus*) caught by the Hawaii troll and handline fisheries, 2015.



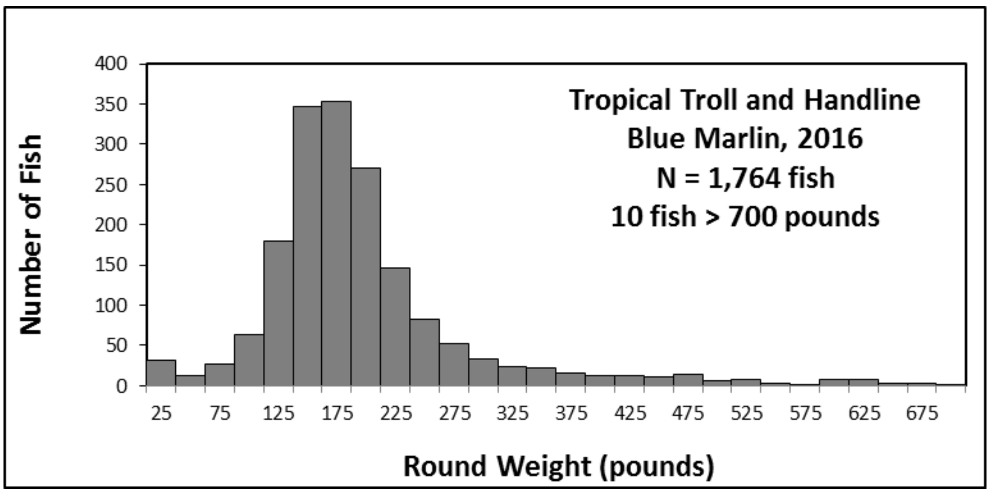


Figure 10. Size distribution of (top) striped marlin (*Kajikia audax*) and (bottom) blue marlin (*Makaira nigricans*) caught by the Hawaii troll and handline fisheries, 2015.

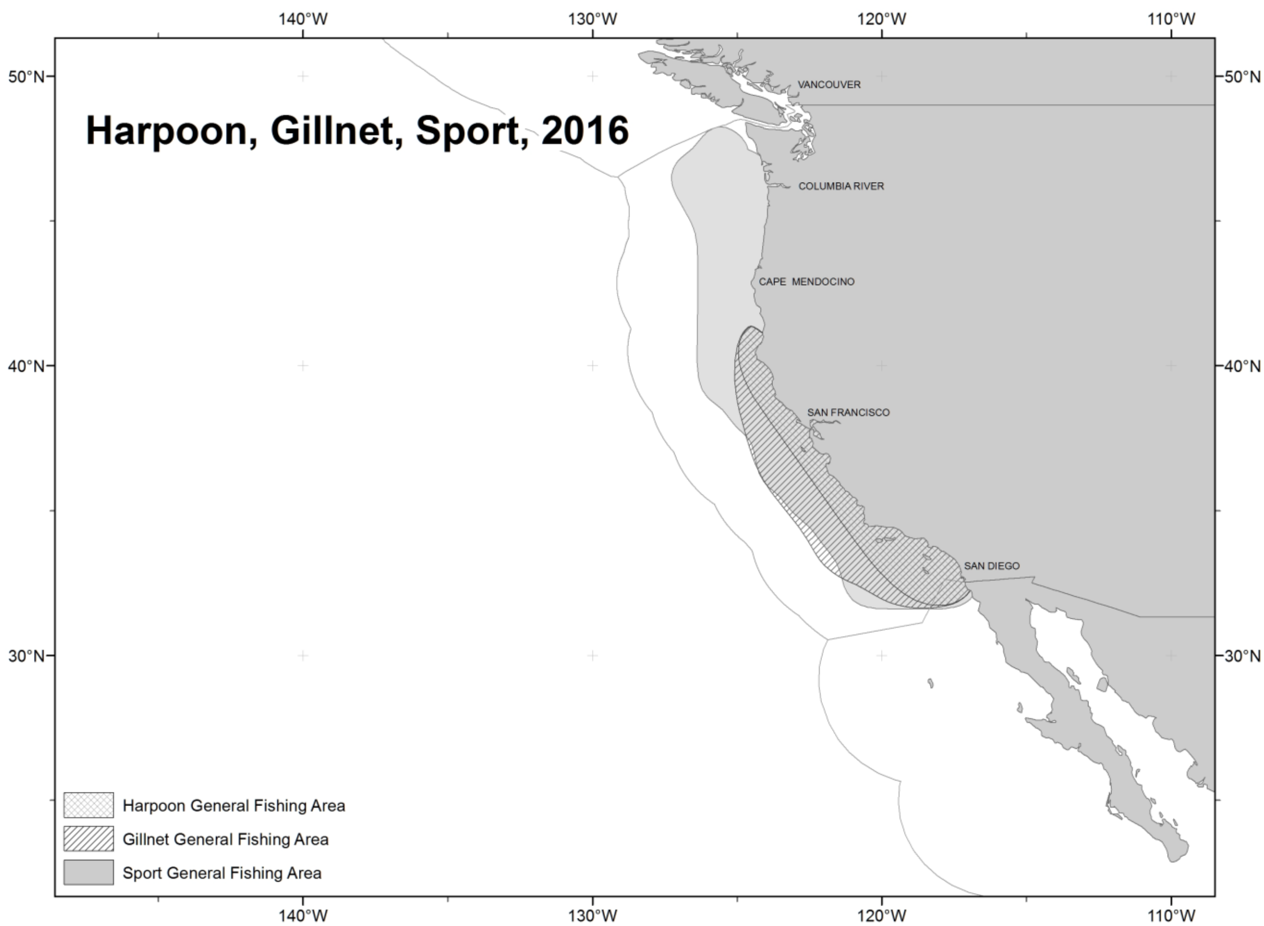


Figure 11. Spatial distribution of reported logbook fishing effort by the 2015 U.S. harpoon, gillnet, and west coast sport fisheries for HMS in the North Pacific Ocean. Effort in some areas is not shown in order to preserve data confidentiality.