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U.S. Fisheries and Research on Tuna and Tuna-like Species in the North Pacific Ocean[1]

National Marine Fisheries Service

Southwest Fisheries Science Center

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

NOAA, National Marine Fisheries Service

Executive Summary

U.S. fisheries harvest tuna and tuna-like species in the North Pacific 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. The small-scale gill net, harpoon, pole-and-line, tropical troll and handline fisheries operate primarily in coastal waters, whereas the large-scale purse seine, distant-water troll, and longline fisheries that account for most of the catch operate both within U.S. Exclusive Economic Zones and on the high seas. The increase in the total USA catches in 2009 was primarily a result of increased catches by purse seine vessels, both in the western and eastern Pacific Ocean. Skipjack tuna (*Katsuwonus pelamis*) landings in the western Pacific Ocean increased from 14,378 t in 2008 to 39,103 t in 2009. Longline landings decreased 23% from 2008 to 2009. The thousands of trollers and handliners operating in the tropical Pacific Islands represent by far the largest number of vessels but contribute a small fraction of the catch.

The National Oceanic and Atmospheric Administration (NOAA) Fisheries conducted research on Pacific tuna and associated species at its Southwest and Pacific Islands Fisheries Science Centers and in collaboration with scientists from other organizations. Fisheries monitoring and economics work included the continuing survey of billfish anglers and efforts to differentiate albacore pole-and-line catch from troll catch. Stock assessment research was conducted almost entirely in collaboration with member scientists of the International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC) and other international Regional Fisheries Management Organizations.

NOAA Fisheries conducts fishery monitoring and socio-cultural research on tunas, billfishes, and animals caught as bycatch in those fisheries. In 2009, the International Billfish Angler Survey continued to provide billfish distribution, catch and angler effort information, shark catch in the Hawaiian longline fishery was summarized, and a study to understand the market impact of regulations on fisheries was begun.

NOAA Fisheries biological and oceanographic research on tunas, billfishes, and sharks addressed fish movements, habitat preferences, post-release survival, feeding habits, abundance, maturity, and age and growth. Significant results include analyses of foraging ecology of tunas in the Southern California Bight and the effects of oceanographic influences on the American Samoa longline fishery for albacore (*Thunnus alalunga*). Billfish research includes migration and life-history studies. Several studies on sharks focused on their survival after capture and release. Shark tagging studies continued, and provide an increasing body of migration data. Research on bycatch and fishing technology included studies to inform why the depleted dolphin stocks in the eastern

tropical Pacific Ocean (ETP) have not yet recovered. Research on sea turtles and sharks focused bycatch mitigation. The change in seabird bycatch rates resulting from new regulations were also evaluated.

I. Introduction

Various U.S. fisheries harvest tuna and tuna-like species in the North Pacific Ocean. Large-scale purse seine, albacore (*Thunnus alalunga*) troll, and longline fisheries operate both in coastal waters and on the high seas. Small-scale gill net, harpoon, handline and pole-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. 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 U.S. Pacific fisheries for tunas and billfishes, fishery monitoring responsibilities are shared by the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries or federal agency) and by partner fisheries agencies in the states of California, Oregon, Washington, Hawaii, and territories of American Samoa, Guam, and the CNMI. On the federal side, monitoring is conducted by the Southwest Regional Office (SWRO) 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. NOAA Fisheries fishery monitoring activities include collection of landings and sales records at markets and ports of landing, 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 placed in the Pacific Fisheries Information Network (PacFIN) system. Some state agencies also collect logbook and size-composition data. In the central and western Pacific Ocean, 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), a federally funded program managed by the PIFSC. The management of data on U.S. Pacific fisheries for tuna and tuna-like species is coordinated among the SWFSC, SWRO, PIFSC, and PIRO.

This report provides information on the number of active vessels by fleet and their catches of tunas and billfishes in the North Pacific Ocean based on the data available through 2009. Data for 2009, however, are considered preliminary and are subject to change. Although the report is focused on tunas and billfishes, many of the fisheries include catch of other pelagic fish important to the fishing fleets and local economies; catch data for these species are not included.

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 summaries of recent and ongoing scientific work by NOAA Fisheries of relevance to the ISC.

II. Fisheries

A. Purse Seine

The U.S. purse seine fishery consists of two separate components, one that operates in the western-central Pacific Ocean (WCPO), and another that operates in the eastern tropical Pacific Ocean (ETP). The ETP purse seine fishery started in the mid 1900s and most catch came from there until 1993 when vessels moved to the WCPO in response to dolphin conservation measures in the ETP. Vessels also moved to the WCPO because fishing access was granted by the South Pacific Tuna Treaty. The WCPO fishery operates mainly in areas between 10°N and 10°S latitude and 130°E and 150°W longitude and the ETP fishery in areas between 20°N and 20°S latitude and between the Central American coastline and 150°W longitude. The number of U.S. vessels participating in the U.S. purse seine fishery and fishing north of the equator decreased from a high of 110 in 1985 to 12 in 2006 (Table 1) increasing to 41 in 2009. Before 1995 the fleet fished mainly on free-swimming schools of tunas in the WCPO and on schools associated with dolphins in the ETP. Since 1995 most catches have been made on fish aggregation devices (FADs) and other floating objects.

U.S. purse seine catches of tunas north of the equator are shown in Table 2. Catches in the North Pacific Ocean, over the past five years (most of the catch is south of the equator), have been primarily skipjack tuna (*Katsuwonus pelamis*) (79%) and yellowfin tuna (*Thunnus albacares*) (17%). Skipjack tuna catches peaked in 1992 at 74,234 t (metric tons) then decreased to 5,075 t in 2006. In 2009, 39,103 t of skipjack tuna were caught by U.S. purse seiners in the North Pacific. Yellowfin tuna catches generally decreased from a high of 123,044 t in 1987 to 1,112 t in 2006. In 2009, 3,553 t of yellowfin tuna were caught by U.S. purse seiners in the North Pacific.

U.S. purse seine vessels fishing in the WCPO have been monitored by NOAA Fisheries under the South Pacific Regional Tuna Treaty since 1988. Logbook and landings data are submitted as a requirement of the Treaty (coverage 100%). Landings are sampled for species and size composition by NOAA Fisheries personnel as vessels land their catches in American Samoa and other ports (coverage approximately 1-2% of landings). Species composition samples are used to separate bigeye tuna (*Thunnus obesus*) from yellowfin tuna in the reported landings. The Forum Fisheries Agency (Treaty Manager) places observers on 100% of the vessel trips.

The Inter-American Tropical Tuna Commission (IATTC) monitors U.S. purse seine vessels fishing in the ETP by large-scale U.S. purse-seine vessels. Logbooks (coverage 100%) are submitted by vessel operators to NOAA Fisheries or the IATTC, and landings (coverage 100%) are obtained from each vessel, canneries or fish buyers. IATTC observers are placed on all large purse seine vessels.

B. Longline

The U.S. longline fishery targeting tuna and tuna-like species in the North Pacific Ocean is made up of two components, the Hawaii-based fishery and the California-based fishery. Vessels transited between the two regimes freely until 2000 when domestic regulations placed restrictions on moving between the two domestic management regimes. The Hawaii-based component of the U.S. 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 swordfish (*Xiphias gladius*) directed effort in 2000 and 2001 followed by a prohibition altogether in 2002 and 2003, after 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. 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 20 March 2006. The vessels that targeted swordfish converted to deep-set longline and targeted tunas for the remainder of the year. The Hawaii-based shallow-set longline fishery stayed below the annual sea turtle interaction limit and remained open throughout the entire year in 2008.

The California-based longline fishery consisted primarily of vessels that also participated in the Hawaii-based fishery. The number of vessels in the California-based fishery was relatively low and was composed mainly of vessels that targeted swordfish. The California-based longline fishery for swordfish was closed in 2004 and resulted in relocation of most of those vessels back to Hawaii. There was only one vessel that fished exclusively in the California longline fishery between 2005 and 2009.

The longline fishery extended from outside the U.S. West Coast 200-mile Exclusive Economic Zone (EEZ) to 175°W longitude and from the equator to 35°N latitude in 2009 (Figure 1). The number of vessels participating in the longline fishery decreased from 141 in 1991 to a low of 114 vessels in 1996 before rebounding to 140 in 1999 (Table 1). Since then, the number of vessels has generally decreased to 128 in 2009. 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. The landed catch is weighed at the fish auction. Conversion factors are used to convert dressed weight to whole weight for reporting of total catches.

Catch levels and catch-species composition in the U.S. longline fishery have changed considerably over the past years in response to fishery and regulatory changes. The majority of the catch now consists of tunas and billfishes and exceeded 10,000 t in 1993, 1999, 2000 and 2008 (Table 2). Bigeye tuna dominates the tuna catch with landings over 4,000 t in the past five years. The 2009 bigeye tuna catch was 4,546 t. Swordfish has been the dominant component of the billfish catch from 1990 and reached a peak of 5,936 t in 1993 before decreasing to 1,185 t in 2004. The 2009 swordfish catch was 1,788 t.

The Hawaii-based longline fishery is monitored by NOAA Fisheries and the State of Hawaii's Division of Aquatic Resources (DAR). Longline fishers are required to complete federal longline logbooks for each fishing operation. The logbook data include information on effort, area fished, catch, and other details of operation. Logbook coverage for the Hawaii-based longline fishery is estimated at 100%. DAR also requires fish dealers to submit landings data, and coverage for the longline fishery is very close to 100%. Observers contracted by NOAA Fisheries are placed on longline vessels to monitor protected species interactions, vessel operations, and catches. Sizes of fish caught in the Hawaii-based longline fishery are shown in Figures 2 and 3. The mandatory observers are required 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.

The California-based longline fishery is monitored by NOAA Fisheries and the California Department of Fish and Game (CDFG). Longline landings are from 100% of the fleet by the CDFG landing receipt program. Logbooks, developed by the fishing industry (similar to the federal logbooks used in Hawaii), were submitted voluntarily to NOAA Fisheries until 1994. Landed swordfish were measured for cleithrum length by CDFG port samplers until 1999. NOAA Fisheries currently places observers on all California-based longline trips. The observers collect data on protected species interactions, fish catch and measure the sizes of fish caught (retained and discarded).

C. Distant-water Troll

The U.S. distant-water troll fishery for albacore in the North Pacific Ocean started in the early 1900s. The fishery operates in waters between the U.S. west coast and 160°E longitude. Fishing usually starts in May or June and ends in October or November. The number of vessels participating in the fishery ranged from a low of 172 in 1991 to a high of 1172 in 1997 (Table 1). In 2009, 652 vessels participated in the fishery.

The troll fishery catches mainly albacore with minor incidental catches of skipjack, yellowfin and bluefin tunas (*Thunnus orientalis*), eastern Pacific bonito (*Sarda chiliensis lineolata*), yellowtail (*Seriola lalandi)*, and mahi mahi (*Coryphaena hippurus*). Since 1985, the albacore catch has ranged from a low of 1,845 t in 1991 to a high of 16,938 t in 1996 (Table 2). In 2009, 10,686 t were caught. Figure 4 shows the size frequencies distribution of albacore caught.

U.S. troll vessels voluntarily submitted logbook records to NOAA Fisheries until 1995 when those vessels fishing on the high-seas were required to submit logbooks. Starting in 2005, all vessels must submit logbooks under a Highly Migratory Species Fishery Management Plan (HMS FMP). Landings are monitored by NOAA Fisheries and various state fisheries agencies through landing receipts and coverage is 100% of the fleet. Landings are also sampled for fork length by state agency port samplers along the U.S. west coast and by NOAA Fisheries personnel in American Samoa.

D. Pole-and-line

There are two components of the pole-and-line fishery, one that operates around the Hawaiian Islands and another that operates in waters along the U.S. west coast. The vessels usually target yellowfin tuna and skipjack tuna (Hawaiian Islands) or albacore (west coast). Skipjack tuna was usually the largest component of the catch by Hawaiian pole-and-line vessels. The highest skipjack tuna catch was 1,709 t in 1988 (Table 2). The highest yellowfin tuna catch for the pole-and-line fishery was 114 t, recorded in 1986. Preliminary pole-and-line catches of skipjack, yellowfin and albacore tunas were 214 t, 17 t, and 2,084 t, respectively, in 2009.

NOAA Fisheries collects West Coast pole-and-line logbook data. Logbook submissions since 2005 are mandatory under the HMS FMP. Albacore fork-length data are collected by NOAA Fisheries through a contract with state agencies of Oregon, Washington, and California. Coverage rates for length data are less than 1% of the landings. Landings data are collected by state agencies (coverage 100%).

