ISC/07/PLENARY/06

7th Meeting of the ISC
July 25-30, 2007
Busan, Korea

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

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July 2007

[1]Prepared for the Seventh Meeting of the International Scientific Committee on Tuna and Tuna-like Species in the North Pacific Ocean (ISC), July *25-30,* 2007, Busan, South Korea. Document should not be cited without permission of the authors.

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Introduction

Various U.S. fisheries harvest tuna and tuna-like species in the North Pacific. Large-scale purse seine, albacore troll, and longline fisheries operate both in coastal waters and on the high seas. Small-scale gill net, harpoon, and pole-and-line fisheries and commercial and recreational troll and handline fisheries usually operate in coastal waters. Overall, the range of U.S. fisheries in the Pacific is extensive, from coastal waters of North America to Guam and the Commonwealth of the Northern Mariana Islands (CNMI) in the western Pacific 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 Marine Fisheries Service (NMFS) 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 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. NMFS fishery monitoring activities include collection of landings and sales records at markets and ports, 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. State agencies are also mandated to collect logbook data and have also collected size composition data. In the central and western Pacific, 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[1]. The management of data on U.S. Pacific fisheries for tuna and tuna-like species is coordinated between the SWFSC, SWRO, PIFSC, and PIRO. Data catalogs, metadata, data summaries, reports, and related information are being assembled as part of a Web-based portal hosted at the SWFSC (still under construction).

[1] http://www/pifsc.noaa.gov/wpacfin/

This report provides information on the number of active vessels by fleet and their catches of tunas and billfishes in the North Pacific based on the data available through 2006. Data for 2006, however, are considered preliminary and are subject to change. Although the report is focused on tunas and billfishes, many of the fisheries described catch other pelagic fishes important to the fishing fleets and local economies; catch data for these species are not included. For the first time, discard information has been supplied for 2005 and 2006 for two major fisheries.

NMFS 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 at the PIFSC and SWFSC of relevance to the ISC.

Fisheries

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 (ETP). The ETP purse seine fishery started in the mid 1900s and dominated the catch until 1993 when vessels moved to the WCPO in response to dolphin conservation measures in the ETP. 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 (Figure 1, plot does not show the ETP fishery as only one vessel fished and these data are confidential). 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 8 in 2006 (Table 1). Before 1995 the fleet fished mainly on free-swimming schools of tunas in the WCPO and on schools associated with dolphins in the ETP. During the last 5 years, fishing in both areas has been about equally distributed between free-swimming schools and schools associated with floating objects.

U.S. catches of tunas north of the Equator are shown in Table 2. Catches in the North Pacific, over the past five years (some of the northern bluefin tuna catch is south of the equator and have been included due to stock considerations), are primarily skipjack tuna (63%) with lesser quantities of yellowfin tuna (25%) and bigeye tuna (12%). Skipjack tuna catches peaked in 1988 at 78,250t (metric tons) then generally decreased to 3,918 t in 2006. Yellowfin tuna catches decreased from a high of 123,044 t in 1987 to a low of 768 t in 2006.

Discards of target and non-target species by the U.S. purse seine fleet in the WCPO fishery have been reported by vessels captains in the Regional Purse Seine Logbooks. These estimates are for the entire fishery that operates north and south of the Equator (Table 3).

U.S. purse seine vessels fishing in the WCPO have been monitored by NMFS 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 measured for fork length by PIRO personnel as vessels land their catches in American Samoa (coverage approximately 1-2% of landings (Figure 2). Species composition samples are also taken and used to separate yellowfin tuna from bigeye tuna in the reported landings. The Forum Fisheries Agency (Treaty manager) places observers on approximately 20% of the vessel trips.

The IATTC monitors U.S. purse seine vessels fishing in the EPO. Logbooks (coverage 100%) are submitted by vessel operators, and landings (coverage 100%) are obtained from each vessel or from canneries or fish buyers. Fish are measured for fork length by port samplers (coverage unknown but probably less than 2% of the fish landed). IATTC observers are placed on all large purse seine vessels.

