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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) 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 2015 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 2015, 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. Reported information includes: age and growth, stock structure, migration patterns and diet studies of albacore, Pacific bluefin tuna and swordfish; modeling mercury dynamics in tunas; reproductive maturity and radiotracer analysis of Pacific bluefin; stock-recruitment resilience of North Pacific striped marlin; micronekton trophic studies in the central North Pacific; transition zone chlorophyll front research; bycatch mitigation on sea turtles; and measuring productivity in the Hawaii longline fishery.

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) 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 2016. Data for 2015 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 2015, there were 50 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. Data for the western and central North Pacific Ocean portion of the catch are not available for 2013 through 2015.

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 nine Hawaii-permitted vessels have landed from 300 t to over 500 t of swordfish caught with shallow-set longline gear to the West Coast in recent years.

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 143 vessels participating in 2015. 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, 2013, 2014 and 2015 (Table 2). Bigeye tuna (*Thunnus obesus*) dominates the tuna catch with landings over 4,000 t during the past twelve years. The 2015 bigeye tuna catch was 8,753 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. 2015 swordfish catch by longline was 1,515 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 2015, 587 vessels 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 hippu*rus). 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 2014 and 2015, 13,369 and 11,571 t of albacore were caught, respectively.

U.S.A. troll and pole-and-line vessels voluntarily submitted logbook records to NOAA Fisheries from 1973 to 1995 when those vessels fishing on the high-seas were required to submit logbooks Vessels fishing within the U.S.A. EEZ continued to submit logbooks voluntarily. 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 and 90 cm. Two age classes are evident in samples collected in 2015, one centered at 68 cm and another centered at 83 cm. Size distribution of the catch for 2015 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. The number of vessels participating declined from a high of 27 in 1985 to a low of one in 2012 and 2015. 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. One or two vessels have participated in the tropical pole-and-line fishery since 2010.

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. Since 2010, too few vessels have participated to publicly report catch data.

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 1,945 troll vessels and 472 handline vessels in 2015 (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 1,162 t in 1992 to 2,326 t in 2012 (Table 2). Yellowfin and skipjack tuna made up 50% and 21% of the total troll and handline catch in 2015, respectively. The next largest species catch components were 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 monitors the tropical troll fishery in the CNMI region using creel surveys and commercial landings.

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 2015 is 66 t, the second lowest the history of the fishery.

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.

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. Twelve vessels participated in the fishery in 2015 (Table 1). Trends in swordfish catches have fluctuated from a high of 305 t in 1985 to 5 t in 2012. Catches since 2012 have remained steady, approximating five metric tons (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 was 924 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 613 t in 2002 to a low of 6 t in 1988. The 2015 catch was 359 t.

The spatial distribution of reported logbook fishing effort by the 2015 U.S.A. harpoon, gillnet, and west coast sport fisheries in the North Pacific Ocean are depicted in Figure 11.

III. Research

NOAA Fisheries research on tunas and billfishes in the Pacific Ocean focuses on improving our understanding of the biology and ecology of the animals to support assessing the effects of fishing and the environment on the population or stock, and on understanding how uncertainty in the biological parameters affects stock assessment results. Described below are highlights of a few recently completed or ongoing studies conducted by NOAA Fisheries. These studies are carried out largely in cooperation with stakeholders and in collaboration with colleagues both in the U.S.A. and abroad.

Simulation testing to evaluate the use of random-at-length observations to fit the growth function
Modeling the growth of fish is a key component of most fish stock assessments and can strongly influence the estimated spawning biomass and exploitation levels. Piner et al. (2016) proposed and tested an alternative method (approximate length-conditional), which assumes each age observation is a random sample at length. The length-conditional method is typically used within an assessment model because the age structure of the sampled population is required for the method. However, Piner et al. (2016) instead approximates the length conditional method by assuming an equilibrium population age structure with a constant total mortality rate and estimating the VBGM parameters outside an assessment model. 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. In addition, the estimates were robust to small errors in the assumed mortality rate. The approximate length-conditional approach was subsequently applied to North Pacific albacore tuna, albeit with some modifications in the code to allow for more flexible binning structure and robust parameterization, which resulted in less biased estimates of length-at-age, especially for the youngest and oldest ages (Xu et al. 2016).

Simulation testing of the effects of age-based movement on growth function estimation
Lee et al. (in press) used simulation methods to further evaluate the length-conditional method in the presence of spatial patterns due to age-based movement. Age-based movement was shown to cause biases in growth parameters estimated from the length-conditional method unless the correct sub-population age structure was incorporated in the analysis. This result argues that the length-conditional method of growth estimation is only appropriate when age-based movement is not present, or when paired age-length samples are incorporated inside the dynamic model with explicit spatial structure or with age-based availability modeled. Special care to understand the biases associated with sampling strategies are needed to reliably estimate growth.

Modeling Mercury Dynamics Mercury (Hg) is an environmental contaminant of global human health concern. The primary route of Hg transfer to humans worldwide is via consumption of marine fish. A collaborative study with Harvard University, Monterey Bay Aquarium, and NOAA Fisheries scientists has modeled Hg dynamics in Pacific bluefin tuna. Application of the model to Hg data from nine large pelagic species showed that Hg dynamics were determined by the interaction of multiple parameters: biodilution via growth, prey Hg concentration, and Hg accumulation due to trophic increase. In some cases, relationships between Hg in the top predators and the Hg concentrations of their prey were counterintuitive, and could not be predicted or inferred from predator [Hg] patterns alone. This new model thus allows for quantitative comparison of factors driving Hg dynamics within and across pelagic species and/or ocean basins. In conjunction with measured data, the model can guide selective wild harvest or captive rearing conditions to minimize Hg in wild or farmed fish destined for human consumption and predict changes in wild fish [Hg] as a result of increasing inputs of Hg into the marine environment. A manuscript describing these results is currently being drafted.

Radioanalysis of Cesium-134 in the Pacific bluefin tuna muscle tissue Understanding movement patterns of migratory marine animals is critical for effective management, but often challenging due to the cryptic habitat of pelagic migrators and the difficulty of assessing past movements. A collaborative study with the State University of New York (SUNY) combined a Fukushima-derived radiotracer (^{134}Cs) with bulk tissue and amino acid stable isotope analyses of Pacific bluefin to distinguish recent migrants from residents of the eastern Pacific Ocean, and to time the migrations of juvenile bluefin as they cross the Pacific Ocean. The proportion of recent migrants to residents decreased in older year classes. All fish smaller than 70 cm FL were recent migrants, confirming that fish caught locally are from the western Pacific. Looking across age classes, the number of recent migrants decreased from ~ 80% for 1-2 year olds to ~30% for 2-3 year olds and ~2% for 3-4 year olds. The peak arrival time from the western Pacific is April and May. This novel toolbox of biogeochemical tracers can provide new insights into the dynamics of migration and can be applied to any species that crosses the North Pacific Ocean. See list of publications for several manuscripts on these results. This work is ongoing and an additional publication is in preparation.

Stock-recruitment resilience of North Pacific striped marlin The resilience of a stock-recruitment relationship is a key characteristic for modeling the population dynamics of living marine resources. Steepness determines the expected resiliency of a fish stock to harvest and is fundamentally important for the estimation of biological reference points such as maximum sustainable yield. Stock-recruitment steepness was the primary uncertainty for the determination of stock status and biological reference points in recent stock assessments of Western and Central North Pacific striped marlin (*Kajikia audax*). Brodziak et al. (2015) estimated probable values of steepness for striped marlin using new information on the mean batch fecundity, spawning frequency, and spawning season duration under an assumption of Beverton–Holt stock-recruitment dynamics. Results indicated that the median steepness was 0.87 with an 80% probable range of (0.38, 0.98). It is very likely that North Pacific striped marlin is highly resilient to reductions in spawning potential. Variation in reproductive and life history parameters had an important influence on the distribution of steepness. Sensitivity analyses showed that steepness was most sensitive to body girth, mean egg weight, and most importantly, early life history stage survival. Sensitivity analyses also confirmed that the effects of changes in life history parameters on steepness were consistent with expected increases or decreases in reproductive output due to changes in body weight or fecundity. This approach can be applied to pelagic fish species to directly assess the probable distribution of stock-recruitment resiliency when sufficient information on reproductive ecology and life history parameters is available.

Composition of oceanic mid-trophic micronekton groups and apex predator biomass in the central North NOAA Fisheries researchers updated and expanded a model of the pelagic ecosystem for the area of the central North Pacific occupied by the Hawaii-based longline fishery (Choy et al. 2016). Specifically, results from the most recent diet studies were used to expand the representation of the lesser-known non-target fish species (e.g. lancetfish, opah, snake mackerel) and nine mid-trophic micronekton functional groups. The model framework Ecopath with Ecosim was used to construct an ecosystem energy budget and to examine how changes in the various micronekton groups impact apex predator biomass. Model results indicate that while micronekton fishes represented approximately 54% of micronekton biomass, they accounted for only 28% of the micronekton production. By contrast, crustaceans represented 24% of the biomass and accounted for 44% of production. Simulated ecosystem changes resulting from changes to micronekton groups demonstrated that crustaceans and mollusks are the most important direct trophic pathways to the top of the food web. Other groups appear to comprise relatively inefficient pathways or 'trophic dead-ends' that are loosely coupled to the top of the food web (e.g. gelatinous animals), such that biomass declines in these functional groups resulted in increased biomass at the highest trophic levels by increasing energy flow through more efficient pathways. Overall, simulated declines in the micronekton groups resulted in small changes in biomass at the very top of the food web, suggesting that this ecosystem is relatively ecologically resilient with diverse food web pathways. However, further understanding of how sensitive micronekton are to changes in ocean chemistry and temperature resulting from climate change is needed to fully evaluate and predict potential ecosystem changes.

Measuring productivity in the Hawaii longline fishery Fisheries productivity is the result of many factors, including endogenous and exogenous elements, such as regulation and stock condition. Understanding changes in productivity and the factors affecting that change is important to fishery management and a sustainable fishing industry. However, no study has been conducted to measure productivity change in the Hawaii longline fishery, the largest fresh bigeye tuna and swordfish producer in the United Stated. Using a Lowe productivity index, productivity change in the Hawaii longline fleet between 2000 and 2012 is measured in this study (Pan and Walden, 2015). In addition, a biomass quantity index is constructed to disentangle biomass impacts in a pelagic environment in order to arrive at an "unbiased" productivity metric. This is particularly important in the Hawaii longline fishery where catches rely mostly on transboundary (shared) stocks with little control on the total amount of extraction. As resource depletion of the transboundary stocks occurs, productivity loss may follow if less output is obtained from the same input usage, or more inputs are used to extract the same catch level from the fishery. Finally, the study compares productivity change under different fishing technologies.