Hawaii DAR monitors the Hawaii pole-and-line fishery using Commercial Fish Catch reports submitted by fishers and Commercial Marine Dealer reports submitted by fish dealers.

E. Tropical Troll and Handline

Troll fisheries operate in Hawaii, Guam, and the CNMI. Handline fisheries also operate in Hawaii. These fisheries catch tuna and tuna-like fish in the North Pacific Ocean. The vessels in these fisheries are relatively small (typically around 8 m in length) and make mainly day long trips fishing in coastal waters. The number of vessels ranged from 1,878 in 1988 to 2,502 in 1999; there were 2,178 vessels in 2009 (Table 1). The operations range from recreational, subsistence, and part-time commercial to full-time commercial. Their catches generally are landed fresh and whole, although some catches are gilled and gutted. Weights of individual fish are obtained when fish are landed (Figures 5 and 6).

The total catch from these troll and handline fisheries ranged from 1,163 t in 1992 to 2,199 t in 2001 (Table 1). Total troll and handline catch was 1,661 t in 2009. Yellowfin tuna made up 47% of the troll and handline catch in 2009. The next largest components were skipjack tuna, bigeye tuna, and blue marlin (*Makaira nigricans*). The Hawaii troll and handline fisheries accounted for 84% of the total U.S. troll and handline landings in 2009.

The Guam Division of Aquatic and Wildlife Resources (DAWR) monitors the troll fishery using a statistically designed creel survey. The Guam DAWR, with the assistance of NOAA Fisheries, extrapolates the creel survey data to produce total catch, fishing effort, and participation estimates. The Hawaii troll and handline fishery catch and effort summaries are compiled from Hawaii DAR Commercial Fish Catch reports and Commercial Marine Dealer reports. The CNMI monitors the troll fishery using their Commercial Purchase database.

F. Gill Net

The U.S. drift and set gill net fisheries operate in areas within the 200-mile EEZ of California and sometimes off Oregon. Tuna and tuna-like fishes are caught mainly by drift gill nets, with minor quantities caught incidentally in set gill nets. The number of vessels participating in the fishery decreased from a high of 220 in 1986 to 33 in 2004 and was 35 in 2009. Swordfish catches are the major portion of the catch and peaked in 1985 at 2,990 t. Since then, swordfish catches have fluctuated while decreasing to 182 t in 2004 before rebounding slightly to 478 t in 2007 (Table 2) and then down to 249 in 2009.

Gill net fishery landings data (100% coverage) are collected by state agencies in California, Washington and Oregon (only minor amounts of tuna and tuna-like fishes are landed in Oregon or Washington). Logbook data for gill net fisheries are collected from 100% of the fleet by the CDFG. CDFG also collected length data for swordfish landings until 1999 from less than 1% of the landings. NOAA Fisheries observers on gill net vessels also collect length data.

G. Harpoon

The harpoon fishery operates in areas within the 200-mile EEZ of California between 32°N and 34°N latitude. The number of vessels participating in the fishery generally decreased from 113 in 1986 to 23 in 2001 (Table 1). Twenty-six vessels fished in 2009. Swordfish is targeted and trends in catches generally decreased from 305 t in 1985 to 20 t in 1991 (Table 2). Forty-eight metric tons were landed in 2008 and 2009.

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

III. RESEARCH

A. Fishery Monitoring, Management, and Socio-Economic Research

Central and western Pacific monitoring –WPacFIN, which manages data from most of the U.S. central and western Pacific fisheries, has integrated Hawaii fisheries catch data (numbers) and fishing trip information from fishermen's reports with fish weight and sales data from dealers sales reports so that weight and value of most catches can be linked. Enhancements are under development, such as linking the weight of longline-caught fish from the Hawaii Marine Dealer data with the Hawaii-based longline logbook data and the longline observer data to approximate weight of catch by geographic location. WPacFIN completed the 24th edition of Fishery Statistics of the Western Pacific which was published as a NOAA report (Hamm et al., 2009).

Shark Catch Summary from Longline Observer Program Data – NOAA Fisheries has documented decreases in shark catches and mortality in the Hawaii-based longline fishery based on fishery observer data. Walsh et al. 2009 quantitatively describes 12 years of shark catch data from the Pacific Islands Regional Observer Program. The results include a detailed summary of the species composition of the sharks catch and additional information pertinent to either the management (e.g., nominal catch rates; disposition of caught sharks; distributions of shark catches relative to those of target species) or the basic biology (e.g., mean sizes; sex ratios) of the common shark species.

Hawaii Pelagic Longline Economics – In 2004 a project to assess the change of important economic indicators of the Hawaii-based pelagic longline fisheries that target tuna and swordfish was started. Data on fishing costs and other economic information were collected by fishery observers for over 1,600 longline fishing trips. The data collected provide important economic indicators of the fisheries. Over the Period 2004-2009, the average trip cost in the Hawaii longline fishery for tuna target trip increased by about 60%, from $13,900 per trip in 2004 to $22,100 per trip in 2009. Fuel cost made up about 52% of the total trip cost in 2009. However, the trip expenditure in 2009 went down compared to that in 2008, mainly because the fuel price in 2009 went down from the peak in 2008 (Pan, 2010). The economics data collection program is continuing with the Hawaii longline fishery and will be extended to other fisheries and areas in Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands.

Hawaii Retail Fish Market and Ahi Poke Study – A new retail monitoring system completed a year of data collection on fresh fish retail markets in Honolulu in 2007 to better understand the economic contribution of fisheries and the market impacts of regulations by exploring how price changes travel through the fish 'value chain' from the fisherman to the consumer. The database includes retail-level price data for bigeye and yellowfin tuna. A related study was launched to investigate the attributes of *ahi poke* (a very popular raw tuna product mixed with seasoning) that contribute to consumer choices and to assess how awareness of carbon monoxide (CO) treatment of the *ahi poke* affects consumer purchases. The *ahi poke* survey was completed in May 2008, and may help differentiate the demand for locally produced fresh tuna versus previously frozen and CO-treated tuna (Pan and Hu, 2009).

Hawaii Small Boat Economics – NOAA conducted an economic survey to assess the fishing trip cost structure within the Hawaii small boat fishery, and shed light on the social and economic importance of small boat fishing. Approximately 345 intercept interviews were conducted at boat ramps across the state of Hawaii from April 2007 – April 2008. Results suggested that fuel is the primary cost fishers must incur on a fishing trip. For an average trolling trip in 2007, fuel accounted for 70% of total trip costs, and the increasing price of fuel may challenge the future economic viability of small boat fishing in Hawaii. A manuscript on this study is in press (Hospital et al., *in press*).

B. Stock Assessment Research

NOAA Fisheries continues to support stock assessment modeling efforts in the Pacific Ocean as part of several international fora including the International Scientific

Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC) and the Western and Central Pacific Fisheries Commission (WCPFC). In particular, NOAA Fisheries analysts have been involved in model development for population analysis on albacore, Pacific bluefin tuna, bigeye tuna, striped marlin, swordfish, and blue shark (*Prionace glauca*).

Stock assessment research generally involves collaborative development of population models, which provide stock status determinations and form the basis for management advice to regional fisheries management organizations (RFMOs). As this work is conducted as international collaborations and reported directly to the RFMOs, it is not further described here.

C. Biological and Oceanographic Research

Tunas

North Pacific Albacore Archival Tagging **–** NOAA Fisheries and the American Fishermen's Research Foundation (AFRF) have worked together since 2001 to study migration patterns and general life history strategies of subadult (ages 2-5) North Pacific albacore using archival tags. Since 2001, 594 archival tags have been deployed along the Oregon and Washington coasts and off southern California, USA and northern Baja California, Mexico. Most of the twenty-two recovered fish were at liberty for over a year and have provided over 7,800 days of data. New analyses of tag returns indicate that: during summer and fall months near the U.S. West Coast off Oregon and Washington, the mean daytime swimming depth of juvenile albacore was roughly 19 m and greater than 70% of their time was spent in the top surface mixed layer of the water column; during summer months off southern California and northern Baja California, Mexico, mean swimming depths were similar. In contrast, preliminary results indicate that in offshore areas during the winter and spring, the mean swimming depth ranged from 41 to 92 m depending upon the region, and average time spent in the upper isothermal layer ranged from 40% to 81%. In areas where chlorophyll-*a* concentrations were lower and the mixed layer depth was poorly defined, albacore spent more time at depth, suggesting a deeper foraging strategy where productivity in the top 50 m may be lower. A manuscript detailing results from this study has been submitted for publication and is currently under peer review.

Foraging Ecology of Tunas in the Southern California Bight – In an effort to collect biological data on the recreationally caught tuna and mahi mahi that seasonally forage in the Southern California Bight (SCB), NOAA Fisheries and the Sportfishing Association of California (SAC) initiated a biological sampling program in 2007 working with commercial passenger fishing vessels. In 2009, the program was expanded to the northeast Pacific Ocean where commercial fishermen began to collect samples off Oregon and Washington. Species collected to date include albacore, bluefin, yellowfin, skipjack, and mahi mahi. Biological samples are collected from each fish caught, including stomach contents and tissue samples in order to understand both the daily and long-term feeding habits of tuna in the SCB. Preliminary analysis of stomach contents shows that tuna forage almost exclusively on juvenile fish and squid. Interannual differences in diet were observed between 2007 and 2008. Studies over multiple years will help determine the impacts of short-term environmental variation on available forage and help explain migration timing and patterns of habitat-use in the California Current.

Central Pacific Bigeye Tuna Tagging -- The spatiotemporal variability in bigeye tuna dive behavior in the central North Pacific Ocean was investigated based on data from 29 pop-up archival transmission (PAT) tags deployed on commercial size tuna (mean fork length 122.2 +/- 7.8 cm SD) in the central North Pacific Ocean from 4ºN - 32ºN. Results published in Howell et al. 2010 indicate the following: during the day, bigeye tuna generally spent time in the 0 – 50 m and 300 – 400 m depth ranges, with spatial and temporal variability in the deep mode; at night, bigeye tuna generally inhabited the 0 – 100 m depth range. More shallow and intermediate dive type behavior was found in the first half of the year, and at latitudes between 14ºN and 16ºN and north of 28º N. A greater amount of deep dive behavior was found in south of 10ºN and between 18ºN and 28ºN during the third and fourth quarters of the year. Dive type also varied with oceanographic conditions, with more shallow and intermediate dive behavior found in colder surface waters. Sea surface temperature had the most significant effect on the pooled intermediate and deep dive behavior, and predicted that the largest percentage of potential interaction would be in the fourth quarter from 18°N to 20ºN, which corresponds to the time and place of the highest catch per unit effort (CPUE) of bigeye tuna by the Hawaii-based longline fishery (Howell et al., 2010).

Oceanographic Influences on the American Samoa Longline Fishery for Albacore -- The American Samoa longline fishery for albacore accounts for about 20% of all albacore caught in the South Pacific and supplies a significant portion of canned albacore to the U.S. market. A dramatic drop in albacore CPUE, preceded by an extraordinary expansion of the fleet in 1999-2001, and a slow recovery in recent years spurred an investigation of the oceanographic environment of the fishing grounds and its effects on albacore. Domokos, 2009 describes the effects of currents, eddies, chlorophyll-*a* concentrations, and presence of forage on CPUE of the fishery. Results suggest that the strength of upwelling and resulting increase in chlorophyll-*a* at New Guinea, as well as the Southern Oscillation Index (SOI), could be used to predict the performance of the American Samoa EEZ fishery (Domokos, 2009).

Billfishes

Electronic Tagging of Swordfish – Since 2006, NOAA Fisheries has been studying swordfish in the Southern California Bight to examine migratory patterns, foraging ecology, and local stock structure. As part of this effort, electronic tags have been used to characterize swordfish habitat. Efforts are focused both on deploying archival tags and towed Fast-Loc GPS satellite tags that will provide regular, highly accurate locations. Of two archival tags deployed in 2009 in conjunction with the juvenile shark longline survey, one was recovered near the tagging location. The two swordfish tagged during the survey were the first longline-caught swordfish to be tagged in the Southern California Bight. The detailed temperature and depth data from the recovered fish reveal the typical day/night dive patterns observed in other records. Interestingly, however, the swordfish made only three basking events in 106 days resulting in very low vulnerability to the harpoon fleet. This rate of basking is less than expected based on data from fish tagged at the surface with pop-off satellite archival (PSAT) tags using a modified harpoon.