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 areas freely until 2000 when domestic regulations placed restrictions on moving between the two domestic management areas. The Hawaii-based component of the U.S. longline fishery comprises a majority of the vessels, fishing effort, and catch. Regulatory restrictions, due to interactions with endangered sea turtles, curtailed swordfish-directed effort in 2000 and 2001. Swordfish targeting was prohibited 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 which the Hawaii-based longline fishery was allowed to resume targeting swordfish. In the following year, the shallow-set longline fishery reached the annual interaction limit of 17 loggerhead sea turtles and was closed March 20, 2006. The vessels that targeted swordfish converted to deep-set longline and targeted tunas for the remainder of the year.

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 active in the California longline fishery in 2005 and 2006.

The longline fishery extends from the outer boundary of the U.S. West Coast 200 mile EEZ to 175° W longitude and from the Equator to 35° N latitude in 2006 (Figure 3). 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 decreased to 128 in 2006. In Hawaii and California, swordfish are generally landed as trunks (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 (Figure 4).

Catch levels and catch species composition in the U.S. longline fishery changed considerably over the past years in response to fishery and regulatory changes. The majority of the catch is of tunas and billfishes and rose to over 10,000 t in 1993, 1999 and 2000 (Table 2). Bigeye tuna dominates the tuna catch with landings over 4,000 t in four of the past five years. The 2006 bigeye tuna catch was 4,447 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 U.S. longline swordfish catch was 1,194 t in 2006.

Estimated total numbers of fishery interactions with non-fish species (all of which are non-target, associated, or dependent species) by vessels in the Hawaii-based longline fishery in 2005 and 2006 are shown in Table 4. These interactions were derived from observer data by raising the number of observed interactions by a factor determined according to the design of the observer sampling program. The interactions do not necessarily result in mortalities.

The Hawaii-based longline fishery is monitored by the PIFSC 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 includes information on effort, area fished, catch, and other details of operation. PIFSC collects the logbook data at the docks. Logbook coverage for the Hawaii-based longline fishery is estimated at 100%. DAR also requires fish dealers to submit landings data and coverage is very close to 100%. Observers contracted by PIRO are placed on longline vessels to monitor protected species interactions, vessel operations, and catches. 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.

California-based longline fishery is monitored by the SWFSC and the California Department of Fish and Game (CDFG). Longline landings are collected from 100% of the fleet by the CDFG Landings Ticket system. Logbooks, developed by the fishing industry (similar to the federal logbooks used in Hawaii), were submitted voluntarily to NMFS until 1994. From 1995 to 1999, CDFG collected logbooks from 100% of the fleet, and SWFSC has continued this collection since 1999. Landed swordfish were measured for cleithrum length by CDFG port samplers until 1999. NMFS's Southwest Regional Office currently places observers on California-based longline vessels. The observers also collect data on protected species interactions, fish catch and measure fish sizes in the catch.

Distant-waterTroll

The U.S. distant-water troll fishery for albacore in the North Pacific Ocean started in the early 1900's. The fishery operates in waters between the U.S. west coast and 160° E longitude (Figure 5). 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 1,172 in 1997 (Table 1). In 2005, 541 vessels participated in the fishery and a preliminary estimate of 604 vessels fished in 2006.

The troll fishery catches mainly albacore with incidental catches of skipjack, yellowfin and bluefin tunas, eastern Pacific bonito, yellowtail, and mahimahi. Since 1985, the albacore catch has ranged between 1,845 t in 1991 and 16,938 t in 1996 (Table 2). In 2005, 8,413 t were caught the preliminary estimate of the 2006 catch is 12,590 t. Sampled albacore caught in 2006 ranged in fork length between 52 and 87 cm and averaged 67 cm (Figure 6).

U.S. troll vessels voluntarily submitted logbook records to the SWFSC 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 (HMSFMP). Logbook coverage rate in 2006 is approximately 66% of the landings. Landings are monitored by SWFSC and various state fisheries agencies through landing receipts and coverage is 100% of the fleet. Landings are also measured for fork length by state agency port samplers along the U.S. west coast and by PIRO personnel in American Samoa. Coverage rate in 2006 is approximately 2% of the landings.