The Transition Zone Chlorophyll Front updated: advances from a decade of research The dynamic ocean feature called the transition zone chlorophyll front (TZCF) was first described fifteen years ago based on an empirical association between the apparent habitat of loggerhead sea turtles and albacore tuna linked to a basin-wide chlorophyll front observed with remotely sensed ocean color data. Subsequent research has provided considerable evidence that the TZCF is an indicator for a dynamic ocean feature with important physical and biological characteristics. New insights into the seasonal dynamics of the TZCF suggest that in the summer it is located at the southern boundary of the subarctic gyre while its position in the winter and spring is defined by the extent of the southward transport of surface nutrients. While the TZCF is defined as the dynamic boundary between low and high surface chlorophyll, it appears to be a boundary between subtropical and subarctic phytoplankton communities. Furthermore, the TZCF is also characterized as supporting enhanced phytoplankton net community production throughout its seasonal migration. Lastly, the TZCF is important to the growth rate of neon flying squid and to the survival of monk seal pups in the northern atolls of the Hawaiian Archipelago. NOAA Fisheries researchers review these and other findings that advance our current understanding of the physics and biology of the TZCF from research over the past decade (Polovina et al. 2015).

Reducing green turtle bycatch in small-scale fisheries using illuminated gillnets Gillnet fisheries exist throughout the oceans and have been implicated in high bycatch rates of sea turtles. In this study, NOAA Fisheries researchers examined the effectiveness of illuminating nets with light-emitting diodes (LEDs) placed on float lines in order to reduce sea turtle bycatch in a small scale bottom-set gillnet fishery (Ortiz et al. 2016). In Sechura Bay, northern Peru, 114 pairs of control and illuminated nets were deployed. The predicted mean catch per unit effort (CPUE) of target species, standardized or environmental variables using generalized additive model (GAM) analysis, was similar for both control and illuminated nets. In contrast, the predicted mean CPUE of green turtles *Chelonia mydas* was reduced by 63.9% in illuminated nets. A total of 125 green turtles were caught in control nets, while 62 were caught in illuminated nets. This statistically significant reduction (GAM analysis, $p < 0.05$) in sea turtle bycatch suggests that net illumination could be an effective conservation tool. Challenges to implementing the use of LEDs include equipment costs, increased net handling times, and limited awareness among fishermen regarding the effectiveness of this technology. Cost estimates for preventing a single sea turtle catch are as low as 34 USD, while the costs to outfit the entire gillnet fishery in Sechura Bay can be as low as 9200 USD. Understanding these cost challenges emphasizes the need for institutional support from national ministries, international non-governmental organizations and the broader fisheries industry to make possible widespread implementation of net illumination as a sea turtle bycatch reduction strategy.

Marine mammals interactions with Hawaii and American Samoa longline fisheries during 2009-2013 NOAA Fisheries researchers reported on the number of marine mammal interactions (i.e., hookings and entanglements) with the Hawaii and American Samoa longline fisheries observed during 2009-2013 by fishery, species, and management area (Bradford and Forney, 2016). These values form the basis of the mortality and serious injury estimates included in the stock assessment reports of stocks affected by these fisheries. Injury determinations were made using a nationally standardized process and established criteria for distinguishing serious from non-serious injuries. In the Hawaii deep-set fishery, 45 marine mammal interactions were observed from 2009 to 2013; most involved false killer whales (53.3%), resulted in death or serious injury (75.6%), and occurred outside the U.S. exclusive economic zone (EEZ) (55.6%). In the Hawaii shallow-set fishery, 43 marine mammal interactions were observed from 2009 to 2013; most involved Risso's dolphins (39.5%), resulted in death or serious injury (69.8%), and occurred outside the U.S. EEZ (90.7%). In the American Samoa deep-set fishery, 13 marine mammal interactions were observed from 2009 to 2013; most involved rough-toothed dolphins (46.2%), resulted in death or serious injury (92.3%), and occurred within the U.S. EEZ (76.9%).

Spillover Effects of Regulation for Sea Turtle Protection in the Hawaii Longline Swordfish Fishery NOAA Fisheries researchers conduct a study to examine spillover effects resulting from U.S. fishing regulations instituted to protect sea turtles (Chan and Pan 2016). Sea turtles, along with U.S. and foreign fisheries for swordfish co-occur on the high seas in the North and Central Pacific and that allows for "spillover effects." When one fishery is required to curtail fishing activity to reduce incidental fishing mortality on sea turtle populations, the activity of other, unregulated fleets may change in ways that adversely affect the very species intended for protection. This study provides an empirical model that estimates these "spillover effects" on sea turtle bycatch resulting from production displacement between regulated US and less-regulated non-US fleets in the North and Central Pacific Ocean. The study demonstrates strong spillover effects, resulting in more sea turtle interaction due to increased foreign fleet activity when Hawaii swordfish production declines.

Collection and Analysis of Biological Samples to Support Stock Assessments Given the uncertainty surrounding current growth models, stock structure, and ecosystem interactions of several tuna and tuna-like species in the North Pacific, NOAA Fisheries scientists are working with a range of partners to collect biological samples of otoliths, muscle, DNA fin biopsies, gonads, and stomachs from a number of species along the U.S. West Coast. In 2007 NOAA Fisheries started a biological sampling program in collaboration with Sportfishing Association of California and the San Diego commercial passenger fishing vessel fleet. This has provided us access to a large number of samples from different species across years and supports a range of research projects. Donations have been expanded to include the local seafood restaurants and private boater donations

Sample collection is ongoing and supports the ISC's proposed North Pacific-wide sampling program to address the uncertainties regarding biological information, notably growth models, maturity schedules, and stock structure of several tuna and tuna-like species. Since 2008, over 3000 samples of albacore, Pacific bluefin, yellowfin, skipjack (*Katsuwonus pelamis*), yellowtail (*Seriola lalandi*), opah (*Lampris guttatus*), and dorado (*Coryphaena hippurus*) have been collected.

These biological samples are used to address an array of questions. These include (1) diets of tunas in the SCB using stomach contents to investigate inter-annual and interspecific differences, (2) stable isotope analysis of muscle tissue aimed at providing an integrated picture of foraging and migration patterns of tunas, opah, yellowtail and swordfish in the California current (CC), (3) using otoliths to better characterize age and growth of albacore, (4) radioanalysis of cesium-134 and 137 found in the muscle tissue of Pacific bluefin tuna exposed to waters containing radionuclides discharged from the failed Fukushima nuclear power plant in Japan, combined with stable isotope analysis to determine migration rates and stock structure of juvenile Pacific bluefin tuna in the CC, (5) using otolith microchemistry to determine the dynamics and stock structure of albacore, bluefin, and swordfish in the North Pacific, (6) characterizing the genetic diversity of California yellowtail in preparation for commercial aquaculture production off southern California, (7) comparing inshore- versus offshorecaught California yellowtail with respect to ontogeny and migration patterns using stable isotope analysis and lab derived trophic discrimination factors, (8) developing a sex-linked genetic marker for albacore, (9) characterizing the diet of opah, (10) exploring mercury dynamics in pelagic predators and (11) examining the reproductive maturity of bluefin in the SCB.

Pacific Bluefin Close-Kin Mark Recapture (CKMR) Sample Collection During 2015, NMFS convened a meeting of international stakeholders and experts to discuss the potential of developing a close-kin genetic parentage based mark-recapture research program to develop an independent abundance estimate for Pacific bluefin tuna. Though a number of unknown variables exist (e.g. connectivity between two known spawning grounds, potential bias in migration/life history parameters between animals from different spawning areas, etc.) it was decided that there were no fatal flaws in the methodology. Given the listed uncertainties, current estimates of abundance, and regional fisheries, a sampling plan was developed that is conservative enough to account for known uncertainties. The method overview and sampling plan were presented to ISC15, whereupon ISC members decided to go forward with developing this program. In 2016, NMFS staff began dockside collections of genetic samples, otoliths for ageing and microchemistry, stomach samples, length, weight, sex, etc. from young PBF caught by San Diego sportfishers. Over 200 samples juveniles have been collected off southern California for CKMR to date in cooperation with the sport fleet, of which 180 have matching otoliths and tissue samples.

Post-release survival of juvenile silky sharks captured in a tropical tuna purse seine fishery -- Juvenile silky sharks (*Carcharhinus falciformis*) comprise the largest component of the incidental elasmobranch catch taken in tropical tuna purse seine fisheries. During a chartered fishing trip on board a tuna purse seine vessel conducting typical fishing operations, University of Hawaii and NOAA researchers investigated the post-release survival and rates of interaction with fishing gear of incidentally captured silky sharks using a combination of satellite linked pop-up tags and blood chemistry analysis (Hutchinson et al., 2015). To identify trends in survival probability and the point in the fishing interaction when sharks sustain the injuries that lead to mortality, sharks were sampled during every stage of the fishing procedure. The total mortality rates of silky sharks captured in purse seine gear was found to exceed 84%. Survival declined precipitously once the silky sharks had been confined in the sack portion of the net just prior to loading. Additionally, shark interactions recorded by the scientists were markedly higher than those recorded by vessel officers and the fishery observer. Future efforts to reduce the impact of purse seine fishing on silky shark populations should be focused on avoidance or releasing sharks while they are still free swimming.

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

Published

Andrews, A.H., Kerr, L.A. 2015. Validated age estimates for large white sharks of the northeastern Pacific Ocean: altered perceptions of vertebral growth shed light on complicated carbon 14 results. Env. Biol. Fish. 98: 971-978. doi:10.1007/s10641-014-0326-8.

Ascani, F., Van Houtan, K.S., Jones, T.T., Polovina, J.J., Di Lorenzo, E. 2016. Juvenile recruitment In loggerhead sea turtles linked to decadal changes in ocean circulation. Glob. Change Biol. 2016

Apr 28. doi: 10.1111/gcb.13331. [Epub ahead of print].

Baumann, H., Wells, R.J.D., Rooker, J.R., Zhang, S., Baumann, Z., Madigan, D.J., Dewar, H., Snodgrass, O.E., Fisher, N.S. 2015. Combining otolith microstructure and trace elemental analyses to infer the arrival of juvenile Pacific bluefin tuna in the California current ecosystem. ICES J. Mar. Sci. : Journal du Conseil, fsv062.

Brodziak, J., Mangel, M., Chi-Lu, S. 2015. Stock-recruitment resilience of North Pacific striped marlin based on reproductive ecology. Fish. Res. 166:140-150. doi:10.1016/j.fishres.2014.08.008.

Cartamil, D., Wraith, J., Wegner, N.C., Kacev, D., Lam, C.H., Santana-Morales, O., Sosa-Nishizaki, O., Escobedo-Olvera, M., Kohin, S., J.B. Graham, J.B., Hastings, P. 2016. Movements and distribution of juvenile common thresher sharks (*Alopias vulpinus*) in Pacific coast waters of the United States and Mexico. MEPS.

Chan, H.L., Pan, M. 2016. Spillover Effects of Environmental Regulation for Sea Turtle Protection in the Hawaii Longline Swordfish Fishery. Mar. Res. Econ. Ahead of Print Available online: http://www.journals.uchicago.edu/doi/abs/10.1086/686672.

Choy, C.A., Wabnitz, C.C.C., Weijerman, M., Woodworth-Jefcoats, P.A., Polovina, J.J. 2016. Finding the way to the top: how the composition of oceanic mid-trophic micronekton groups determines apex predator biomass in the central North Pacific. MEPS 549:9-25. doi:10.3354/meps11680.