Billfish Life History Studies – NOAA Fisheries continued efforts to collect central North Pacific samples from striped marlin for life history studies. Dorsal fins and head samples are collected at sea by observers onboard Hawaii-based longline vessels and the respective dorsal fin rays and otoliths extracted and processed in the lab for future age and growth studies (Kopf et al., 2009). Gonad sub-samples are concurrently collected for determination of gender and sex-specific length at 50% reproductive maturity. A non-toxic gonad preservative now used at sea by Hawaii-based longline observers has been found to yield high quality histological sections of gonads comparable to formaldehyde preserved sections. Observers also continue to collect small (<110 cm eye-fork length) whole juvenile specimens; billfish of this size are rarely available. An age and growth study of central North Pacific striped marlin will be conducted in close collaboration with a colleague in Australia who has recently completed a similar study on western South Pacific striped marlin.

NOAA Fisheries collaborates to archive billfish tissues sampled from regions across the Pacific, and particularly from early life stages collected in Hawaiian waters, for DNA-based stock structure analysis to be conducted in La Jolla. New information on billfish stock structure will assist current and future stock assessment studies conducted by NOAA and with other international partners across the Pacific.

Elemental composition analysis on the otoliths of young-of-year (YOY) swordfish *Xiphias gladius* have been conducted using the laser ablation-inductively coupled plasma-mass spectrometer (LA-ICP-MS) instrument at Oregon State University. The study is being conducted to determine whether otoliths contain trace elemental "fingerprints" unique to particular swordfish nursery regions in the Pacific. If nursery areas can be uniquely characterized, this could provide the ability to determine the origins of adult swordfish that compose the Hawaii-based swordfish fishery. Sagittal otoliths were prepared to expose the otolith core region and the daily growth increments formed during the larval stage (ca. first 100 increments). The LA-ICP-MS instrument sampled otoliths for the presence of 12 trace elements (plus calcium and strontium); results of these sample runs continue to be analyzed.

Pelagic Sharks

Abundance Surveys

To track trends in abundance NOAA Fisheries conducts annual fishery-independent surveys for juvenile blue and shortfin mako (*Isurus oxyrinchus*) sharks and neonates of common thresher (*Alopias vulpinus*) shark along the U.S. West Coast. In addition to the catch data, these cruises provide a valuable opportunity to conduct complementary studies on age and growth, migrations, essential habitat and foraging ecology.

Juvenile Mako and Blue Sharks -- In 2009, the sixteenth juvenile shark survey since 1994 was conducted for blue and mako sharks. Working aboard the *F/V Southern Horizon*, a total of 5,575 hooks during 27 daytime sets inside seven focal areas within the Southern California Bight were fished. From the catch data, the index of relative abundance for juvenile sharks, defined as catch per 100 hook-hours, was calculated for the seven target survey areas. The preliminary data indicate that the nominal survey catch rate was 0.453 per 100 hook-hours for shortfin mako and 0.314 per 100 hook-hours for blue sharks. The nominal CPUE for blue sharks dropped substantially from 2008 and was the second lowest in the survey's history. There is a declining trend in nominal CPUE for both species over the time series of the survey.

Additional research projects were also conducted during the cruise and after the shark survey was completed. An experiment directed by a graduate student of the University of Hawaii was conducted to examine the potential for using rare earth metals to reduce shark bycatch. Preliminary analyses from over 25 sets indicate that the rare earth metals did not reduce the catch rate of shortfin mako sharks. Other objectives of the cruise were to deploy satellite tags and conventional spaghetti tags, continue age and growth studies, and collect biological samples from sharks and swordfish. A total of 337 conventional tags were deployed on a range of species.

For common thresher sharks, a pre-recruit index and nursery ground survey was initiated in 2003 and has been conducted each year since. In 2009, 50 longline sets were made over an 18-day cruise and 216 common thresher, 11 soupfin (*Galeorhinus galeus*), 7 shortfin mako, 3 spiny dogfish (*Squalus acanthias*), 1 leopard (*Triakis semifasciata*), and 1 Pacific angel (*Squatina californica*) shark were caught. Two hundred and six sharks were tagged with conventional tags; 190 sharks were marked with oxytetracycline (OTC) for age validation studies; 212 DNA samples were collected. In addition, colleagues from Scripps Institution of Oceanography tagged 17 neonate common thresher sharks with mini PSATs. The preliminary survey data indicate that the average nominal catch rate by set was 2.13 per 100 hook-hours for common thresher sharks. This is down but not significantly different from 2008 when the catch rate was 2.85 per 100 hook-hours.

Migration Studies – Since 1999, NOAA has used satellite technology to study the movements and behaviors of a number of large pelagic fish species and to link the data to physical and biological oceanography in the California Current. In recent years, tag deployments have been carried out in collaboration with the Tagging of Pacific Pelagics research program (www.topp.org), Mexican colleagues at CICESE (Centro de Investigación Científica y de Educación Superior de Ensenada) and Canadian colleagues at the DFO (Department of Fisheries and Oceans) Pacific Biological Station in Nanaimo, British Columbia.Since 1999, a total of 91 makos, 76 blue sharks, 27 common threshers, 2 hammerheads and 4 ocean sunfish have been satellite tagged through these collaborative projects.

Smart Position or Temperature Transmitting (SPOT) tag deployments from 2009 provided relatively long-term records for 3 blue and 12 mako sharks whose tags were still transmitting in early 2010. Two satellite tags deployed in 2008 on mako sharks were also still reporting. These longer-term and multiyear records provide an opportunity to examine seasonal movement patterns and regional fidelity. An ongoing analysis of blue shark habitat use suggests a range of patterns: sharks moved offshore from July through October. As sea surface temperature (SST) increased, the swimming depth increased. Archival records also suggests a distinct diel pattern with substantially deeper depths attained during the day than at night. The regular timing of individual dives is consistent with behavioral thermoregulation; the sharks return to the surface mixed layer between foraging bouts to warm. The diel shift in depth distribution and increase in depth as sharks moved offshore is consistent with daytime foraging on organisms associated with the deep scattering layer (DSL) and similar to what has been observed for swordfish.

Age, Growth and Maturity Studies –Since 1997, NOAA Fisheries has been studying band deposition periodicity for mako, common thresher, and blue sharks using oxytetracycline (OTC) tagging. When a tagged shark is recaptured and the vertebrae recovered, the number of bands laid down since OTC injection can be used to determine band deposition periodicity. Since the beginning of the program, over 2,000 OTC-marked individuals have been released during juvenile shark surveys. In 2009, 184 mako, 114 blue, and 186 common thresher sharks were tagged and marked with OTC. As of March 2010, recaptured OTC-marked sharks included 81 mako, 56 common thresher, and 56 blue sharks. Vertebrae have been returned for roughly 60 percent of the recaptured sharks. Time at liberty ranged from 1 to 1,938 days, and the maximum net movement for an individual shark was 3,410 nmi. An analysis of mako shark band deposition patterns that demonstrates more rapid growth of juvenile makos in the eastern North Pacific than previously reported is nearly complete and a manuscript is being drafted.

Foraging Ecology of Shortfin Mako, Blue and Common Thresher Sharks –Three of the most abundant juvenile sharks in the California Current are the shortfin mako, blue and common thresher sharks. To better understand niche separation and the ecological role of these overlapping species, NOAA Fisheries has been analyzing stomach content analyses since 2002. Stomachs are obtained primarily from the California/Oregon drift gillnet fishery observer program. To date, a total of 713 stomachs have been collected and analyzed. Of the 330 shortfin mako shark stomachs examined (sizes 53 to 248 cm FL), 238 contained 43 prey taxa. Jumbo squid (*Dosidicus gigas*) and Pacific saury (*Cololabis saira*) were the most important prey. Of the 158 blue shark stomachs examined (sizes 76 to 248 cm FL), 114 contained 38 prey taxa. Jumbo and *Gonatus* spp. squids were the most important prey. Of the 225 thresher shark stomachs examined (sizes 108 to 228 cm FL), 157 stomachs contained 18 prey taxa. Northern anchovy (*Engraulis mordax*) and Pacific sardine (*Sardinops sagax*) were the most important prey. Overall, results indicate that mako sharks have the most diverse diet, feeding on a range of teleosts and cephalopods; blue sharks generally prefer cephalopods; and thresher sharks are more specialized, feeding primarily on small schooling teleosts. Despite similarities in life history characteristics and spatial and temporal overlap, diets of the three species are strongly differentiated.

Survival after Capture-and-Release Studies
Blue Sharks Released by the California Drift Gillnet Fishery – NOAA Fisheries has been conducting a study to determine the survivability of blue sharks caught and released alive by the California drift gillnet fishery since 2007. Results to date suggest a 100% survival rate for male blue sharks released in fair or better condition after capture. Tagging efforts during the 2010-2011 season will focus on smaller sharks, females and animals released in poor condition.

Thresher Sharks Released by the Recreational Fishery – A collaborative project was initiated by NOAA Fisheries and Pfleger Institute of Environmental Research (PIER) in spring 2007 to determine the survivability of thresher sharks caught by tail hooking and released. Recent analyses of data from twenty sharks suggest a hooking mortality rate of 26%, with a post-release mortality estimate of 17% for adult and subadult thresher sharks. In addition, blood chemistry was analyzed to assess the stress response associated with tail-hook capture. The two parameters that showed a significant increase with fight time were lactate and hematocrit. In an effort to educate the recreational fishermen about the biology and conservation of the thresher sharks and to promote responsible fishing techniques, an outreach brochure was developed and distributed among the community. Public education about effective catch and release methodologies and research into gear innovations to increase post-release survivorship and reduce trailing gear will continue in 2010.

Pelagic Sharks Released by the Longline Fishery – NOAA Fisheries has been developing biochemical and physiological profiling techniques for use in estimating post-release survival of blue sharks, which are frequently caught as bycatch of Pacific longliners. Using NOAA research vessels and longline gear, they captured 211 sharks, of which 172 were blue sharks. Using blue sharks, NOAA scientists and collaborators developed a model to predict long-term survival of released animals (verified by PSAT data) based on analysis of small blood samples. These data suggest that a shark captured without obvious physical damage or physiological stress (the condition of 95 percent of the sharks they captured) would have a high probability of surviving upon release.

In addition, five species of pelagic sharks (bigeye thresher (*Alopias superciliosus*), blue shark, oceanic white-tip (*Carcharhinus longimanus*), shortfin mako, silky shark (*C. falciformis*)) released from longline gear were tagged with PSATs. Of 44 PSATs reporting, there was definitive data for post-release mortality in only 2 cases (male blue shark after 7days, female oceanic whitetip after 9 days) for an overall mortality estimate of 4.5% (95% bootstrap CI, 0 to 11%). In summary, the studies demonstrate a high rate of post-release survival of pelagic sharks captured and released from longline gear fished with circle hooks (Musyl et al., 2009).

Incidental Take of Blue Sharks in the U.S. West Coast Drift Gillnet and Longline Fisheries for Swordfish – To characterize the catch of blue sharks and to identify seasons, areas and gear configurations that yield the lowest blue shark to swordfish catch ratios

NOAA Fisheries has been analyzing observer and logbook data. To compare catch ratios for drift gillnets and longlines, over 250,000 sets from logbooks and over 100,000 observed sets have been compiled for the California drift gillnet and longline fisheries and the Hawaii longline fishery. Preliminary results show that on average the drift gillnet fishery has a lower blue shark to swordfish catch ratio than the California and Hawaii longline fisheries combined; however, significant differences were apparent between the logbook and observer data for each of the fisheries, likely due to under-reporting of blue shark catch in the logbooks. Temporal analyses demonstrated lower blue shark to swordfish ratios during the month of August for both fisheries. Additional analyses using multivariate statistical methods are currently underway to tease apart the complex relationships among the environment, location, data type and gear type.

Genetic Analysis of Shortfin Mako Shark – The shortfin mako is a commonly encountered shark in temperate marine fisheries but little is known about regional connectivity. A recent master's thesis completed in collaboration with the University of San Diego provided evidence of regional stock structure within the Pacific. The study, using mitochondrial haplotype data, showed a strong subdivision between northern and southern hemisphere populations, with additional subdivision between southeast and southwest Pacific populations. Unfortunately, insufficient samples were available from the northwest Pacific to evaluate whether a subdivision exists between northeast and northwest Pacific populations.