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 to areas off Central America and South America. The vessels usually target yellowfin tuna and skipjack tuna or albacore. The number of pole-and-line vessels operating north of the equator decreased from 27 in 1985 to 7 in 2000 with 12 vessels active in 2006 (Table 1). Skipjack tuna was usually the largest component of the catch. The highest skipjack tuna catch 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. Pole-and-line catches of skipjack and yellowfin tunas were 280 t and 5 t respectively in 2006.

For the west coast pole-and-line fishery, logbook data are collected by the IATTC and SWFSC. Logbook submissions since 2005 are mandatory under the HMSFMP. Fork-length data for yellowfin and skipjack tunas are collected by the IATTC. Albacore fork-length data are collected by the SWFSC 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.

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. 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 1,937 in 2001 to 2,166 in 1996 with 2,001 vessels in 2006. 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 (Figure 7).

The total catch from these troll and handline fisheries ranged from 1,163 t in 1992 to 2,199 t in 2001. Troll and handline catch was 1,241 t in 2006. Yellowfin tuna made up 37% of the troll and handline catch. The next largest components were skipjack tuna, bigeye tuna and blue marlin. The Hawaii troll and handline fisheries accounted for 81% of the total U.S. troll and handline landings in 2006.

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 PIFSC, 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.

Gill Net

The drift gill net fishery operates mainly in areas within the 200 mile EEZ of California and sometimes off Oregon (Figure 8). 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 220 in 1986 to 33 in 2004 and increased to 45 in 2006 (Table 1). Swordfish, mako sharks and thresher sharks are usually targeted. Swordfish catches were 2,990 t in 1985and have fluctuated while decreasing to182 t in 2004 and rebounding slightly to 442 t in 2006 (Table 2).

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. Less than 1% of the landings were sampled. NMFS places observers on gill net vessels and also collects length data.

Harpoon

The harpoon fishery operates in areas within the 200-mile EEZ of California between 32°N and 34°N latitude (Figure 9). The number of vessels participating in the fishery decreased from 113 in 1986 to 21 in 2005 and 2006 (Table 1). Swordfish is targeted and catches decreased from 305 t in 1985 to 20 t in 1991 (Table 1). The 2006 estimated swordfish catch is 71 t.

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.

Research

U.S. government research on tunas and tuna-like species of the North Pacific Ocean is shared between the SWFSC and PIFSC. Studies are largely carried out from laboratories in La Jolla, California for the SWFSC and in Honolulu, Hawaii for the PIFSC, and in collaboration with scientists of other government or university institutions, both in the U.S. and abroad. Both Centers have studies devoted to stock assessment, biological and oceanographic research, and fishery management issues, but each Center does concentrate on different species and fisheries in order to minimize duplication. In this section, selected studies that are underway are described and recent results are provided.

Southwest Fisheries Science Center (SWFSC)

The Southwest Fisheries Science Center has a long history of research on stocks and fisheries for highly migratory species (HMS). During the past few years, the SWFSC has focused increased resources on research of North Pacific HMS in order to address growing concerns about resource status and sustainability. Studies described in the following section are primarily designed to address the growing concerns and are guided by NMFS strategic plan objectives of promoting resource stewardship and building sustainable fisheries.

Stock Assessment Studies – The SWFSC investment in stock assessment research is founded on delivering accurate information on stock status and subsequently, for providing meaningful advice to fishery managers. During the past year, SWFSC scientists have been conducting assessment related research to support the goals of the ISC Albacore, Marlin, and Bluefin Working Groups.