Croll, D.A., Dewar, H., Dulvy, N.K., Fernando, D., Francis, M.P., Galván-Magaña, F., Hall, M., Heinrichs, S., Marshall, A., Mccauley, D., Newton, K.M. 2015. Vulnerabilities and fisheries impacts: the uncertain future of manta and devil rays. Aquatic Conserv: Mar. Freshw. Ecosyst. doi: 10.1002/aqc.2591.

Forney, K.A., Becker, E.A., Foley, D.G., Barlow, J., Oleson, E.M. 2015. Habitat-based models of cetacean density and distribution in the central North Pacific. Endangered Species Research 27: 1-20. doi:10.3354/esr00632.

Howell, E.A., Bograd, S.J., Hoover, A.L., Seki, M.P., Polovina, J.J. 2015. Variation in phytoplankton composition between two North Pacific front zones along 158 degrees west during winter-spring 2008-2011. Prob. Ocean. 2015. doi:10.1016/j.pocean.2015.06.003.

Howell, E., Hoover, A., Benson, S.R., Bailey, H., Polovina, J.J., Seminoff, J.A., Dutton, P.H. 2015. Enhancing the TurtleWatch product for leatherback sea turles, a dynamic habitat model for ecosystem-based management. Fish. Ocean 24(1):57-68. doi:10.1111/fog.12092.

Hutchinson, M.R., D.G. Itano, J.A. Muir, K.N. Holland. 2015. Post-release survival of juvenile silky sharks captured in a tropical tuna purse seine fishery. Mar Ecol Prog Ser 521:143-154.

Lee, H.H., L.R., Thomas, K.R. Piner, and M.N., Maunder (in press). Effects of age-based movement on the estimation of growth assuming random-at-age and random-at-length data. J. Fish. Bio.

Lehodey, P., Conchon, A., Senina, I., Domokos, R., Calmettes, B., Jouanno, J., Hernandez, O., Kloser, R. 2015. Optimization of a micronekton model with acoustic data. ICES J. Mar. Sci. doi:10.1093/icesjms/fsu233.

Maxwell, S.M., E.L. Hazen, R.L. Lewison, D.C. Dunn, H. Bailey, S.J. Bograd, D.K. Briscoe, S. Fossette, A.J. Hobday, M. Bennett, S. Benson, M. Caldwell, D. Costa, H. Dewar, T. Eguchi, S. Kohin, T. Sippel, and L. Crowder, L. 2015 Dynamic ocean management: Defining and conceptualizing real-time management of the ocean. Mar. Pol. 58:42–50.

Martin, S.L., Ballance, L.T., Groves, T. 2016. An ecosystem services perspective for the oceanic eastern tropical Pacific: commercial fisheries, carbon storage, recreational fishing, and biodiversity. Front. Mar. Sci 3:50. doi: 10.3389/fmars.2016.00050.

Newton, K.C., Wraith, J., Dickson, K.A. 2015. Digestive enzyme activities are higher in the shortfin mako shark, *Isurus oxyrinchus*, than in ectothermic sharks as a result of visceral endothermy. Fish Phy. Bioc. 41(4): 887-898.

Ortiz, N., Mangel, J.C., Wang, J., Alfaro-Shigueto, J., Pingo, S., Jiminez, A., Suarez, T., Swimmer, Y., Carvalho, F., Godley, B.J. 2016. Reducing green turtle bycatch in small-scale fisheries using illuminated gillnets: the cost of saving a sea turtle. MEPS 545: 251-259. doi:10.3354/meps11610.

Pan, M., Li, S. 2016. Evaluation of fishing opportunities under sea turtle interaction limits – a decision support model for Hawaii-based longline swordfish fishery Management. Mar. Fish. Rev. 77(3) (February 2016). http://spo.nmfs.noaa.gov/mfr773/mfr7733.pdf

Pan, M., Walden, J. 2015. Measuring productivity in a shared stock fishery: a case study of the Hawaii longline fishery. Marine Policy 62: 302-308. doi:10.1016/j.marpol.2015.07.018.

Piner, K.R. Lee, H.H., Maunder, M.N. 2016. Evaluation of using random-at-length observations and an equilibrium approximation of the population age structure in fitting the von Bertalanffy growth function, Fish. Res. 180: 128-137 http://dx.doi.org/10.1016/j.fishres.2015.05.024.

Polovina, J.J., Howell EA, Kobayashi DR, Seki MP. 2015. The Transition Zone Chlorophyll Front updated: advances from a decade of research. Prog. Ocean. doi:10.1016/j.pocean.2015.01.006.

Richmond, L., Kotowicz, D., Hospital, J. 2015. Monitoring socioeconomic impacts of Hawai'i's 2010 bigeye tuna closure: Complexities of local management in a global fishery. Ocean Coast. Man. 106: 87-96. doi:10.1016/j.ocecoaman.2015.01.015.

Thys, T., J. Ryan, H. Dewar, C. Perle, K. Weng, E. Hazen, C. Farwell, J. O'Sullivan, M. Howard, D. Foley and S. Bograd. 2015 Movements and behaviors of the world's largest jelly predator, *Mola mola*, in the Western Pacific. J. Exp. Mar. Bio. Eco. 471:64-76.

Van Houtan, K.S., Francke, D.L., Alessi, S., Jones, T.T., Martin, S.L., Kurpita, L., King, C.S., Baird, R.W. 2016. The developmental biogeography of hawksbill sea turtles in the North Pacific. Ecol. Evo. doi:10.1002/ece3.2034.

Wegner, N., O. Snodgrass, H. Dewar, and J. Hyde. 2015. Whole-body endothermy in a mesopelagic fish, the opah, *Lampris guttatus.* Science 348:6236, 786-789.

Wegner, N.C. 2016. Elasmobranch gill structure. *In:* Fish Physiology Volume 34A: Physiology of Elasmobranch Fishes: Structure and Interaction with Environment (R.E. Shadwick, *et al.*, eds). Academic Press: Amsterdam, p. 101-151.

Xu, Y., Teo, S.L.H., Piner, K.R., Chen, K.-S. Wells, R.J.D. 2016. Using an approximate length-conditional approach to estimate von Bertalanffy growth parameters of North Pacific albacore (*Thunnus alalunga*), Fish. Res. 180: 138-146 http://dx.doi.org/10.1016/j.fishres.2015.08.017.

Technical Reports, Administrative Reports, and Working Papers

Boggs, C.H., Gonzales, D.P., Kokubun, R.M. 2015. Marine mammals reported under catch lost to predators on fishermen's commercial catch reports to the State of Hawaii, 2003-2014. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-15-006, 14 p. doi:10.7289/v5pr7szm.

Bradford, A.L., Forney, K.A. 2016. Injury determinations for marine mammals observed interacting with Hawaii and American Samoa longline fisheries during 2009-2013. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-PIFSC-50. 26 pp.

Bradford, A.L., Lyman, E. 2015. Injury determinations for humpback whales and other cetaceans reported to NOAA response networks in the Hawaiian Islands during 2007-2012. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-45, 29 p. doi:10.7289/V5TX3CB1.

Bradford, A.L., Oleson, E.M., Baird, R.W., Boggs, C.H., Forney, K.A., Young, N.C. 2015. Revised stock boundaries for false killer whales (*Pseudorca crassidens)* in Hawaiian waters. U.S. Dept. of Commerce, NOAA Technical Memorandum, NOAA-TM-NMFS-PIFSC-47, 29 p. doi:10.7289/V5DF6P6J.

Curran, D., Bigelow, K. 2016. Length-weight relationships for 73 species and species groups as reported in the 2011-2013 national bycatch reports for pelagic longline fisheries in Hawaii and American Samoa. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-16-004, 9 p. doi:10.7289/V5CF9N42.

Fisheries Monitoring Branch, Pacific Islands Fisheries Science Center. 2015. The Hawaii-based Longline Logbook Summary Report, January-December 2014. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-15-007, 14 p. doi:10.7289/v5z899d2.

Fisheries Research and Monitoring Division, Pacific Islands Fisheries Science Center, NOAA Fisheries. 2016. PIFSC report on the American Samoa limited-access longline fishery from 1 January to 31 December 2015. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-16-005, 14 p. doi:10.7289/V57P8WDB.

Fisheries Research and Monitoring Division, Pacific Islands Fisheries Science Center, NOAA Fisheries. 2016. PIFSC report on the Hawaii-based limited-access longline fishery from

1 January to 31 December 2015. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-16-006, 17 p. doi:10.7289/V53X84NJ.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. 2016. Submission of 2014-2015 U.S. fishery statistics for the western and central Pacific Ocean and other areas to the Western and Central Pacific Fisheries Commission. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-16-010, 11 p.

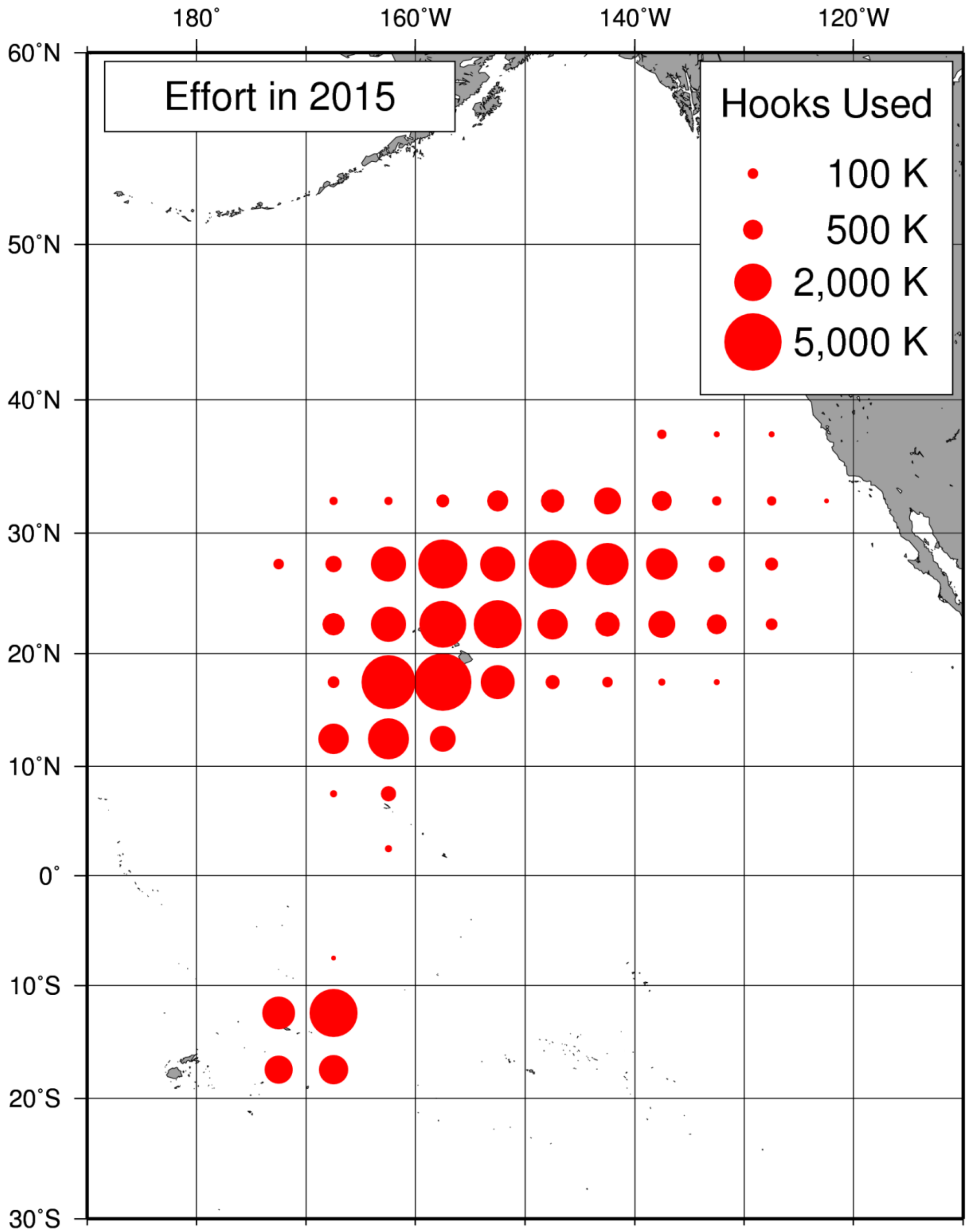


Figure 1. Spatial distribution of reported logbook fishing effort by the 2015 U.S. longline fishery in the Pacific Ocean, in 1,000s of hooks. The size of circles is proportional to the amount of effort. Effort in some areas is not shown in order to preserve data confidentiality.