Meta-Analysis of Archival Tags – NOAA is analyzing the performance of pop-off archival transmitting (PSAT) tags deployed on a wide array of highly migratory species to help improve attachment methodologies, selection of target species, and experimental designs, particularly with respect to post-release survival studies. Based on the fate of 1433 tags described in the literature and data from 731 tags provided by collaborators in a performance assessment database, there is a 77% overall reporting rate. PSATs in the performance assessment database had a very similar overall reporting rate. Shark species in the database include bigeye thresher, blue, shortfin mako, silky, oceanic whitetip, great white (*Carcharodon carcharias*), and basking sharks (*Cetorhinus maximus*). Other species include: black (*Makaira indica*), blue, and striped marlins; broadbill swordfish; bigeye, yellowfin, and bluefin tunas; tarpon; and green (*Chelonia mydas*), loggerhead, and olive Ridley (*Lepidochelys olivacea*) turtles. Of the tags that recorded data, 106 (18 percent) hit their programmed pop-off date and 471 tags popped off earlier than their program date. The 154 (21 percent) non-reporting tags are not assumed to reflect fish mortality. Logistic regression models showed that reporting rates have improved significantly over time and are lower in species undertaking large vertical excursions. Information derived from this study should allow an unprecedented and critical appraisal of the overall efficacy of the technology (Musyl et al., *in prep*).

D. Bycatch and Fishing Technology Research

Dolphins

NOAA Fisheries conducts research of dolphin stocks historically depleted by the ETP tuna purse seine fishery (spinner (*Stenella longirostris*) and pantropical spotted (*Stenella attenuata attenuata)* dolphins) with an ecosystem approach.

Assessment of Relative Fishery Exposure for ETP Dolphins – For the past half century, the purse seine fishery for yellowfin tuna has significantly affected dolphins in the ETP. However, little is known about how frequently an individual dolphin is exposed to the fishery, and there are no methods available for accurately assessing the prior exposure of dolphins encountered at sea. Archer et al. (accepted for publication) developed an index to estimate how frequently individual dolphins are exposed to the purse-seine fishery based on a model of dolphin movement derived from data collected from multiple tracking studies. The authors used the method to examine the spatial and temporal distribution of this index over an 11-year period for which there are detailed data on purse seine sets. Planned studies for this index include examining its relationship to evasive behavior, calf production as assessed from aerial photographs, and reproductive rates as measured from skin biopsies.

Variation and Predictors of Vessel Response Behaviors in ETP Dolphins –Archer et al. (2010) used a tree-based modeling method to investigate the influence of geography, time of day, species composition, and fishery exposure on the responses of five species of dolphins in the ETP, comprising ten management stocks. Data were collected for 2,667 sightings during four research cruises between 1998 and 2003. The relative frequency of five responses (approaching the vessel, bow-riding, running, school splitting, and low-swimming) showed significant variability among species, as well as among stocks within the same species. Striped (*Stenella coeruleoalba*), whitebelly spinner (*S. longirostris*), and western-southern pantropical spotted dolphins (*S. attenuata attenuata*) tended to be evasive, while coastal spotted (*S. attenuata graffmani*) and common bottlenose dolphins (*Tursiops truncatus*) tended to be attracted to the vessel. There was a strong tendency of dolphins sighted offshore to be significantly more evasive than those less than about 100 nmi from the coast. The degree of evasiveness in stocks that are frequently targeted by the tuna purse seine fishery (northeastern spotted, *S. attenuata;* eastern spinner, *S. longirostris orientalis*; and short-beaked common, *Delphinus delphis*) was greater with more purse seine activity in the vicinity, while no significant relationship was found for those stocks that are rarely set upon.

Dolphin Swimming Kinematics Research – During 2009, NOAA Fisheries continued a series of studies investigating swimming kinematics of mother and calf dolphins, as part of an effort to determine whether chase and encirclement of dolphin mother-calf pairs by tuna purse seiners in the ETP may be contributing to lack of population recovery. The study during 2009 (Noren and Edwards, in prep.) examined the effects of late pregnancy on swimming kinematics of bottlenose dolphins. The study compared swimming kinematics (swim speed, fluke stroke amplitude, and fluke stroke frequency) of two bottlenose dolphins within 1-10 days pre-parturition, and up to two years postpartum. During late-term pregnancy, body surface area increased, stroke amplitude decreased, distance per stroke decreased, and swim speed decreased, all significantly. The results demonstrate for the first time that late-term pregnancy in dolphins significantly decreases swim performance, implying altered maternal energy budgets as well as decreased foraging and predator evasion efficiencies.

Port Sampling and Observer Program to Monitor Small Purse Seine Vessels – In 2006, NOAA Fisheries began working with IATTC to expand the at-sea observer and in-port sampling programs currently implemented in the ETP tuna purse seine fishery under the Agreement on the International Dolphin Conservation Program (IDCP). Upon completion of this program in May 2009, a total of 750 unloadings by Class 4 and 5 international purse seine vessels have been sampled. NOAA Fisheries and IATTC are collaborating to analyze tuna species and size composition data along with other catch characteristics to explore the feasibility of using this type of data to identify if small purse seine vessels have harvested tuna in association with dolphins. This work has several potential applications, including using unusual length-frequency data from small vessels to estimate potential unobserved dolphin mortality for inclusion in stock assessments and for consideration in management.

Metrics of Ecosystem Impact of the ETP Purse Seine Fishery – Previous analyses in the ETP compared the relative impacts of three methods of purse seine fishing based only on numbers of individuals in the bycatch (defined here as non-target species, either retained or discarded), and found levels of discarded bycatch in floating-object sets thousands of times greater than in dolphin sets and hundreds of times greater than in unassociated tuna sets. NOAA Fisheries expanded the analysis by examining a mix of ecosystem indicators based on the type and amount of biomass of species and functional groups caught (total removals) by the fishery. Removals (landings and discards) were compared in three ways: trophic level, replacement time, and diversity.

Total annual biomass removals averaged more than 500,000 t per year over the 16-year period from 1993 to 2008 and were dominated by the primary target species, yellowfin, skipjack and bigeye tunas. Fishing by setting on dolphins, floating objects, and unassociated schools of tuna averaged 30%, 44%, and 26% of the biomass removed, respectively. The mean trophic levels of total removals were similar for the three fishing methods, and there was no indication of a decline in trophic level over the 16-year period. Mean time to replace biomass varied by fishing method: lowest for dolphin sets (0.48 years), intermediate for unassociated sets (0.57 years), and highest for floating-object sets (0.74 years). Diversity of removals across the whole time period was lowest for dolphin sets (0.64), intermediate for unassociated sets (1.30) and highest for floating-object sets (1.41). Diversity declined over time for floating-object and unassociated sets and increased for dolphin sets, so that the differences among the three fishing methods were less in 2008 than in 1993. Discards (non-retained bycatch and target species), as a percentage of total removals in biomass, were 0.8% for dolphin sets, 11.0% for floating-object sets, and 2.3% for unassociated sets. The tunas were the major component (77%) of the discards. Discarded bycatch in floating-object sets was 16 times greater than in dolphin sets and 9 times greater than in unassociated sets, not thousands and hundreds of times greater, when biomass and replacement time are considered. A manuscript is under preparation for publication.

Sea turtles

American Samoa Study on Effects of Removing Longline Hooks Close to Floats – NOAA conducted a study involving to provide data on the efficacy of removing hooks adjacent to floats as a way to reduce turtle interactions and to estimate corresponding changes in CPUE of target fish species as well as incidental and bycatch species. They used time-depth recorders (TDRs) to measure hook depths in the fishery and determined the frequency distribution of "hook-at-capture" - the tendency of fish to be caught on a given hook in relation to the hook's proximity to the nearest longline float. The full results of the study are contained in a NOAA internal report issued in March 2009.

Research on Escape Solutions in Japan Pound Nets – A new NOAA collaborative effort provided technical information and expertise to the Sea Turtle Association of Japan (STAJ), Tokyo University of Marine Science and Technology, and ProPeninsula to help develop methods to identify mitigation measures useful in reducing loggerhead sea turtle bycatch in mid-water pound net fisheries in Japan. In the initial phase of this project, the researchers designed and constructed a 50% scale model of the cod end of a pound net (4.5m x 4.5m x 3m). The scale model was used to test turtle escape solutions in a controlled tank environment to simulate the conditions experienced by sea turtles inside actual pound net gear. A system of panels was designed that allowed researchers to change out different prototype pound net escape devices (PEDs) during testing. Six PED designs were developed based on observations of gear in pound net and other fisheries. By testing these designs, a protocol was established for handling turtles and characterizing turtle escape behavior, and one promising PED prototype was identified. The next phases of this project are being planned.

Longline Gear Modification to Reduce Bycatch -- NOAA Fisheries is contracting or otherwise assisting in longline fishing vessel trials to test the efficacy of sea turtle bycatch mitigation methods in Costa Rica, Brazil, Uruguay, Spain, Cook Islands, Vietnam, and Italy. The trials will measure effects of gear modifications (e.g., use of large circle hooks, appendage hooks, hook offsets, rings) on the rates of hooking and entanglement of sea turtles in longline fisheries (Swimmer et al., 2010; Sales et al., *in press*). Research from the previous few years indicate that relatively large circle hooks effectively reduce the bycatch of both loggerhead and leatherback sea turtles (Piovano et al., 2009). These hooks also show acceptable catch rates of tuna species, but slightly reduced catch rates of targeted swordfish. In addition, use of circle hooks has been found to reduce the rates of capture of pelagic stingrays (*Pteroplatytrygon violacea*), motivating some fishermen, particularly in Italy, to convert to circle hooks. Technical assistance was provided to numerous programs, both governmental and non-governmental, as experimental longline tests expand worldwide. A recently completed regional database linked to NOAA's bycatch web site provides public access to the data.

NOAA Fisheries also continues its investigations of the post-release mortality of sea turtles after their release from fishing gear. There are manuscripts in press regarding use of pop-up satellite archival tages (PSATs) and platform terminal transmitters (PTTs) to estimate post-release survival of loggerhead turtles caught on longline fishing gear in the North Pacific Ocean, South Atlantic Ocean and Mediterranean Sea. Preliminary results of tracking studies indicate no differences in duration of transmissions as a function of turtles 'severity' of injury, specifically deep or shallow hookings, and that most sea turtles were tracked for the duration of the tags' battery life.

Sharks

Longline Gear Effects on Shark Bycath – A NOAA study using fishey observers was conducted to compare bycatch rates under different operational factors (e.g., hook type, branch line material, bait type, the presence of light sticks, soak time, etc.) in the longline fishery that might reduce shark bycatch. A preliminary analysis was completed that compared the catches of vessels using traditional tuna hooks to vessels voluntarily using size 14/0 to 16/0 circle hooks in the Hawaii-based tuna fleet. Eighteen contracted vessels were used to test large (size 18/0) circle hooks versus tuna hooks in controlled comparisons. Preliminary analysis does not indicate that large circle hooks increase the catch rate of sharks, in contrast to findings of increased shark catch on circle hooks in studies comparing smaller circle hooks with J hooks in other fisheries. There was no significant difference in the catch of the target species, bigeye tuna by hook type. However, results showed strong statistical evidence that the use of large circle hooks would reduce the catch of incidental species such as billfish, pelagic sharks, opah (*Lampris guttatus*), and mahi mahi in the Hawaii-based tuna longline fishery (Curran and Bigelow, 2010).

Testing Deeper Sets – Experiments conducted in 2006 altered current commercial tuna longline setting techniques by eliminating all shallow set hooks (less than 100 m depth) from tuna longline sets. The objective was to maximize target catch of deeper dwelling species such as bigeye tuna, and reduce incidental catch of many marketable but less desired species (e.g., billfish and sharks). Results for this study are detailed in Beverly et al., 2009.

Chemical and Electromagnetic Deterrents to Shark Bycatch – Beginning in early 2007, the NOAA Fisheries began testing the ability of electropositive metals (lanthanide series) to repel sharks from longline hooks. Electropositive metals generate large oxidation potentials when placed in seawater, and may perturb the electrosensory system in sharks and rays, causing the animals to exhibit aversion behaviors. Since commercially targeted pelagic teleosts do not have an electrosensory sense, this method of perturbing the electric field around baited hooks may selectively reduce the bycatch of sharks and other elasmobranchs.