Albacore

Researchers participated in an assessment-based meeting of the ISC Albacore Working Group (ISC-ALBWG), which was held in November-December 2006 in Shimizu, Japan, and was attended by researchers from Japan, Taiwan, and Canada. The meeting primarily focused on assessment-related activities, including: (1) completing a formal assessment based on a backward-simulation Virtual Population Analysis (VPA) model; (2) developing a preliminary forward-simulation Stock Synthesis 2 (SS2) model; (3) continuing discussion regarding appropriate biological reference points for potential management of the stock; (4) research studies needed to improve knowledge of albacore biology; and (5) maintenance and improvement of the ISC Albacore Working Group database catalog, which contains catch, length, and catch and effort information collected from the various international fleets that harvest the stock. Scientists from the SWFSC presented various papers that addressed the meeting topics above. Assessment results indicated the population is currently being harvested at a spawning potential ratio of roughly $F_{17\%}$. Figure 10 presents the spawning stock biomass (historical, current, and projected) time series estimated from the assessment model. Finally, further fishery-related statistics and conclusions concerning the status of the stock generated from the assessment research are presented in the overall meeting report.

Work continues concerning population analysis efforts based on a fully integrated, length-based and age-structured modeling platform (SS2), which in the near future is expected to become the formal model for assessing the status of the albacore stock in the North Pacific Ocean; currently, a robust baseline model configuration has been developed. In this context, an intersessional meeting will be held in spring 2008 that will address two assessment-related topics: (1) refinement of the SS2 model, along with (2) re-evaluation of CPUE indices of abundance utilized in the current assessments of this species, including discussion regarding prioritizing/omitting particular indices, spatial/temporal characteristics of the indices, ageaggregated vs. age-specific time series, etc. Finally, the next formal assessment-related meeting of the ISC-ALBWG is scheduled for late 2008.

Marlin

In 2006, marlin assessment research at the SWFSC focused on meeting the ISC Marlin Working Group (ISC-MARWG) goal of completing a North Pacific striped marlin assessment in 2007. The SWFSC scientists participated in an ISC-MARWG meeting held in Shimizu, Japan. That initial meeting was held to prepare data for an assessment that should be completed in March 2007 at a meeting held in Chinese-Taipei. The SWFSC scientists were charged by the working group with producing initial assessment model runs for presentation at the March meeting in Taipei. In addition, SWFSC scientists, in conjunction with international colleagues, will use the initial modeling results to develop the final model configuration at the 2007 meeting. Results of the Working Group's assessment efforts will be presented at the 2007 ISC Plenary meeting.

Bluefin Tuna

In 2006, bluefin tuna assessment research at the SWFSC focused on completing a North Pacific bluefin tuna assessment in 2008. The SWFSC scientists participated in an ISC Bluefin Tuna Working Group (ISC-PBFWG) meeting held in Shimizu, Japan, in 2006, where an initial assessment of bluefin tuna was presented. That assessment of bluefin tuna was conducted using a Virtual Population Analysis, and several areas of uncertainty within the assessment were discovered. The SWFSC scientists are participating with international scientists in the Working Group to improve the reliability of the data and to develop alternative assessment modeling approaches. Results of the Working Group's efforts to improve the stock assessment of bluefin tuna will be presented at the 2007 ISC Plenary meeting.

Biological and Oceanographic Research – The SWFSC conducts research on the biology of a tuna, billfishes and pelagic sharks. Projects range from behavior and movement of North Pacific albacore to food habits of sharks. A few of the projects are described below.

Albacore

Since 1971, the SWFSC has had an ongoing partnership with the West-Coast based U.S. albacore fishing industry. Research is conducted in cooperation with the American Fishermen's Research Foundation (AFRF), a private foundation established by the Western Fishboat Owner's Association to promote research on albacore and related species. Since 2001, SWFSC and AFRF have been conducting an archival tagging project to study migratory patterns, depth and temperature preferences of North Pacific albacore. The original objectives of the long-term study were to deploy 500 archival tags from 2001-06 and recover tags from 50 fish assuming a 10% recovery rate. Through October 2006, 504 archival tags were deployed of which 17 have been recovered. Most fish were at liberty for over a year and have provided over 5,000 days of data and nearly 8 million records of depth, water temperature, and body temperature as well as information on large-scale movement patterns. Fish ranged from the southern tip of Baja to Vancouver Island and from the coast of North America to the central North Pacific. Most fish demonstrated a diurnal pattern of repetitive deep diving (routinely to depths of 250 to 300 meters) during the day while remaining in the upper 50 m at night.