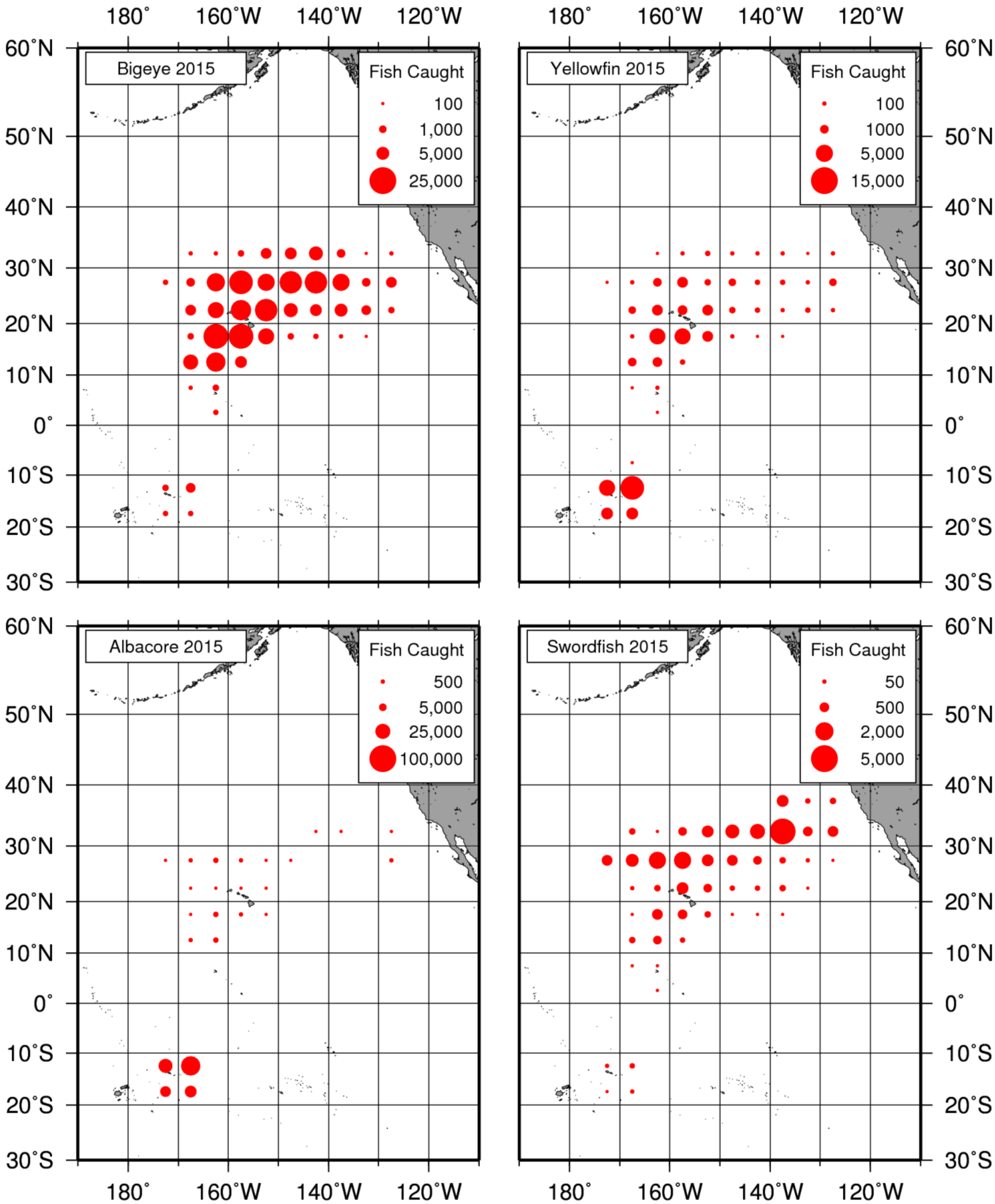


Figure 2. Spatial distribution of reported logbook fishing catch by the U.S. longline fishery in the Pacific Ocean, in numbers of fish, in 2015 for bigeye (*Thunnus obesus*), albacore (*T. alalunga*), yellowfin (*T. albacares*) and swordfish (*Xiphias gladius*). The size of circles is proportional to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

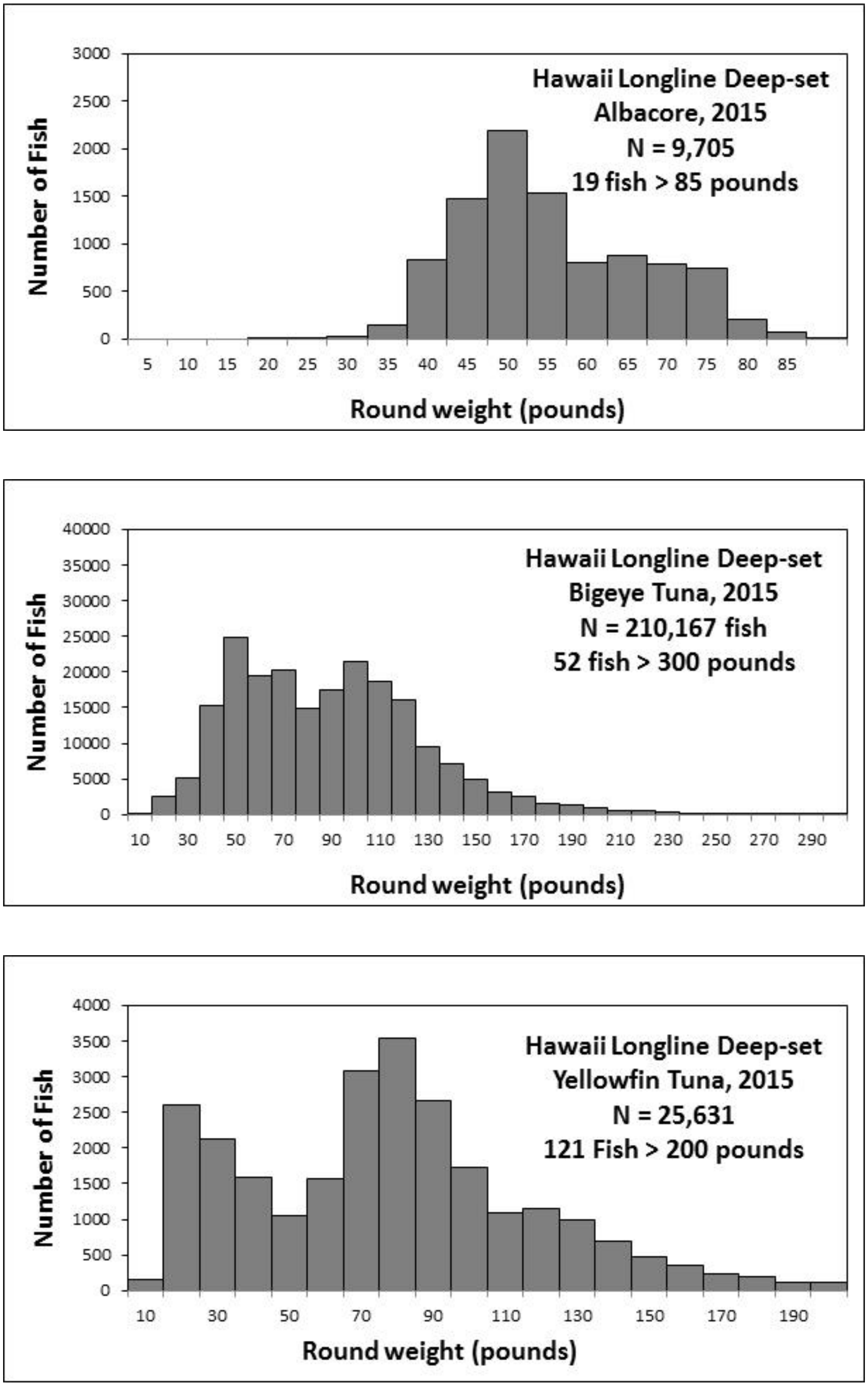


Figure 3. Size distribution of (top) albacore (*Thunnus alalunga*), (middle) bigeye tuna (*Thunnus obesus*), and (bottom) yellowfin tuna (*Thunnus albacares*) caught by the Hawaii-based deep-set longline fishery in the North Pacific Ocean, 2015.