Feeding behavior experiments were conducted to determine whether the presence of these metals would deter sharks from biting fish bait. Experiments were conducted with Galapagos sharks (*Carcharhinus galapagensis*) and sandbar sharks (*Carcharhinus plumbeus*) off the coasts off the North Shore of Oahu. Results indicate that sharks significantly reduced their biting of bait in proximity to electropositive metal objects. In addition, sharks exhibited significantly more aversion behaviors as they approached bait associated with these metals. Further studies on captive sandbar sharks in tanks indicated sharks would not get any closer than 40 cm to baits in the presence of the metal objects (ingots approximately the same size as a 60g lead fishing weight used by Hawaii longline fishermen).

Initial experiments to examine the effects of Nd/Pr (Neodymiun/Praseodymium) alloy on the catch rates of sharks on bottom set longline gear and to examine the effects of Nd/Pr alloy and other lanthanide alloys on the feeding and swimming behavior of scalloped hammerhead (*Sphyrna lewini)* and sandbar *(Carcharhinus plumbeus)* sharks are being conducted through a collaboration with the University of Hawaii's Hawaii Institute of Marine Biology (HIMB). Preliminary results from longline field trials in Kaneohe Bay, Hawaii suggest that catch rates of juvenile scalloped hammerhead sharks are reduced by 63% on branch lines with the Nd/Pr alloy as compared to lead weight-controls (Wang et al., 2009; Brill et al., 2009).

Seabirds

Seabird Regulations in the Hawaii Longline Fishery -
Federal regulations were adopted in 2001 to reduce seabird bycatch in the Hawaii longline tuna fishery. NOAA evaluated the change in seabird bycatch rates from the pre- to post-regulation period, as well as the efficacy of alternative combinations of seabird bycatch reduction methods employed during the post-regulation period. Results indicate that there was a significant 67% (95% CI: 62 to 72) reduction in the seabird bycatch rate following the introduction of regulations (Gilman, et al., 2008).

Other

*Genetic Analysis of Opah –*Though caught mainly as bycatch in pelagic tuna fisheries, opah command a high price in the market and thus few are discarded. The existence of two opah morphotypes in the North Pacific was recently discovered by NOAA Fisheries port samplers in Honolulu. The most conspicuous difference between these morphotypes is the relative size of the eye, leading to the labeling of the morphotypes as "big-eye" and "small-eye" opah. NOAA Fisheries conducted genetic analyses to confirm that the two morphotypes are genetically distinct and in fact represent separate species. A description of this species complex, the distribution of the component species, and identification key is currently in preparation.

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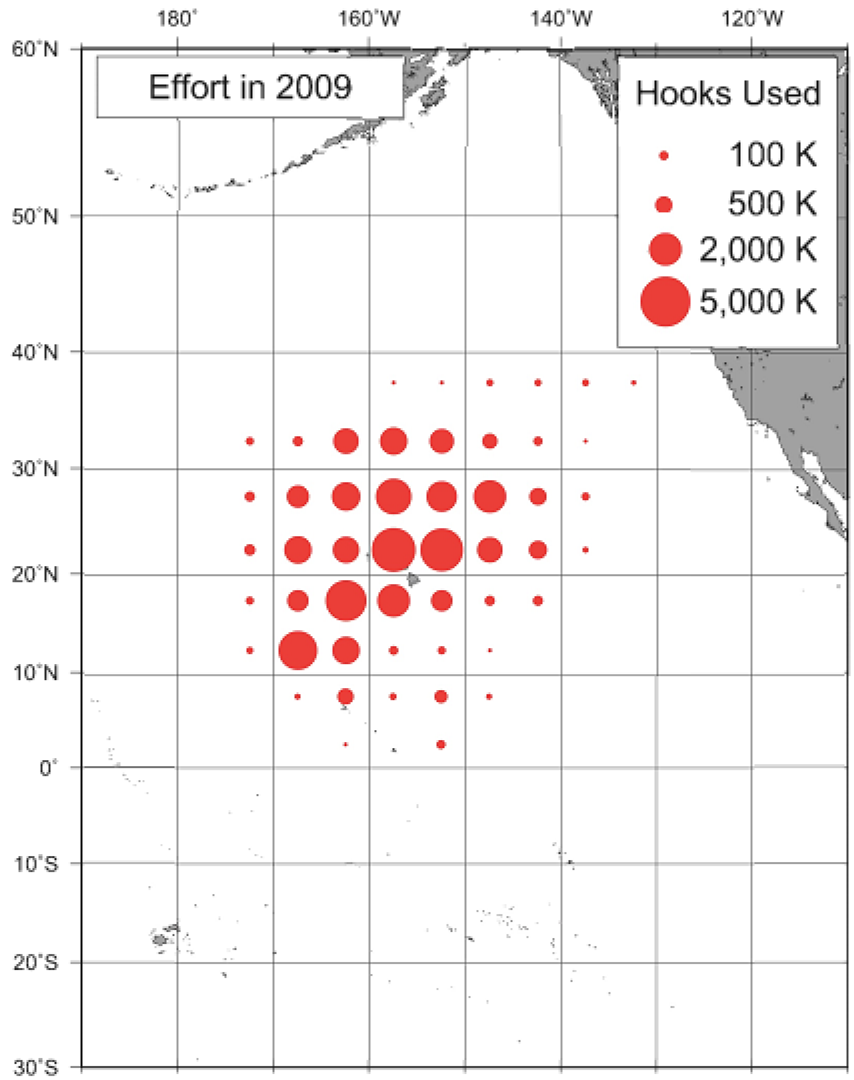


Figure1. Spatial distribution of reported logbook fishing effort by the U.S. longline fleet, in 1000s of hooks (K), in 2009 (provisional data). Area of circles is proportional to effort. Effort in some areas is not shown in order to preserve data confidentiality.

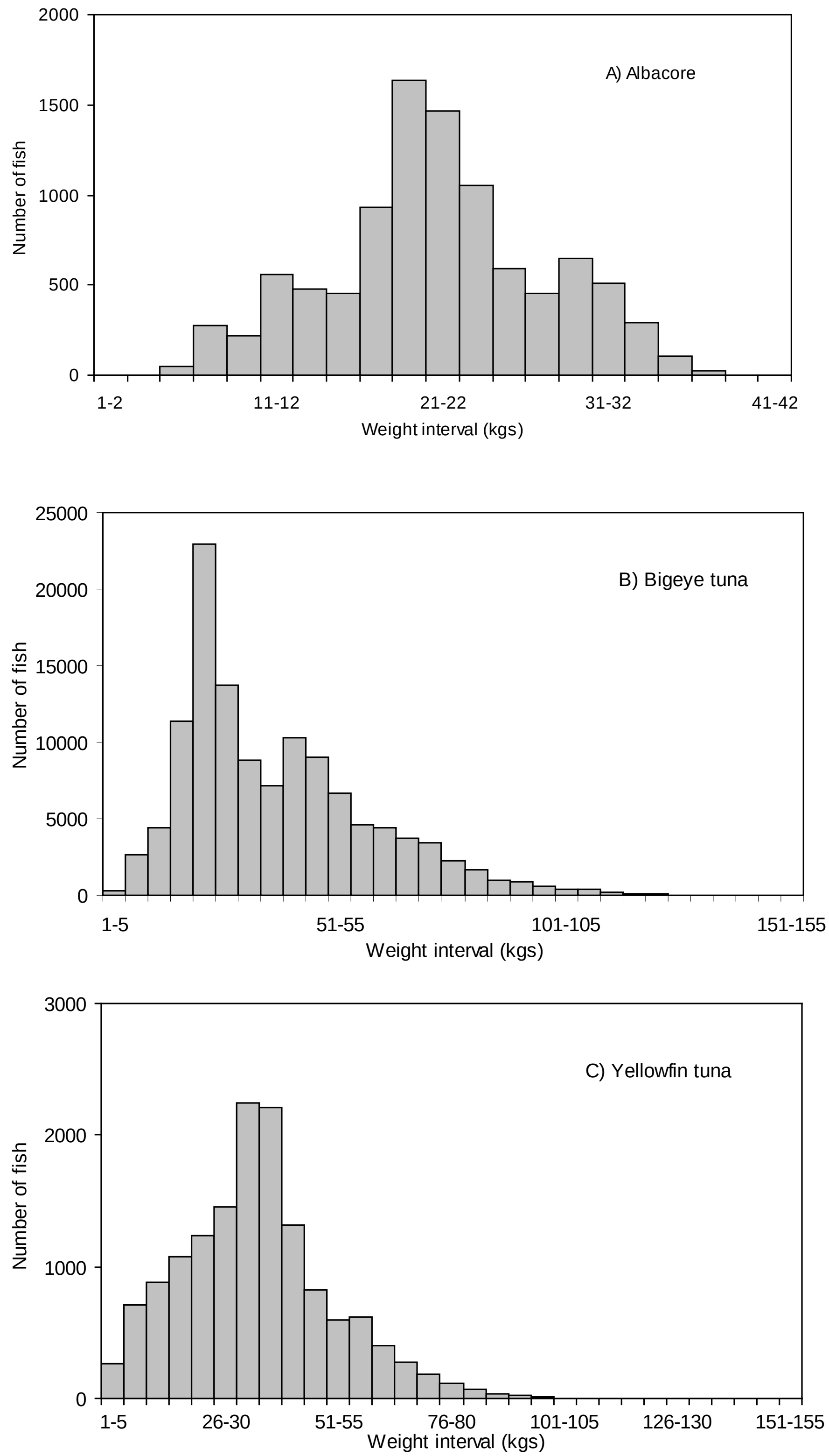


Figure 2. Size distribution of (A) albacore (*Thunnus alalunga*), (B) bigeye tuna (*Thunnus obesus*), and (C) yellowfin tuna (*Thunnus albacares*) caught by the Hawaii-based longline fishery in the north Pacific Ocean, 2009.

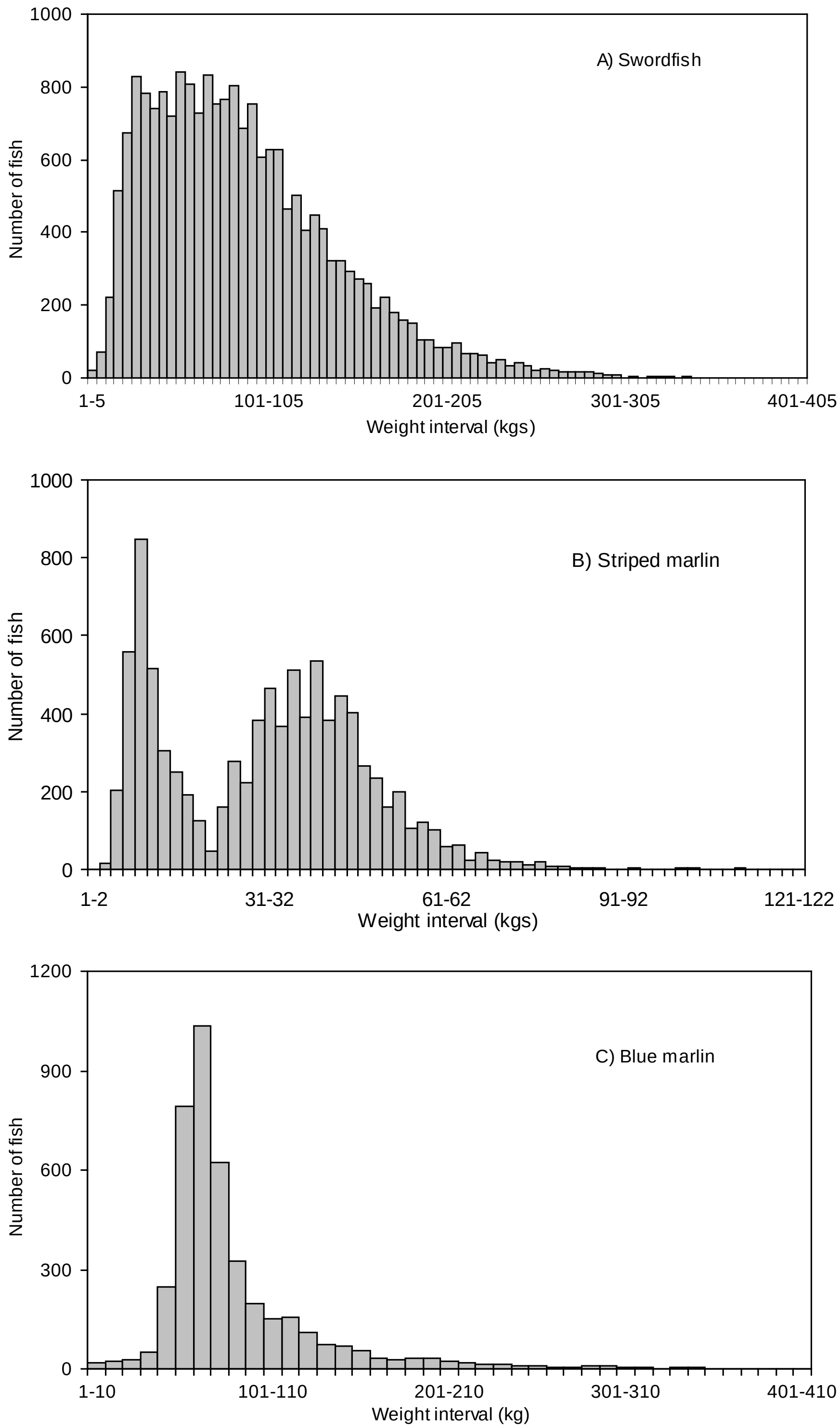


Figure 3. Size distribution of (A) swordfish (*Xiphias gladius*), (B) striped marlin (*Tetrapturus audax*) , and (C) blue marlin (*Makaira nigricans*) catch by the Hawaii-based longline fishery in the north Pacific Ocean, 2009.