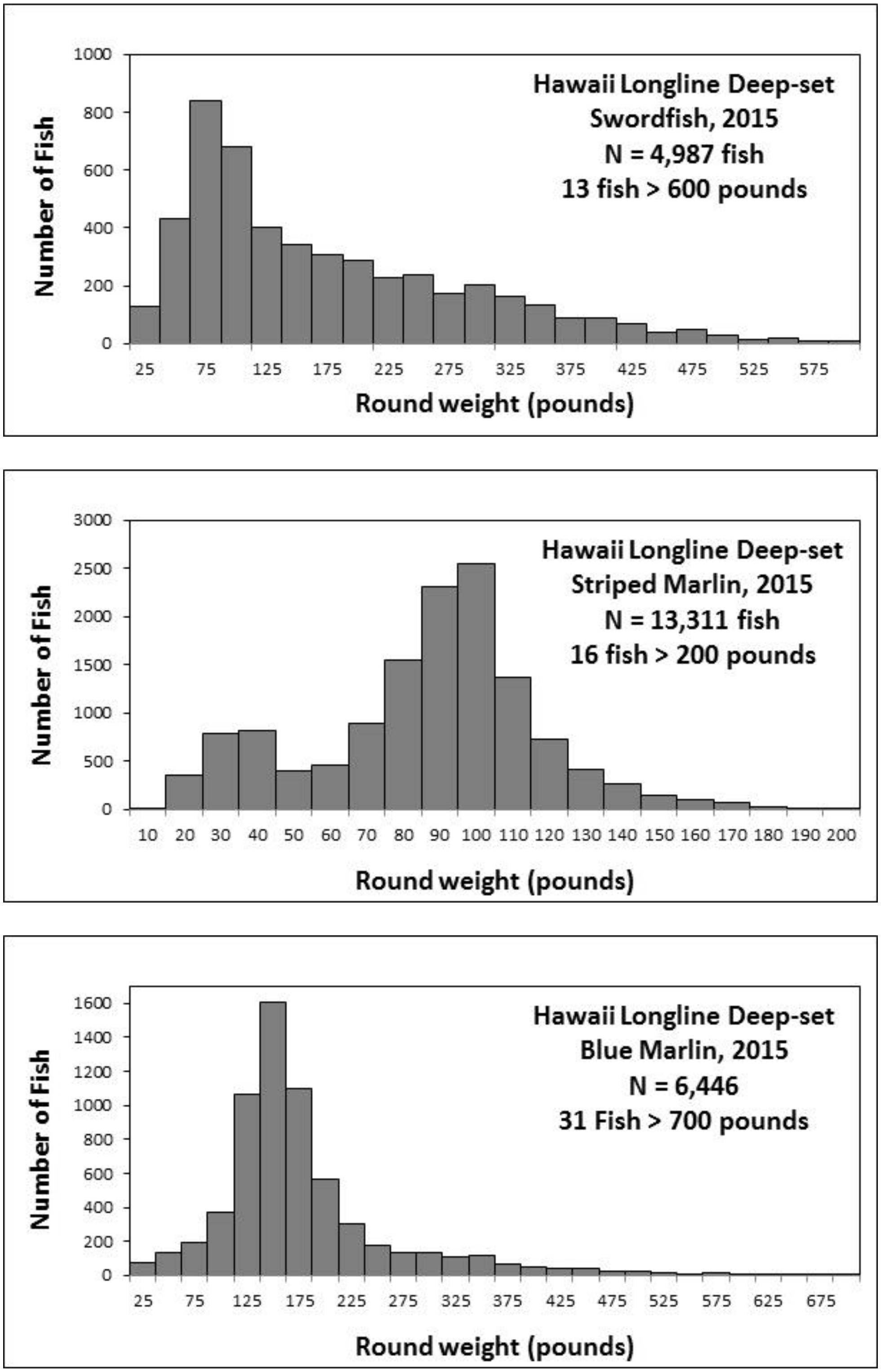
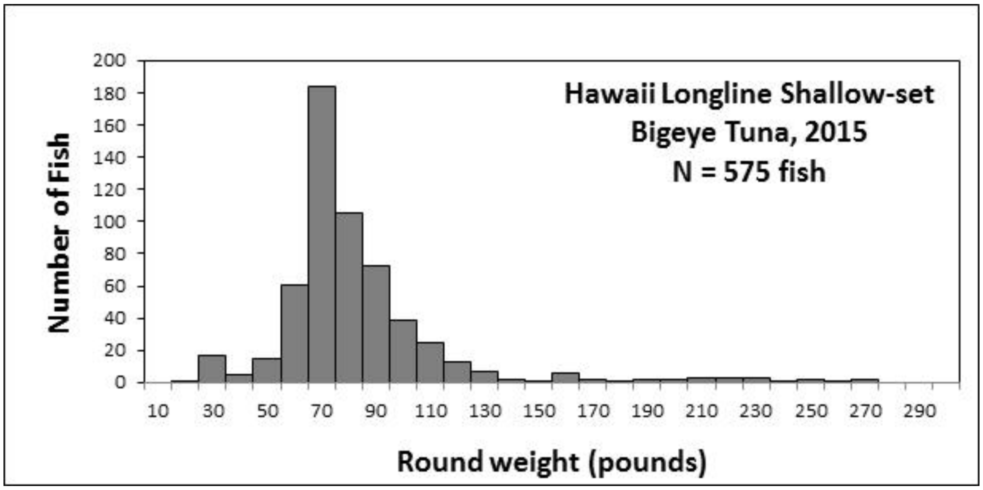


Figure 4. Size distribution of (top) swordfish (*Xiphias gladius*), (middle) striped marlin (*Kajikia audax*), and (bottom) blue marlin (*Makaira nigricans*) caught by the Hawaii-based deep-set longline fishery in the North Pacific Ocean, 2015.



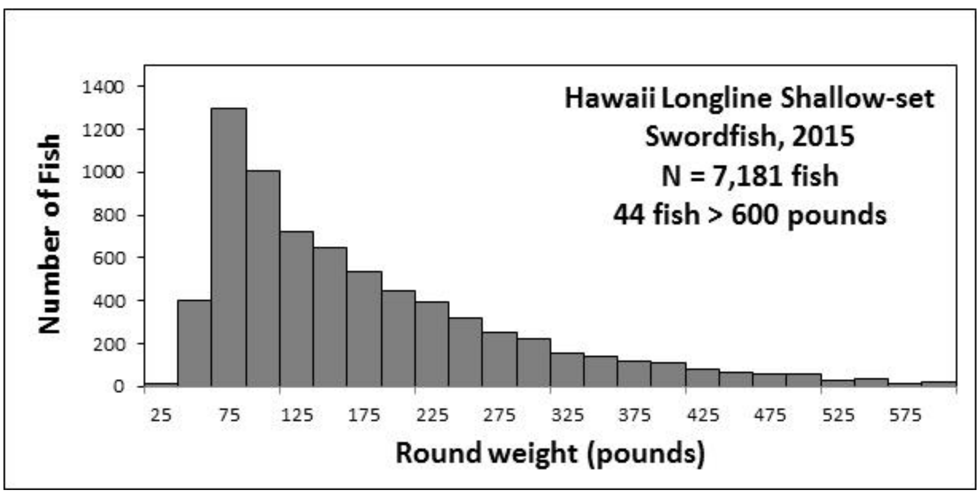


Figure 5. Size distribution of (top) bigeye tuna (*Thunnus obesus*), and (bottom) swordfish (*Xiphias gladius*) caught by the Hawaii-based shallow-set longline fishery in the North Pacific Ocean, 2015.

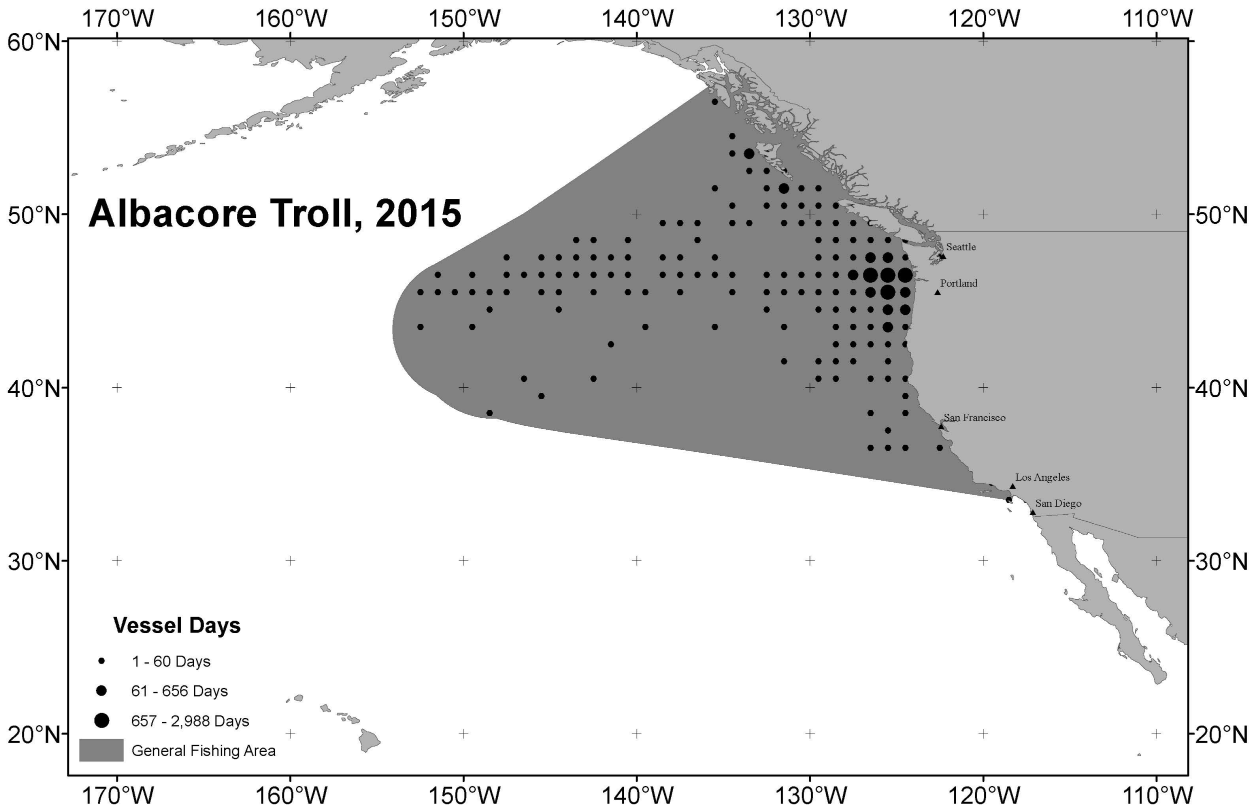


Figure 6. Spatial distribution of reported logbook fishing effort by the 2015 U.S. albacore troll and pole-and-line fishery in vessel days. The size of circles is proportional to the amount of effort. Effort in some areas is not shown in order to preserve data confidentiality.

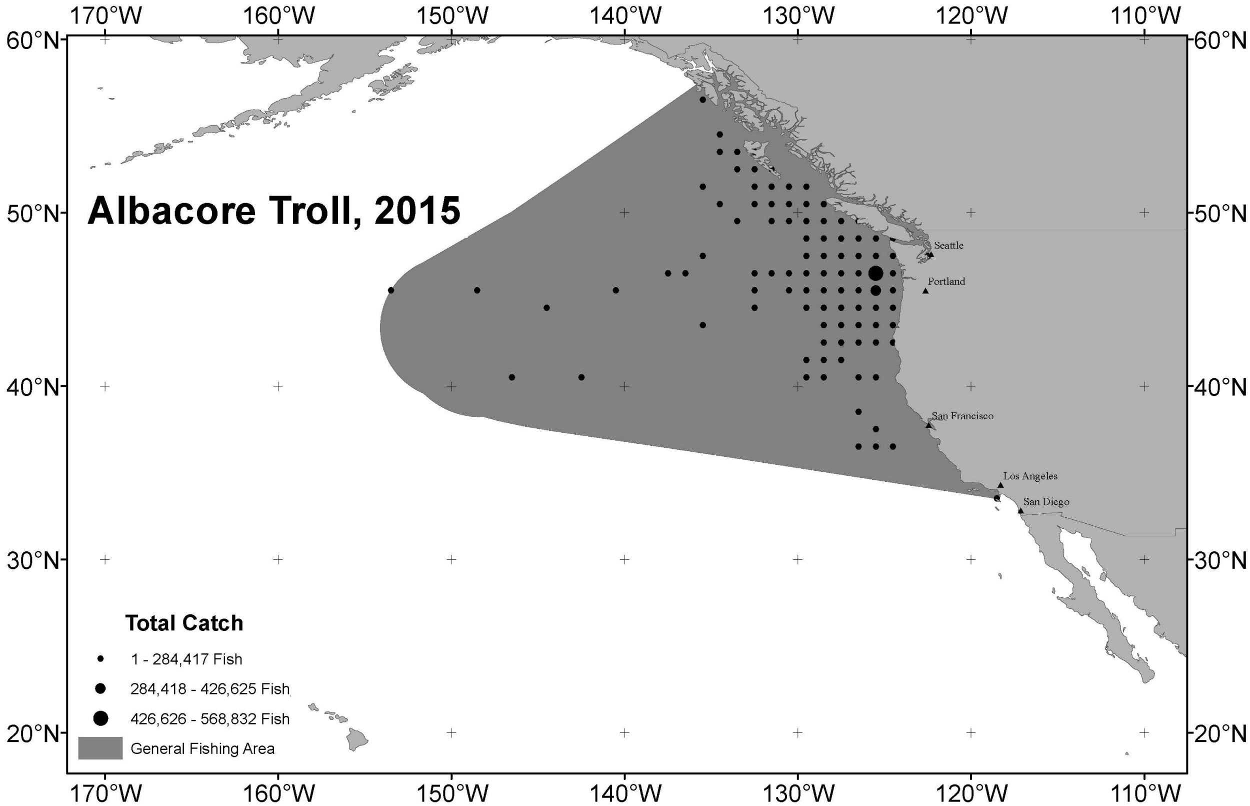


Figure 7. Spatial distribution of reported logbook fishing catch by the 2015 U.S. albacore troll and pole-and-line fishery in number of fish. The size of circles is proportional to the amount of catch. Catch in some areas is not shown in order to preserve data confidentiality.

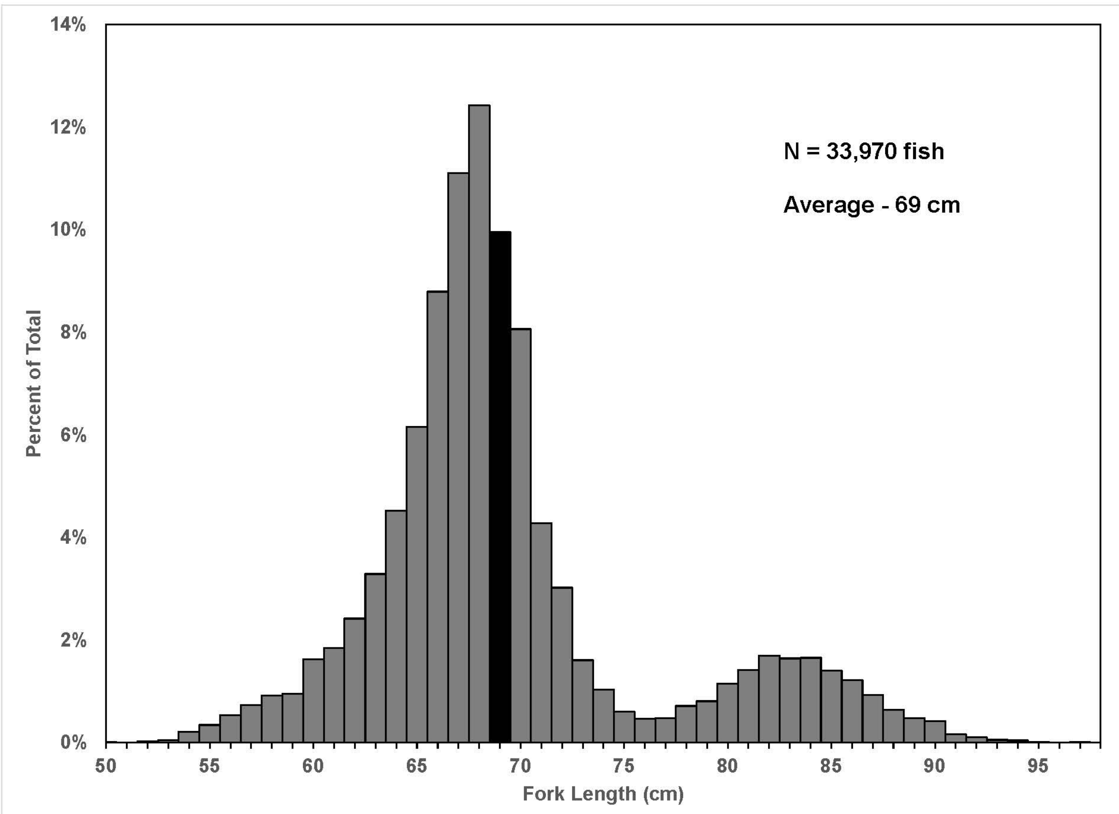
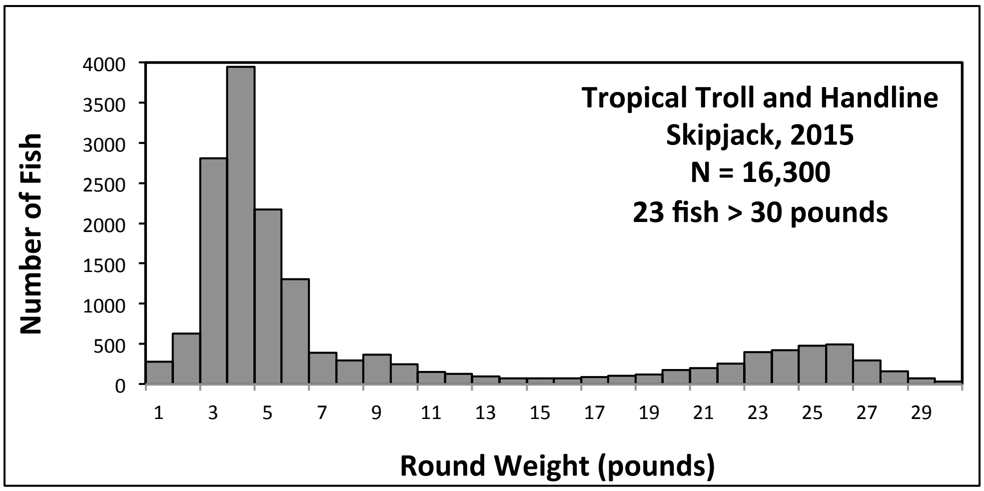


Figure 8. Size distribution of albacore catch by the U.S.A. North Pacific albacore (*Thunnus alalunga*) troll and pole-and-line fishery in 2015.



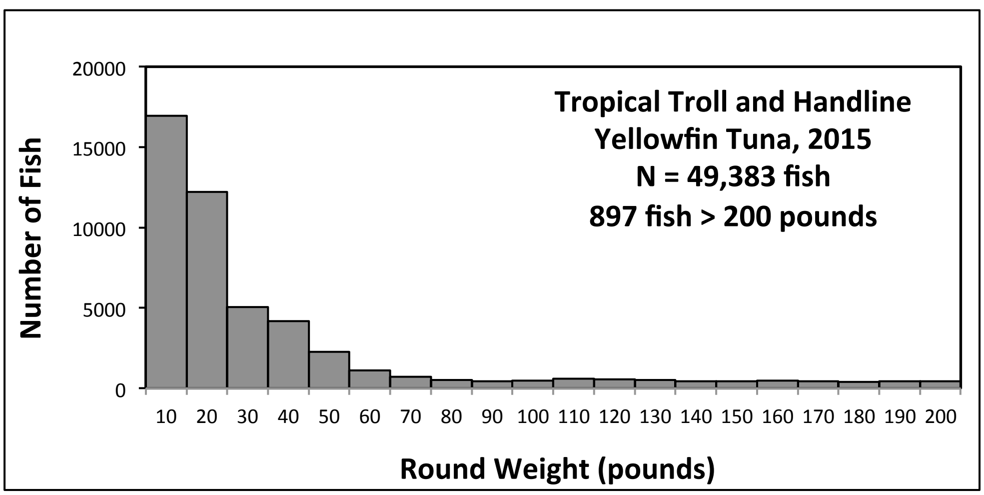
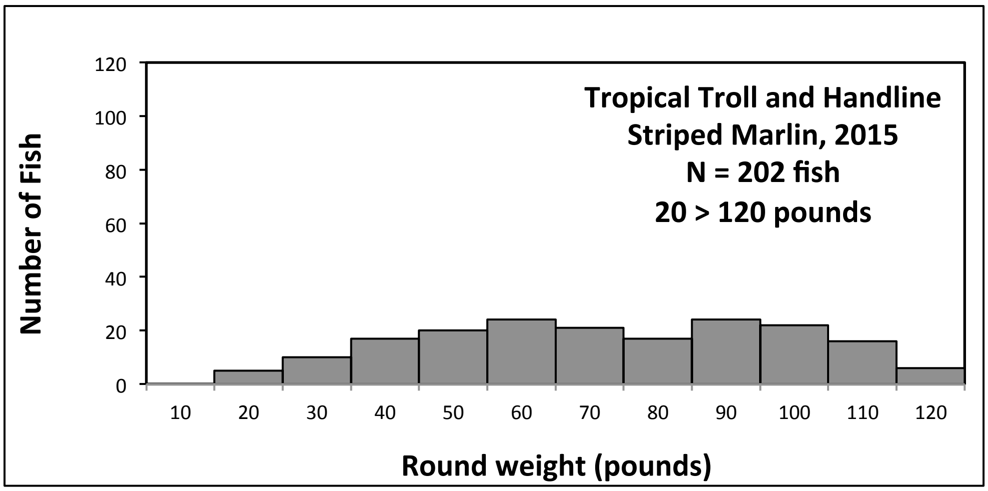


Figure 9. Size distribution of (top) skipjack tuna (*Katsuwonus pelamis*) and (bottom) yellowfin tuna (*Thunnus albacares*) caught by the Hawaii troll and handline fisheries, 2015.



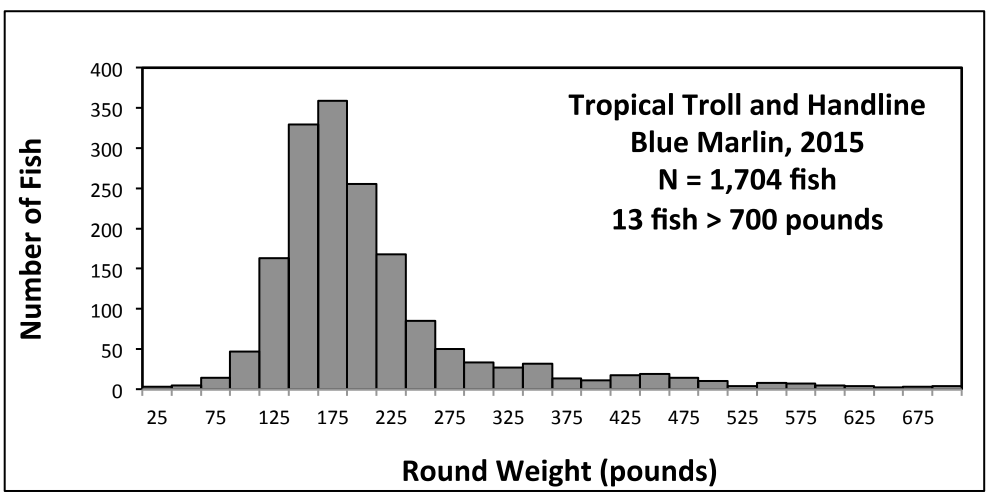


Figure 10. Size distribution of (top) striped marlin (*Kajikia audax*) and (bottom) blue marlin (*Makaira nigricans*) caught by the Hawaii troll and handline fisheries, 2015.