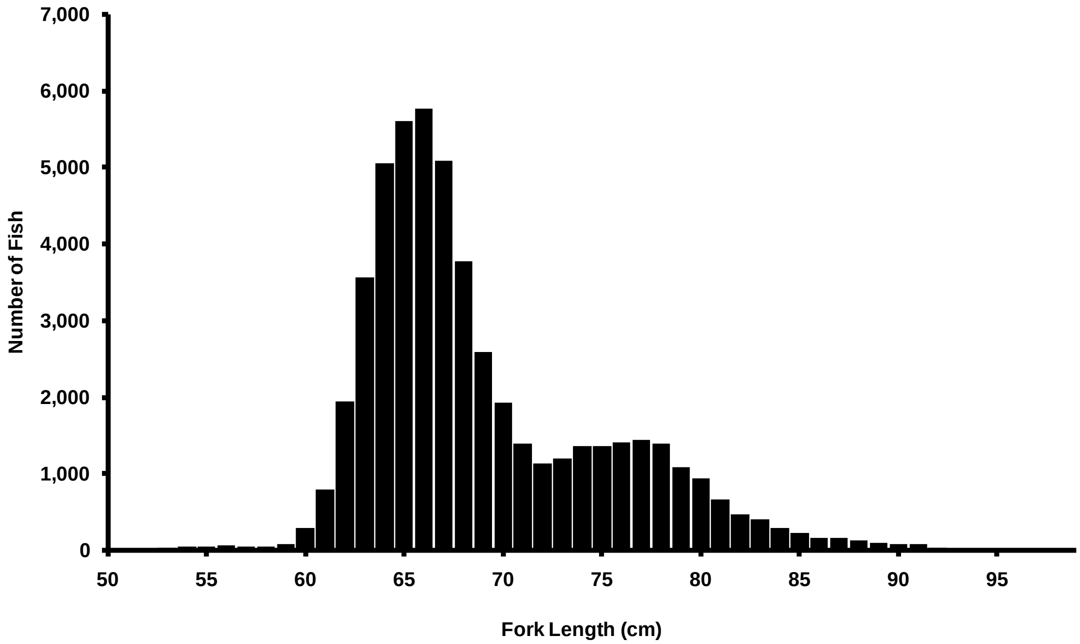
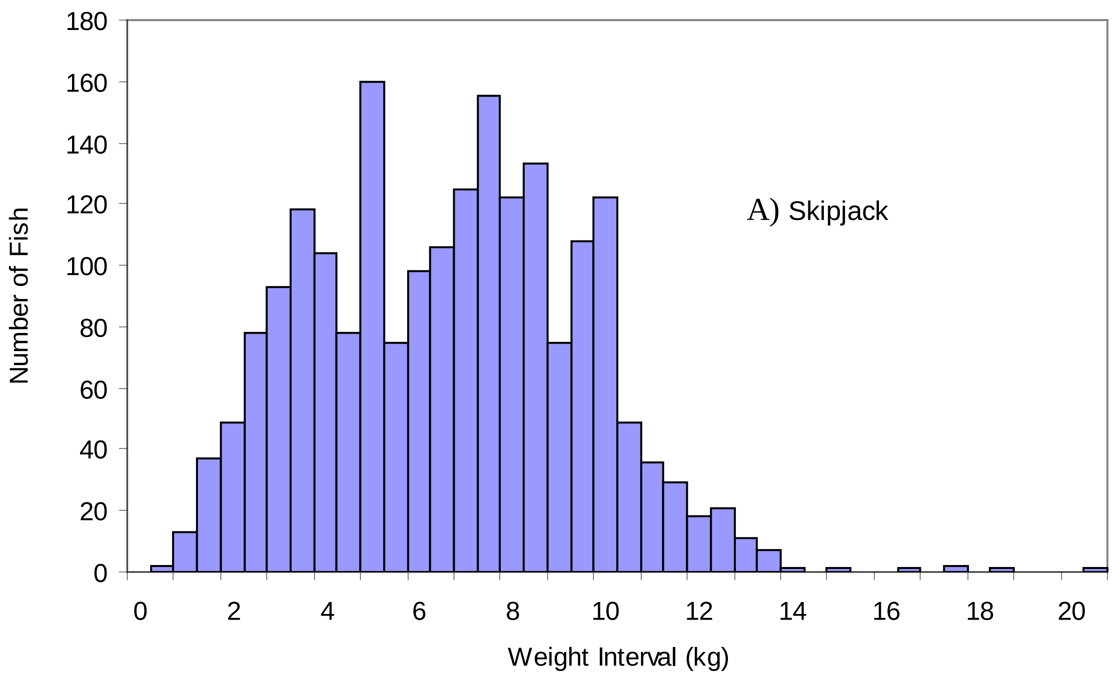


Figure 4. Size distribution of albacore catch by the U.S. albacore (*Thunnus alalunga*) troll and pole-and-line fishery in 2009.



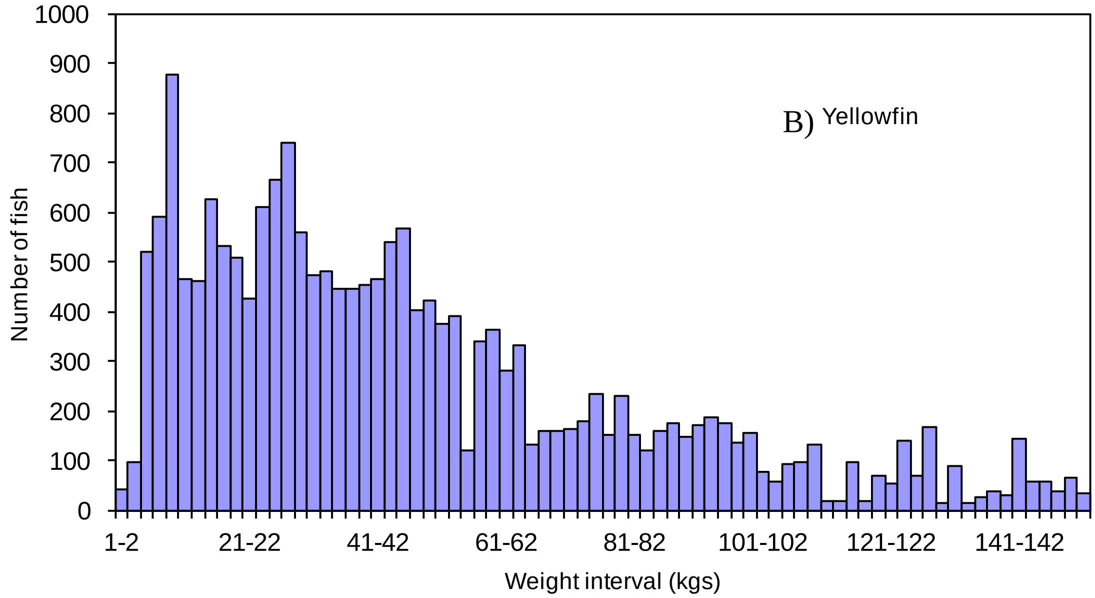


Figure 5. Size distribution of (A) skipjack tuna (*Katsuwonus pelamis*) and (B) yellowfin tuna (*Thunnus albacares*) catch by the Hawaii troll and handline fishery, 2009.

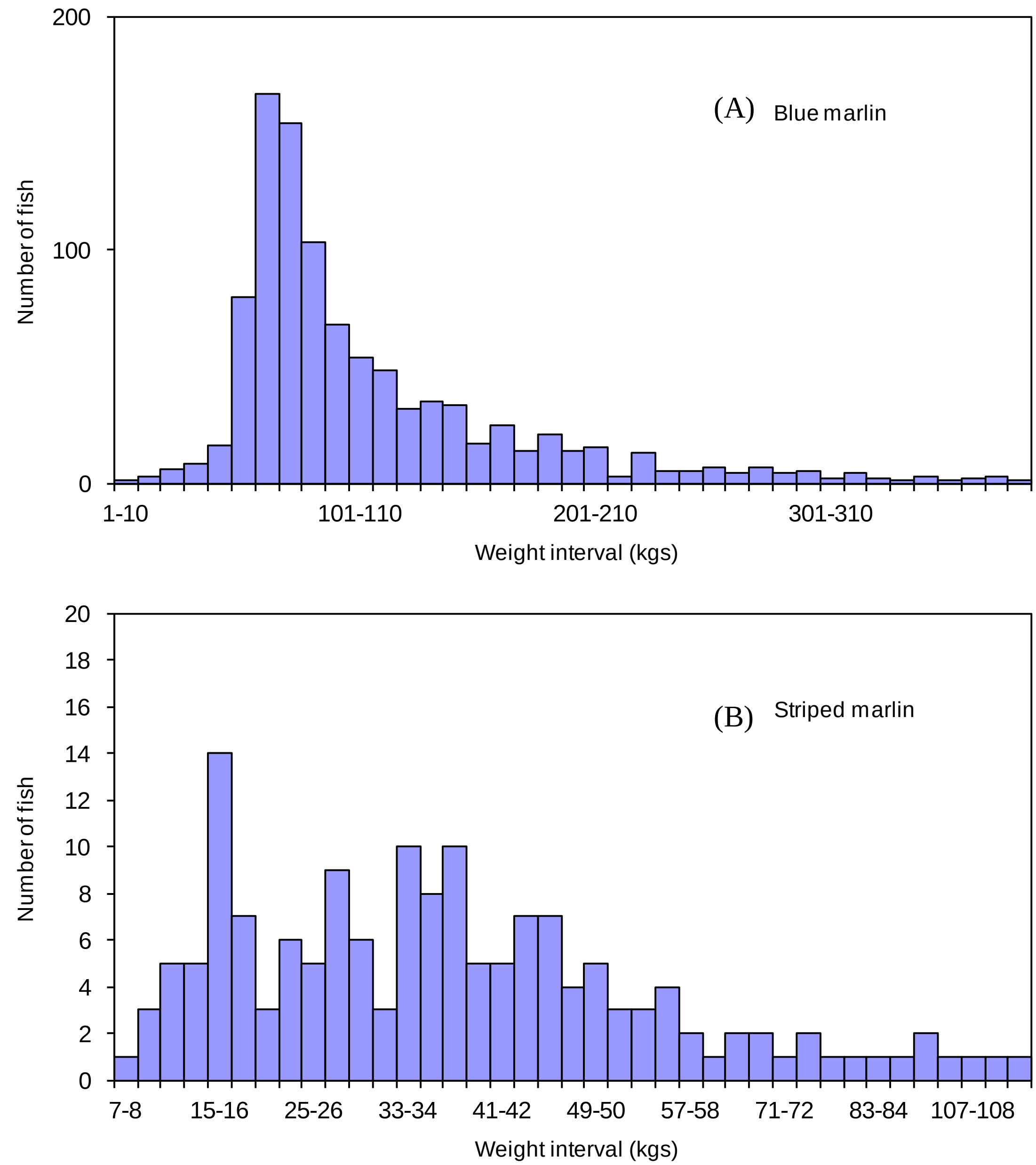


Figure 6. Size distribution of (B) blue marlin (*Makaira nigricans*) and (A) striped marlin (*Tetrapturus audax*) and caught by the Hawaii troll and handline fishery, 2009.