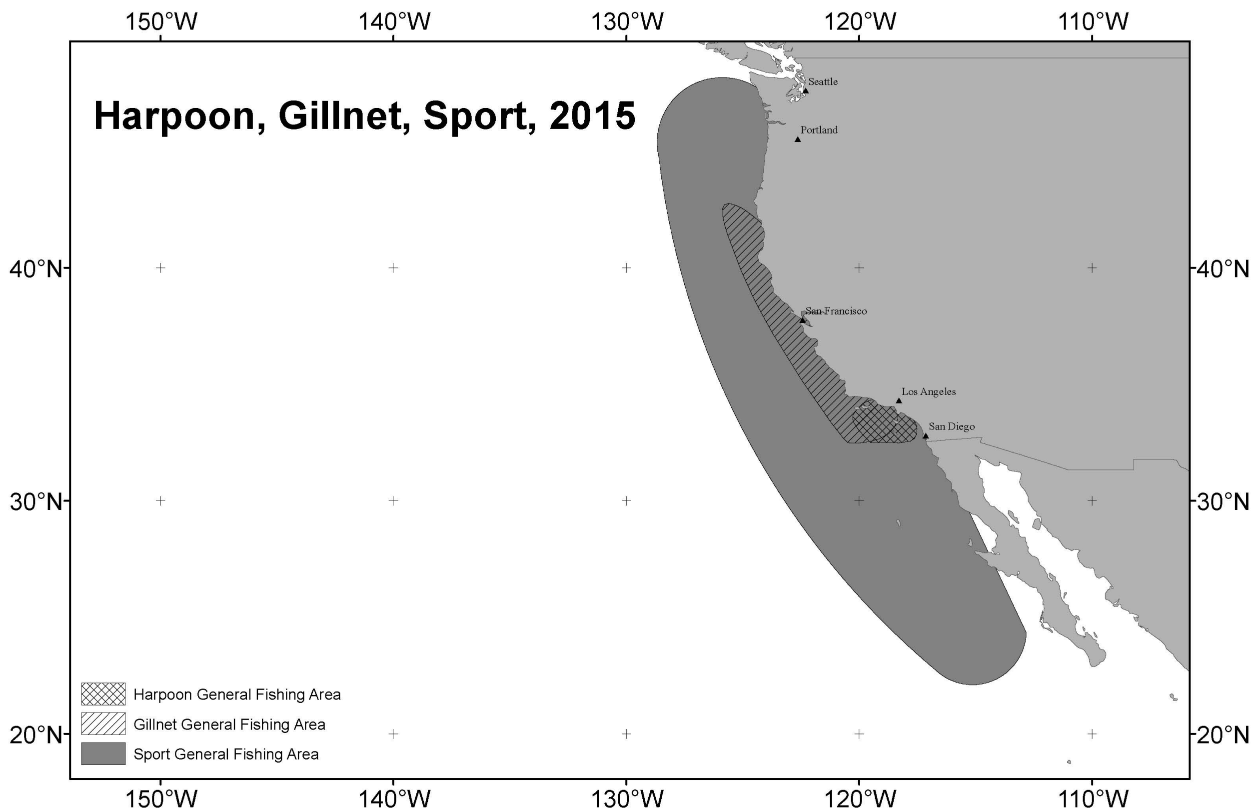


Figure 11. Spatial distribution of reported logbook fishing effort by the 2015 U.S. harpoon, gillnet, and west coast sport fisheries for HMS in the North Pacific Ocean. Effort in some areas is not shown in order to preserve data confidentiality.

Table 1. Number of vessels fishing in the North Pacific Ocean in various U.S. fisheries. Data for 2015 are preliminary. -- indicates data are not available.

Year	Purse Seine [1]	Longline	Albacore Troll and Pole-and-Line	Tropical Pole and Line	Tropical Troll [2]	Tropical Handline	Gillnet	Harpoon
1985	53	36	792	27			210	99
1986	51	39	419	19			220	113
1987	47	37	486	18	1,899		210	98
1988	74	50	531	17	1,878		192	83
1989	73	88	338	18	2,002		158	44
1990	71	138	368	12	2,042		146	49
1991	59	141	172	12	2,117		123	32
1992	72	124	602	11	2,160		113	48
1993	68	122	608	13	2,132		105	44
1994	72	127	721	11	2,210		112	49
1995	65	116	471	11	2,387		127	39
1996	61	114	676	9	2,411		100	30
1997	68	117	1,172	9	2,400		104	31
1998	68	122	841	9	2,370		87	26
1999	42	140	776	9	2,502		78	30
2000	40	130	645	7	2,229		77	26
2001	43	125	860	9	2,208		64	23
2002	31	123	644	13	2,045		45	29
2003	29	128	729	14	1,960		37	34
2004	28	126	695	11	2,012		33	29
2005	23	126	541	10	1,917		37	24
2006	11	128	601	11	1,916		45	24
2007	22	130	676	3	1,869	424	49	28
2008	36	130	525	3	1,978	475	51	32
2009	46	128	687	6	2,083	552	35	28
2010	37	125	635	2	2,042	480	26	26
2011	39	129	656	2	2,100	508	22	17
2012	40	129	841	1	2,084	576	17	10
2013	40	136	703	2	2,185	534	18	13
2014	48	141	625	2	2,115	499	21	11
2015	50	143	587	1	1,945	472	19	12

[1] Number of Purse Seine vessels are counts of unique vessels from EPO and WCPO fisheries

[2] Number of tropical troll vessels for 1987-2006 include tropical handline vessels

Table 2. U.S. catches (metric tons) of tunas and tuna-like species by fishery in the North Pacific Ocean, north of the equator. Data for 2015 are preliminary. Species codes: ALB = albacore, YFT = yellowfin tuna, SKJ = skipjack tuna, BET = bigeye tuna, PBF = Pacific bluefin tuna, SWO = swordfish, BUM = blue marlin, MLS = striped marlin, BIL = other billfish, TUN = other tunas, ALV = common thresher shark, PTH = pelagic thresher shark, BTH = bigeye thresher shark, SMA = shortfin mako shark, BSH = blue shark, SKH = other sharks . Zeros indicate less than 0.5 metric tons. -- indicates data are not available.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	TUN	SWO	BUM	MLS	BIL [5]	ALV [6]	PTH	BTH	SMA [6]	BSH	SKH	TOTAL
Purse Seine [1]																	
1985	26	92,623	47,634	1,751	3,320												145,354
1986	47	102,736	52,817	264	4,851												160,715
1987	1	123,044	48,667	222	861												172,795
1988	17	88,302	78,250	1,120	923												168,612
1989	1	77,744	35,671	516	1,046												114,978
1990	71	63,722	53,213	674	1,380												119,060
1991		26,789	50,107	415	410												77,721
1992		29,668	74,234	3,709	1,928												109,539
1993		23,805	60,485	3,035	580												87,905
1994		10,516	30,183	2,472	906												44,077
1995		16,934	60,036	5,803	657												83,430
1996	11	6,653	20,646	6,884	4,639												38,833
1997	2	20,866	37,525	8,702	2,240												69,335
1998	33	20,831	25,258	3,645	1,771												51,538
1999	48	4,989	18,710	3,236	184												27,167
2000	4	1,670	5,508	454	693												8,329
2001	51	5,362	17,794	1,122	292												24,621
2002	4	6,612	4,002	580	50												11,248
2003	44	3,562	21,212	3,528	22												28,368
2004	1	3,810	6,860	1,437													12,108
2005		6,792	19,171	3,992	201												30,156
2006		1,112	5,075	1,492													7,679
2007	77	1,112	5,075	1,492	42												7,797
2008		2,725	11,045	555													14,325
2009	31	3,694	14,378	512	410												19,025
2010		7,136	41,523	1,557			0	1	1	15						34	50,267
2011		3,996	30,348	1,893		65		6	0	10				0		30	36,348
2012		5,837	42,479	1,038													49,354
2013		--	--	--													-
2014		993	18	--	401												1,413
2015		566	106		86												758
Longline [2]																	
1985							2										2
1986							2										2
1987	150	261	1	815			24	51	272	45							1,619
1988	307	594	4	1,239			24	102	504	68							2,842
1989	248	986	10	1,442			218	356	612	132							4,004
1990	177	1,098	5	1,514			2,437	378	538	58							6,205
1991	312	733	30	1,555	2		4,535	297	663	69							8,196
1992	334	346	22	1,486	38		5,762	347	459	142							8,936
1993	438	633	36	2,124	42		5,936	339	471	100							10,119
1994	544	610	53	1,827	30	5	3,807	362	326	99							7,663
1995	882	984	101	2,099	29		2,981	570	543	182							8,371
1996	1,185	634	41	1,846	25	2	2,848	467	418	115							7,581
1997	1,653	1,143	106	2,526	26	2	3,393	487	352	143							9,831
1998	1,120	724	76	3,274	54	9	3,681	395	378	172							9,883
1999	1,542	477	99	2,820	54	10	4,329	357	364	242							10,294
2000	940	1,137	93	2,708	19		4,834	314	200	152							10,397
2001	1,295	1,029	211	2,418	6		1,969	399	351	136							7,814
2002	525	572	127	4,396	2		1,524	264	226	160							7,796
2003	524	809	207	3,618	1		1,958	363	538	248							8,266
2004	361	715	142	4,339	1	9	1,185	283	376	200							7,611
2005	296	712	91	4,999	1		1,622	337	511	216							8,785
2006	270	958	94	4,466	1		1,211	409	611	174							8,194
2007	250	844	93	5,822	0	0	1,735	262	276	160	44			128	8	7	9,629
2008	354	875	120	5,959	0	0	2,014	349	427	238	41			133	7	4	10,521
2009	203	527	136	4,628	1	0	1,817	360	258	124	30			120	9	6	8,219
2010	421	568	153	5,440	0	0	1,676	306	165	131	18			94	7	3	8,982
2011	708	937	207	5,701	0	0	1,623	373	362	249	19			68	13	2	10,262
2012	660	887	245	5,873	0	0	1,395	298	282	173	14			68	16	1	9,912
2013	317	736	233	6,504	1	0	1,270	406	398	227	6			52	1	0	10,151
2014	208	658	187	7,131	0	0	1,665	535	426	238	7			53			11,108
2015	243	910	212	8,753	0		1,515	624	494	277	7			58			13,093