Table 1. Number of vessels fishing in the North Pacific Ocean in various U.S. fisheries. Data for 2008 and 2009 are preliminary[1]

Year	Purse Seine	Longline	Distant-water troll	Pole-and-Line	Troll & Handline	Gill Net	Harpoon
1985	110	36	792	27	na	210	99
1986	85	39	419	19	na	220	113
1987	85	37	486	18	1,899	210	98
1988	87	50	531	17	1,878	192	83
1989	84	88	338	18	2,002	158	44
1990	85	138	368	12	2,042	146	49
1991	65	141	172	12	2,117	123	32
1992	62	124	602	11	2,160	113	48
1993	62	122	608	13	2,132	105	44
1994	62	127	721	11	2,210	112	49
1995	55	116	471	11	2,387	127	39
1996	40	114	676	9	2,411	100	30
1997	38	117	1,172	9	2,400	104	31
1998	37	122	841	9	2,370	87	26
1999	25	140	776	9	2,502	78	30
2000	27	130	645	7	2,229	77	26
2001	29	125	860	9	2,208	64	23
2002	27	123	644	13	2,045	45	29
2003	29	128	729	14	1,960	37	34
2004	19	126	695	11	2,012	33	29
2005	23	126	541	10	1,917	37	24
2006	12	128	601	11	1,924	45	24
2007	18	130	628	59	1,888	49	28
2008	33	130	523	44	2,076	41	31
2009	41	128	652	47	2,178	35	26

[1] Estimations of west coast vessels targeting ISC species is currently under revision.

Table 2. U.S. catches (metric tons) of tunas and tuna-like species (FAO codes) by fishery in the North Pacific Ocean, north of the equator. Data for 2008 and 2009 are preliminary. Dashes indicate missing data. Species codes: ALB = albacore, YFT = yellowfin tuna, SKJ = skipjack tuna, BET = bigeye tuna, PBF = Pacific bluefin tuna, BKJ = black skipjack, BEP = bonito, SWO = swordfish, BUM = blue marlin, MLS = striped marlin.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	BKJ	BEP	SWO	BUM	MLS	UNSPEC. BILLFISH	UNSPEC. TUNA	TOTAL
Eastern Pacific Ocean Purse Seine													
1985	26	81809	9,607	1,751	3,320	0	3,360	32	0	0	0	0	99,905
1986	47	87908	12,874	264	4,851	5	171	87	0	0	0	132	106,339
1987	1	94600	13,449	222	861	1	3,093	2	0	0	0	56	112,285
1988	17	79883	35,741	249	923	34	3,416	4	0	0	0	9	120,276
1989	1	71569	20,508	167	1,046	85	795	6	0	0	0	70	94,247
1990	71	49850	12,944	205	1,380	260	3,687	0	0	0	0	39	68,436
1991	0	17943	12,595	48	410	2	218	2	0	0	0	7	31,225
1992	0	13830	11,504	2,448	1,928	2	770	13	0	0	0	0	30,495
1993		7108	9,029	1,681	580		186	17	0	0	0	0	18,601
1994		2559	2,834	2,231	906	30	75	0	0	0	0	8	8,643
1995		1976	5,471	4,305	657	9	20	0	0	0	0	0	12,438
1996	11	4319	7,467	5,209	4,639	39	202	0	0	0	0	0	21,886
1997	2	2788	6,549	3,977	2,240		115	2	0	0	0	7	15,680
1998	33	1263	3,139	2,416	1,771	34	418	1	0	0	0	0	9,075
1999	48	2591	10,280	2,284	184	62	18	0	0	0	0	0	15,467
2000	4	574	1,881	454	693		32	0	0	0	0	0	3,638
2001	51	1015	904	684	292	13	0	0	0	0	0	0	2,959
2002	4	1472	586	454	50	37	0	1	0	0	0	0	2,604
2003	44	394	3,524	1,209	22	70	0	0	0	0	0	0	5,263
2004	1	665	1,346	986	0	78	0	0	0	0	0	0	3,076
2005	0	93	277	403	201	0	0	0	0	0	0	0	974
2006	0	542	1,915	1,448	0	0	0	0	0	0	0	0	3,905
2007	0	396	537	261	42	0	0	0	0	0	0	0	1,236
2008	0	61	3	0	0	0	603	0	0	0	0	0	667
2009	39	15	4	0	410	0	2,132	0	0	0	0	0	2,600
Central-Western Pacific Purse Seine													
1985	0	10,814	38,027	0	0	0	0	0	0	0	0	0	48,841
1986	0	14,828	39,943	0	0	0	0	0	0	0	0	0	54,770
1987	0	28,444	35,218	0	0	0	0	0	0	0	0	0	63,662
1988	0	8,419	42,509	871	0	0	0	0	0	0	0	0	51,799
1989	0	6,175	15,163	349	0	0	0	0	0	0	0	0	21,687
1990	0	13,872	40,269	469	0	0	0	0	0	0	0	0	54,610
1991	0	8,846	37,512	367	0	0	0	0	0	0	0	0	46,725
1992	0	15,838	62,730	1,261	0	0	0	0	0	0	0	0	79,829
1993	0	16,697	51,456	1,354	0	0	0	0	0	0	0	0	69,507
1994	0	7,957	27,349	241	0	0	0	0	0	0	0	0	35,548
1995	0	14,958	54,565	1,498	0	0	0	0	0	0	0	0	71,021
1996	0	2,334	13,179	1,675	0	0	0	0	0	0	0	0	17,189
1997	0	18,078	30,976	4,725	0	0	0	0	0	0	0	0	53,779
1998	0	19,568	22,119	1,229	0	0	0	0	0	0	0	0	42,916
1999	0	2,398	8,430	952	0	0	0	0	0	0	0	0	11,781
2000	0	1,096	3,627	0	0	0	0	0	0	0	0	0	4,723
2001	0	4,347	16,890	438	0	0	0	0	0	0	0	0	21,675
2002	0	5,140	3,416	126	0	0	0	0	0	0	0	0	8,682
2003	0	3,168	17,688	2,319	0	0	0	0	0	0	0	0	23,176
2004	0	3,145	5,514	451	0	0	0	0	0	0	0	0	9,110
2005	0	6,699	18,894	3,589	0	0	0	0	0	0	0	0	29,183
2006	0	570	3,160	44	0	0	0	0	0	0	0	0	3,773
2007	0	2,329	10,508	294	0	0	0	0	0	0	0	0	13,131
2008	0	3,633	14,375	512	0	0	0	0	0	0	0	0	18,520
2009	0	3,538	39,099	835	0	0	0	0	0	0	0	0	43,472

Table 2. Continued.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	BKJ	BEP	SWO	BUM	MLS	UNSPEC. BILLFISH	UNSPEC. TUNA	TOTAL
Pole and Line (Eastern Pacific Ocean)													
1985	1,498	369	475	0	3	0	0	68	0	0	0	0	2,413
1986	432	440	426	0	1	0	0	9	0	0	0	1	1,309
1987	158	1783	577	0	0	0	1	22	0	0	0	0	2,541
1988	598	1064	1,741	5	5	0	26	40	0	0	0	0	3,479
1989	54	1308	1,123	0	9	0	1	26	0	0	0	3	2,524
1990	115	136	66	0	61	0	0	21	0	0	0	2	401
1991	0	922	887	0	0	0	0	22	0	0	0	0	1,831
1992	0	1912	981	0	2	0	0	33	0	0	0	2	2,930
1993	0	2631	1,888	0	5	0	0	139	0	0	0	5	4,668
1994	0	1835	1,908	0	1	0	187	19	0	0	0	18	3,968
1995	80	379	1,823	0	1	0	0	21	0	0	0	0	2,304
1996	24	695	496	0	0	0	0	9	0	0	0	1	1,225
1997	73	468	874	0	1	0	0	1	0	0	0	0	1,417
1998	79	2205	685	0	4	0	6	5	0	0	0	0	2,984
1999	60	47	15	4	2	0	0	17	0	0	0	0	145
2000	72	2	0	1	12	0	0	24	0	0	0	0	111
2001	139	2	0	0	1	0	0	14	0	0	0	0	156
2002	382	0	0	0	2	0	0	0	0	0	0	2	386
2003	59	2	1	0	3	0	1	1	0	0	0	0	67
2004	127	1	0	0	0	0	1	37	0	0	0	0	166
2005	66	0	0	0	0	0	0	0	0	0	0	0	66
2006	23	1	0	0	0	0	0	0	0	0	0	0	24
2007	21	0	0	0	0	0	0	0	0	0	0	0	21
2008	1,050	2	0	0	0	0	1	1	0	0	0	1	1,055
2009	2,084	1	0	0	0	0	0	0	0	0	0	0	2,085
Pole-and-Line (Hawaii)													
1985	0	103	853	0	0	0	0	0	0	0	0	0	956
1986	0	114	941	0	0	0	0	0	0	0	0	0	1,055
1987	0	78	1,510	0	0	0	0	0	0	0	0	0	1,588
1988	0	76	1,709	0	0	0	0	0	0	0	0	0	1,785
1989	0	10	1,333	0	0	0	0	0	0	0	0	0	1,343
1990	0	18	487	0	0	0	0	0	0	0	0	0	505
1991	0	20	953	0	0	0	0	0	0	0	0	0	973
1992	0	16	763	0	0	0	0	0	0	0	0	0	779
1993	0	5	962	0	0	0	0	0	0	0	0	0	967
1994	0	9	514	0	0	0	0	0	0	0	0	0	523
1995	0	15	570	0	0	0	0	0	0	0	0	0	585
1996	0	1	835	0	0	0	0	0	0	0	0	0	836
1997	0	0	881	0	0	0	0	0	0	0	0	0	881
1998	0	1	382	0	0	0	0	0	0	0	0	0	383
1999	0	10	586	0	0	0	0	0	0	0	0	0	596
2000	0	1	320	0	0	0	0	0	0	0	0	0	321
2001	0	2	448	0	0	0	0	0	0	0	0	0	450
2002	0	2	420	0	0	0	0	0	0	0	0	0	422
2003	0	33	586	0	0	0	0	0	0	0	0	4	623
2004	0	17	279	0	0	0	0	0	0	0	1	0	297
2005	0	68	353	0	0	0	0	0	0	0	0	1	422
2006	0	3	294	0	0	0	0	0	0	0	0	3	300
2007	0	23	272	0	0	0	0	0	0	0	0	1	296
2008	0	23	293	0	0	0	0	0	0	0	0	4	320
2009	0	17	214	0	0	0	0	0	0	0	0	1	232