Table 2. Continued.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	TUN	SWO	BUM	MLS	BIL [5]	ALV	PTH	BTH	SMA	BSH	SKH	TOTAL
Albacore Troll and Pole-and-Line																	
1985	6,415	5															6,420
1986	4,708	1															4,709
1987	2,766	76															2,842
1988	4,212	7															4,219
1989	1,860	1															1,861
1990	2,718																2,718
1991	1,845																1,845
1992	4,572																4,572
1993	6,254	137	62			1											6,454
1994	10,978	769	352														12,099
1995	8,125	211	1,157														9,493
1996	16,962	606	393		2												17,963
1997	14,325	4	2		1												14,332
1998	14,489	1,246	2		128												15,865
1999	10,120	52	16		20												10,208
2000	9,714	3	4		1	1											9,723
2001	11,349	1	1		6												11,357
2002	10,768				1												10,769
2003	14,161		2														14,163
2004	13,473	1															13,474
2005	8,479																8,479
2006	12,547																12,547
2007	11,908																11,908
2008	11,761																11,761
2009	12,340		0		0									0			12,340
2010	11,689		0														11,690
2011	10,143		0		0												10,143
2012	14,149		0		0												14,149
2013	12,310		0		0										0		12,310
2014	13,369	0			0												13,369
2015	11,571		0											0		0	11,571
Tropical Pole-and-Line																	
1985		472	1,328														1,800
1986		554	1,367			1											1,922
1987		1,861	2,087														3,948
1988		1,140	3,450	5													4,595
1989		1,318	2,456			3											3,777
1990		154	553			2											709
1991		942	1,840														2,782
1992		1,928	1,744			2											3,674
1993		2,636	2,850			5											5,491
1994		1,844	2,422			18											4,284
1995		394	2,393														2,787
1996		696	1,331			1											2,028
1997		468	1,755														2,223
1998		2,206	1,067														3,273
1999		57	601	4													662
2000		3	320	1													324
2001		4	448														452
2002		2	420			2											424
2003		35	587			4											626
2004		18	279							1							298
2005		68	353			1											422
2006		4	294			3											301
2007		23	272			1											296
2008		23	293			4											320
2009		17	214			1											232
2010																	-
2011																	-
2012																	-
2013																	-
2014																	-
2015																	-

Table 2. Continued.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	TUN	SWO	BUM	MLS	BIL [5]	ALV [6]	PTH	BTH	SMA [6]	BSH	SKH	TOTAL
Tropical Troll [3]																	
1985	7	967	101	8		2		145	18	12							1,260
1986	5	1,493	120	5		4		220	19	14							1,880
1987	6	1,616	137	8		11		261	29	20							2,088
1988	9	941	172	17		11		266	54	20							1,490
1989	36	828	153	14		11		326	24	23							1,415
1990	15	891	138	25		11		295	27	17							1,419
1991	72	802	237	25		9		346	41	25							1,557
1992	54	602	167	13		10		260	37	17							1,160
1993	71	861	157	3		6		311	67	20							1,496
1994	90	870	138	7		8		298	35	22							1,468
1995	177	978	152	20		7		315	52	29							1,730
1996	188	934	224	7		5		409	53	18							1,838
1997	133	770	196	26		4		378	37	17							1,561
1998	88	766	143	9		6		242	26	19							1,299
1999	331	1,019	181	24		4		293	27	33							1,912
2000	120	1,080	415	207		15		235	15	20							2,107
2001	194	878	523	226		13		291	44	32							2,201
2002	235	632	355	586		6		225	30	13							2,082
2003	85	735	268	213		25		210	29	18							1,583
2004	157	746	251	381		45		188	31	23							1,822
2005	175	679	259	295		14		187	20	15							1,644
2006	95	508	296	303		12		160	21	14							1,409
2007	3	501	266	63		8	1	127	13	12							994
2008	1	451	481	74		7		198	14	14							1,240
2009	3	471	412	59		12	0	15	10	8							990
2010	2	426	416	118		25		148	19	12						1	1,167
2011	4	496	385	110		16		199	16	18						1	1,245
2012	3	644	381	155		18	1	141	11	16						1	1,371
2013	2	528	535	148		5	1	137	8	16						1	1,381
2014	3	579	364	143		14	1	159	12	12	1					1	1,289
2015	2	555	398	59		15	1	196	11	17						1	1,255
Tropical Handline																	
1985							4										4
1986							4										4
1987							4		1								5
1988							6										6
1989							7		0								7
1990							5		0								5
1991							6		0								6
1992							1		1								2
1993							4		1								5
1994							4		0								4
1995							6		0								6
1996							5		1								6
1997							7		1								8
1998							7		0								7
1999							9		1								10
2000																	-
2001																	-
2002									0								-
2003							10		0								10
2004							7		2								9
2005							5		0								5
2006							4		0								4
2007	94	254	7	324		1	5	1									686
2008	28	227	9	148		1	6	1									420
2009	97	317	11	136		3	5	1									570
2010	53	265	7	340		4	3	2			1			1			676
2011	84	357	9	296		1	5	2									754
2012	253	381	12	298		1	6	2			1			1			955
2013	46	442	14	393		1	6	3			1						906
2014	49	385	8	206		2	7	4									661
2015	62	401	5	202		1	5	3			1						680

Table 2. Continued.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	TUN	SWO	BUM	MLS	BIL [5]	ALV	PTH	BTH	SMA	BSH	SKH	TOTAL
Gillnet																	
1985	2	12		2	8		2,990				856	0	90	129	0		4,089
1986	3	14		3	16	4	2,069				455	0	34	250	1		2,849
1987	5	3		6	2	5	1,529				354	2	18	208	1		2,133
1988	15	7		5	4	2	1,376				352	1	7	106	0		1,875
1989	4	1	5		3	3	1,243				430	0	16	117			1,822
1990	29	1	1	1	11	2	1,131				266	1	30	229	0		1,702
1991	17	1	3	3	4	3	944				542		31	125	0		1,673
1992		4	1	1	9	6	1,356				256	0	18	118	1		1,770
1993		7	2		32	9	1,412				243	1	41	87	0		1,834
1994	38				28	2	792				292	0	32	80	0		1,264
1995	52	2	70	1	20	1	771				234	5	30	79	0		1,265
1996	83	2	2		43		761				298	1	20	85	0		1,295
1997	60	3	2	5	58		708				291	35	29	118	0		1,309
1998	80	2	3	4	40	2	931				332	2	11	85	0		1,492
1999	149			2	22	1	606				285	10	5	52	0		1,132
2000	55	1		2	30		649				252	3	4	64	0		1,060
2001	94	5	1		35		375				319	1	1	30			861
2002	30	1			7		302				271	2		69			682
2003	16		9	6	14		216				280	4	6	57	0		608
2004	12	1			10		182				94	2	5	38			344
2005	20	2			5		220				167	0	10	25			449
2006	3	1	2		1	1	443				132	0	4	38			625
2007	4	0	0		2		490				184	2	5	37	9		733
2008	1	0	0		1		405				128		6	27			568
2009	4	1	0		3		253				38		7	21			326
2010	5				1		62				41		1	10			120
2011	5		0		18		119				55	0	1	8			206
2012	8		1	0	4		118				37			9		1	177
2013	5		0		7		95				48		1	16		0	172
2014	0		0	0	5		124				25	6	1	7			169
2015	1	1	0		4		66				18	2	0	6			98
Harpoon																	
1985							305				0			1			306
1986							291						0	1			292
1987							235						0	3			238
1988							198				0			3			201
1989							62							1			63
1990							64				0			3			67
1991							20				0			1			21
1992							75				0			3			78
1993							168							1			169
1994							157				0			1			158
1995							97				0			1			98
1996							81				0			1			82
1997							84							3			87
1998							48				0		0	1			49
1999							81							0			81
2000							90							0			90
2001							52							1			53
2002							90				0			0			90
2003							107							0			107
2004							69							1			70
2005							77							1			78
2006							71				2			0			73
2007							59							0			59
2008							48							1			49
2009							50				0			1			51
2010							37				0			0			37
2011							24				0			0			24
2012							5				0			0			5
2013							6							0			6
2014							5							0			5
2015							5				0						5

Table 2. Continued.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	TUN	SWO	BUM	MLS	BIL [5]	ALV	PTH	BTH	SMA	BSH	SKH	TOTAL
Sport																	
1985	1,176				89				42								1,307
1986	196				12				19								227
1987	74				34				28								136
1988	64				6				30								100
1989	160				112				52								324
1990	24				65				23								112
1991	6				92				12								110
1992	2				110				25								137
1993	25				283				11								319
1994	106				86				17								209
1995	102				245				14								361
1996	88				40				20								148
1997	1,018				131				21								1,170
1998	1,208				422				23								1,653
1999	3,621				408				12								4,041
2000	1,798				319				10								2,127
2001	1,635				344				0								1,979
2002	2,357				613				0								2,970
2003	2,214				355				0								2,569
2004	1,506				50				0								1,556
2005	1,719				73				0								1,792
2006	385				94				0								479
2007	461				12				0								473
2008	418				63												481
2009	944	766	2		156												1,868
2010	862	276			88												1,226
2011	421	324			225												970
2012	1,212	708			400												2,320
2013	839	433	4		809												2,085
2014	1,045	1,881	54		436				1		18			9	0		3,444
2015	924	1,241	100		359						7			1	0		2,633
Other [4]																	
1985	118	58	5	1	20	468	104				332		5	19	1		1,131
1986	66	227		6	41	6	109				93		14	59	1		622
1987	139	2,159	633	1	18	67	31				116		1	188	1		3,354
1988	76	936	372	1	46	2	64				67		2	214	3		1,783
1989	10	849	103		18		56				65		1	137	6		1,245
1990	20	508	147		81	1	43				90		0	141	20		1,051
1991	20	235	137		0		44				42		0	91	1		570
1992	40	1,119	1,014		14	2	47				35		3	19	1		2,294
1993	194	2,031	2,279		29		161				25		2	32	0		4,753
1994	66	3			1		24				37		4	46	12		193
1995	4	5	263		0		29				34		1	14	5		355
1996	10			4	0		15				21		0	9	0		59
1997	12		83		48		11				27	0	3	11	0		195
1998	15	43			59	1	19				22	0	0	12	1		172
1999	61				88		27				32	1	0	9	0		218
2000	24	1			11		33				44	0	0	12	0		125
2001	39				1		19				40	1	0	10	0		110
2002	13	27	1		2	1	3	1			30			12	0		90
2003	8	8	2	3	3		11				21		0	9	0		65
2004	3	27	2	132	0		44	5			21		0	13	0		247
2005	1				1		5				11	0		8	0		26
2006	0	349	12		0		5				24	0	0	7	0		397
2007	0	0	0		0						20	0	0	6	0		26
2008	0	2	0	5	0		19				19	0	0	5			50
2009		7	1		2		0				66	0	1	7	1		85
2010	0	0			0						55		0	10	0		65
2011	0	1			100	0					20		0	8	0		130
2012	2	0	0		38		1				30	1		11	0		84
2013	0	2	1		3		7				18	6	0	12	0		49
2014		8	0		2	0	0				15	0	0	9	0		35
2015	7	14	1		6	0	1		0		24	0	1	5	1		62

1 Purse Seine catches include EPO and WCPO fisheries, except where less than 3 vessels fished in the EPO. Estimates from 2013 through 2015 from WCPO are not available.

2 Longline includes American Samoa, Hawaii, and California fisheries.

3 Tropical troll 1985-2006 includes tropical handline catches

4 Other catches include incidental catches from non-HMS fisheries

5 BIL catches for Tropical Troll and Longline include Black Marlin, Sailfish, Spearfish, and other billfish

6 Thresher and mako shark catches are not reported at the species level in the Longline, Tropical Troll and Tropical Handline fisheries but are listed under ALV and SMA, respectively.