Table 2. Continued.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	BKJ	BEP	SWO	BUM	MLS	UNSPEC. BILLFISH	UNSPEC. TUNA	TOTAL
Distant-water Troll:													
1985	6,415	5	0	0	0	0	0	0	0	0	0	0	6,420
1986	4,708	1	0	0	0	0	0	0	0	0	0	0	4,709
1987	2,766	76	0	0	0	0	33	0	0	0	0	0	2,875
1988	4,212	7	0	0	0	0	0	2	0	0	0	0	4,221
1989	1,860	1	0	0	0	0	0	0	0	0	0	0	1,861
1990	2,603	0	0	0	0	0	55	0	0	0	0	0	2,658
1991	1,845	0	0	0	0	0	0	0	0	0	0	0	1,845
1992	4,572	0	0	0	0	0	0	0	0	0	0	0	4,572
1993	6,254	137	62	0	0	0	0	1	0	0	0	1	6,455
1994	10,978	769	352	0	0	0	0	0	0	0	0	0	12,099
1995	8,045	211	1,157	0	0	0	0	1	0	0	0	0	9,414
1996	16,938	606	393	0	2	0	0	1	0	0	0	0	17,940
1997	14,252	4	2	0	1	0	0	1	0	0	0	0	14,260
1998	14,410	1,246	2	0	128	0	10	6	0	0	0	0	15,802
1999	10,060	52	16	0	20	0	0	1	0	0	0	0	10,149
2000	9,645	3	4	0	1	0	0	8	0	0	0	1	9,662
2001	11,210	1	1	0	6	0	0	0	0	0	0	0	11,218
2002	10,387	0	0	0	1	0	0	2	0	0	0	0	10,390
2003	14,102	0	2	0	0	0	0	0	0	0	0	0	14,104
2004	13,346	1	0	0	0	0	0	0	0	0	0	0	13,347
2005	8,413	0	0	0	0	0	0	0	0	0	0	0	8,413
2006	12,524	0	0	0	0	0	0	0	0	0	0	0	12,524
2007	11,887	0	0	0	0	0	0	0	0	0	0	0	11,887
2008	10,672	0	0	0	0	0	0	0	0	0	0	0	10,672
2009	10,686	0	0	0	0	0	0	0	0	0	0	0	10,686
Longline:													
1985	0	0	0	0	0	0	0	2	0	0	0	0	2
1986	0	0	0	0	0	0	0	2	0	0	0	0	2
1987	150	261	1	815	0	0	0	24	51	272	45	0	1,619
1988	307	594	4	1,239	0	0	0	24	102	503	68	0	2,842
1989	248	986	10	1,442	0	0	0	281	356	612	132	0	4,067
1990	177	1,098	5	1,514	0	0	0	2,437	378	538	58	0	6,205
1991	312	733	30	1,555	2	0	0	4,535	297	663	69	0	8,196
1992	334	346	22	1,486	38	0	0	5,762	347	459	142	0	8,936
1993	438	633	36	2,124	42	0	0	5,936	339	471	100	0	10,120
1994	544	610	53	1,827	30	0	0	3,807	362	326	99	5	7,663
1995	882	984	101	2,099	29	0	1	2,981	570	543	182	0	8,372
1996	1,185	634	41	1,846	25	0	0	2,848	467	419	115	2	7,581
1997	1,653	1,143	106	2,526	26	0	0	3,393	487	352	143	2	9,830
1998	1,120	724	76	3,274	54	0	0	3,681	395	378	172	9	9,883
1999	1,542	477	99	2,820	54	0	0	4,329	357	364	242	10	10,294
2000	940	1,137	93	2,708	19	0	0	4,834	314	200	152	0	10,397
2001	1,295	1,029	211	2,418	6	0	0	1,969	399	352	136	0	7,815
2002	525	572	127	4,396	2	0	0	1,524	264	226	160	0	7,796
2003	524	809	207	3,618	1	0	0	1,958	363	538	248	0	8,266
2004	360	715	142	4,339	1	0	0	1,185	283	376	200	9	7,610
2005	296	712	91	4,999	1	0	0	1,622	337	511	215	0	8,784
2006	270	958	94	4,466	1	0	0	1,211	409	611	174	0	8,194
2007	250	844	93	5,798	0	0	0	1,735	262	276	160	0	9,418
2008	353	869	121	5,927	0	0	0	1,980	348	426	239	0	10,263
2009	203	495	136	4,546	1	0	0	1,788	362	259	124	0	7,914

Table 2. Continued.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	BKJ	BEP	SWO	BUM	MLS	UNSPEC. BILLFISH	UNSPEC. TUNA	TOTAL
Longline (Hawaii)													
1985								2					
1986								2					
1987	150	261	1	815	0	0	0	24	51	272	45	0	1,619
1988	307	594	4	1,239	0	0	0	24	102	503	68	0	2,841
1989	248	986	10	1,442	0	0	0	281	356	612	132	0	4,067
1990	177	1,098	5	1,514	0	0	0	2,437	378	538	58	0	6,205
1991	312	733	30	1,553	2	0	0	4,508	297	663	69	0	8,167
1992	333	346	22	1,486	38	0	0	5,700	347	459	142	0	8,873
1993	438	631	36	2,121	42	0	0	5,909	339	471	100	0	10,087
1994	497	606	53	1,787	24	0	0	3,176	362	326	99	0	6,930
1995	879	979	101	2,051	25	0	0	2,713	570	543	182	0	8,043
1996	1,182	630	41	1,787	22	0	0	2,502	467	419	115	0	7,165
1997	1,645	1,141	106	2,449	24	0	0	2,881	487	352	143	0	9,228
1998	1,111	722	76	3,226	16	0	0	3,263	395	378	172	0	9,359
1999	1,474	473	99	2,719	10	0	0	3,100	357	364	242	0	8,838
2000	919	1,137	93	2,625	4	0	0	2,949	314	200	152	0	8,393
2001	1,271	1,013	211	2,366	1	0	0	220	399	352	136	0	5,969
2002	524	570	127	4,386	1	0	0	204	264	226	160	0	6,462
2003	522	809	207	3,589	0	0	0	147	363	538	248	0	6,423
2004	358	715	142	4,317	1	0	0	287	283	376	200	0	6,679
2005	296	712	91	4,999	1	0	0	1,622	337	511	215	0	8,784
2006	270	958	94	4,466	1	0	0	1,211	409	611	174	0	8,194
2007	250	844	93	5,798	0	0	0	1,735	262	276	160	0	9,418
2008	353	869	121	5,927	0	0	0	1,980	348	426	239	0	10,263
2009	203	495	136	4,546	1	0	0	1788	362	259	124	0	7,914
Gill Net													
1985	2	12	0	2	7	0	289	2,990	0	0	0	0	3,302
1986	3	14	0	3	16	0	58	2,069	0	0	0	4	2,167
1987	5	3	0	6	2	0	95	1,529	0	0	0	5	1,645
1988	15	7	0	5	4	0	33	1,376	0	0	0	2	1,442
1989	4	1	5	0	3	0	12	1,243	0	0	0	3	1,271
1990	29	1	1	1	11	0	35	1,131	0	0	0	2	1,211
1991	17	1	3	3	4	0	14	944	0	0	0	3	989
1992	0	4	1	1	8	0	7	1,356	0	0	0	6	1,383
1993	0	7	2	0	33	0	8	1,412	0	0	0	9	1,471
1994	38	0	0	0	28	0	1	792	0	0	0	2	861
1995	52	2	70	1	19	0	2	771	0	0	0	1	918
1996	83	2	2	0	43	0	2	761	0	0	0	0	893
1997	60	3	2	5	57	0	6	708	0	0	0	0	841
1998	80	2	3	4	40	0	4	931	0	0	0	2	1,066
1999	149	0	0	2	21	0	1	606	0	0	0	1	780
2000	55	1	0	2	30	0	1	649	0	0	0	0	738
2001	94	5	1	0	33	0	0	375	0	0	0	0	508
2002	30	1	0	0	6	0	1	302	0	0	0	0	340
2003	16	0	9	6	14	0	1	216	0	0	0	0	262
2004	12	1	0	0	10	0	2	182	0	0	0	0	207
2005	20	2	0	0	5	0	0	220	0	0	0	0	247
2006	3	1	2	0	1	0	0	443	0	0	0	1	451
2007	4	0	0	0	2	0	0	478	0	0	0	0	484
2008	1	0	0	0	1	0	4	405	0	0	0	1	412
2009	3	1	0	0	4	0	1	249	0	0	0	0	258

Table 2. Continued.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	BKJ	BEP	SWO	BUM	MLS	UNSPEC. BILLFISH	UNSPEC. TUNA	TOTAL
Harpoon													
1985	0	0	0	0	0	0	0	305	0	0	0	0	305
1986	0	0	0	0	0	0	0	291	0	0	0	0	291
1987	0	0	0	0	0	0	0	235	0	0	0	0	235
1988	0	0	0	0	0	0	0	198	0	0	0	0	198
1989	0	0	0	0	0	0	0	62	0	0	0	0	62
1990	0	0	0	0	0	0	0	64	0	0	0	0	64
1991	0	0	0	0	0	0	0	20	0	0	0	0	20
1992	0	0	0	0	0	0	0	75	0	0	0	0	75
1993	0	0	0	0	0	0	0	168	0	0	0	0	168
1994	0	0	0	0	0	0	0	157	0	0	0	0	157
1995	0	0	0	0	0	0	0	97	0	0	0	0	97
1996	0	0	0	0	0	0	0	81	0	0	0	0	81
1997	0	0	0	0	0	0	0	84	0	0	0	0	84
1998	0	0	0	0	0	0	0	48	0	0	0	0	48
1999	0	0	0	0	0	0	0	81	0	0	0	0	81
2000	0	0	0	0	0	0	0	90	0	0	0	0	90
2001	0	0	0	0	0	0	0	52	0	0	0	0	52
2002	0	0	0	0	0	0	0	90	0	0	0	0	90
2003	0	0	0	0	0	0	0	107	0	0	0	0	107
2004	0	0	0	0	0	0	0	69	0	0	0	0	69
2005	0	0	0	0	0	0	0	77	0	0	0	0	77
2006	0	0	0	0	0	0	0	71	0	0	0	0	71
2007	0	0	0	0	0	0	0	59	0	0	0	0	59
2008	0	0	0	0	0	0	0	48	0	0	0	0	48
2009	0	0	0	0	0	0	0	48	0	0	0	0	48
Unclassified,other and recreational													
1985	1,176	58	5	1	107	0	426	100	0	42	0	468	2,383
1986	196	227	0	6	52	0	28	105	0	19	0	6	639
1987	74	2,159	633	1	52	0	266	27	0	28	0	67	3,307
1988	74	936	372	1	48	0	335	58	0	30	0	2	1,856
1989	183	849	103	0	121	0	137	49	0	52	0	0	1,494
1990	28	508	147	0	85	0	227	38	0	23	0	1	1,057
1991	77	235	137	0	92	0	69	38	0	12	0	0	660
1992	74	1,119	1,014	0	123	0	78	46	0	25	0	2	2,481
1993	25	2,031	2,279	0	322	0	140	157	0	11	0	0	4,965
1994	319	3	0	0	89	0	12	20	0	17	0	0	460
1995	103	5	263	0	258	0	0	23	0	14	0	0	666
1996	88	0	0	4	40	0	0	10	0	20	0	0	162
1997	1,019	0	83	0	203	0	0	4	0	21	0	0	1,330
1998	1,210	43	0	0	467	0	0	12	0	23	0	1	1,756
1999	3,622	0	0	0	528	0	0	18	0	12	0	0	4,180
2000	1,801	1	0	0	342	0	0	33	0	10	0	0	2,186
2001	1,635	0	0	0	356	0	0	19	0	0	0	0	2,010
2002	2,357	27	1	0	654	0	0	3	1	0	0	1	3,044
2003	2,214	8	2	3	394	0	0	1	0	0	0	0	2,622
2004	1,506	27	2	132	49	0	0	37	5	0	0	0	1,758
2005	1,719	0	0	0	79	0	2	0	0	0	0	0	1,800
2006	385	349	12	0	102	0	0	1	0	0	0	0	849
2007	1225	0	0	0	15	0	0	12	0	0	0	0	1252
2008	257	0	0	0	102	0	16	1	0	0	0	0	376
2009	541	0	0	0	151	0	0	2	0	0	0	0	694

Table 2. Continued.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	BKJ	BEP	SWO	BUM	MLS	UNSPEC. BILLFISH	UNSPEC. TUNA	TOTAL
Hawaii, Guam, & CNMI Troll and Handline													
1985	7	967	101	8	0	0	0	4	145	18	12	2	1,264
1986	5	1493	120	5	0	0	0	4	220	19	14	4	1,884
1987	6	1616	137	8	0	0	0	4	261	31	20	11	2,094
1988	9	941	172	17	0	0	0	6	266	54	20	11	1,496
1989	36	828	153	14	0	0	0	7	326	24	23	11	1,422
1990	15	891	138	25	0	0	0	5	295	27	17	11	1,424
1991	72	802	237	25	0	0	0	6	346	41	25	9	1,563
1992	54	602	167	13	0	0	0	1	260	39	17	10	1,163
1993	71	861	157	3	0	0	0	4	311	69	20	6	1,502
1994	90	870	138	7	0	0	0	4	298	35	22	8	1,472
1995	177	978	152	20	0	0	0	6	315	52	29	7	1,736
1996	188	934	224	7	0	0	0	5	409	55	18	5	1,845
1997	133	770	196	26	0	0	0	7	378	39	17	4	1,570
1998	88	766	143	9	0	0	0	7	242	26	19	6	1,306
1999	331	1019	181	24	0	0	0	9	293	29	33	4	1,923
2000	120	1080	415	207	0	0	0	0	235	14	20	15	2,106
2001	194	878	523	226	0	0	0	0	291	42	32	13	2,199
2002	235	632	355	586	0	0	0	0	225	29	13	6	2,081
2003	85	738	277	213	0	0	0	10	211	29	18	25	1,606
2004	157	749	260	381	0	0	0	7	188	35	23	45	1,845
2005	175	682	264	295	0	0	0	5	187	20	15	14	1,657
2006	95	508	296	303	0	0	0	4	160	21	14	12	1,413
2007	98	759	272	386	0	0	0	5	128	13	12	9	1682
2008	29	680	384	222	0	0	0	6	181	14	13	8	1537
2009	99	783	357	206	0	0	0	0	180	11	9	16	1661

[1] California catches have been combined with Hawaii catches for those years where less than 3 vessels participated in the California longline fishery.