The SWFSC is also collaborating with PIFSC scientists to better define albacore habitat in the north Pacific. Catches recorded in logbook data from the U.S. albacore troll fishery are being examined in relation to satellite derived images of oceanographic features on a fine scale resolution (sea surface temperature, chlorophyll and height).

Billfishes

The SWFSC's Billfish Tagging Program began in 1963 and has provided tagging supplies to recreational billfish anglers for 44 continuous years. Tag release and recapture data are used to determine movement and migration patterns, species distribution, and the age and growth patterns of billfish. This volunteer tagging program depends on the participation and cooperation of recreational anglers, sport fishing organizations, and commercial fishers. Since its inception over 54,000 fish of 75 different species have been tagged and released. Emphasis continues to be on the skillful tagging of billfish and bluefin tuna only. The tagging of other sport fish is not encouraged by this program. Billfish Tagging Report cards received for 2005 indicate that a total of 1,359 billfish and 122 other fish were tagged and released by 1,010 anglers and 173 fishing captains In all, 728 blue marlin, 268 striped marlin, 164 sailfish, 184 spearfish, 9 black marlin and 5 unknown billfish were reported tagged and released.

In 2002, National Marine Fisheries Service scientists from the SWFSC and SEFSC joined forces with the Presidential Challenge billfish tournament series conducted off the coasts of Central America and Mexico to establish the Adopt-A-Billfish satellite tagging program. During Phase I efforts, 41 satellite archival tags were deployed on sailfish during tournaments in central Mexico, Guatemala, Costa Rica and Panama yielding a wealth of information on the vertical and horizontal movements. In August 2006, the program embarked on Phase II to monitor sailfish in the Sea of Cortez and to study larger animals on their spawning grounds. The first research trip of Phase II was conducted August 8-10, 2006 at East Cape, Baja California Sur, Mexico. Working with two colleagues from Mexican Research Institutes, the NMFS team deployed 4 satellite tags on sailfish and conducted plankton net tows for billfish larvae. Although the sailfish were on the small size, averaging 40 lbs or less, the tags of all 4 fish had reported by 120 days. Predictably, the sailfish moved to the southeast toward warmer water. Plankton samples are being analyzed to determine whether billfish were spawning in the area. Further efforts in the Sea of Cortez are planned for 2007.

The SWFSC continued monitoring recreational billfish catch in the Pacific through the Billfish Angler Survey. Results for recreational fishing in 2005 were compiled in 2006 and published in the 2006 angler survey. In 2005, billfish anglers reported catching 2,471 Pacific billfish during 4,103 fishing days. The mean CPUE for all billfish in the Pacific for 2005 was 0.62, which is lower than the record set in 2003 of 0.87 but similar to the average over the last 6 years (0.62-0.66). This was a new high six-year average catch rate for the entire time series, which extends back to 1969. The lowest value (0.34) was reported for the late 1970s (1975-1979) when billfish stocks were being impacted by large, international, commercial fisheries. CPUE time series were extended for each of the main species caught (Pacific blue marlin, striped marlin, Pacific sailfish, and black marlin) in the main fishing areas (Tahiti, Hawaii, Baja, southern California, Mexico, Guatemala, Costa Rica, Panama, and Australia).

Starting in 2006 SWFCS initiated studies on the movements and behaviors of swordfish in the Southern California Bight. Swordfish are the primary target species of the local drift gillnet fishery and a summer harpoon fishery and movements, behaviors, and stock structure are all poorly understood. Two of the primary objectives of this study are to examine the vertical and geographic movements of swordfish and determine the impact of oceanography on their distribution and behavior. This study is being conducted using pop-up satellite tags deployed in collaboration with the California harpoon fleet. Efforts over the last year have focused primarily on data analysis. Results to date indicate distinct shifts in vertical movements with location. For example, in fish that moved southwest away from the tagging locations, daytime depth increased from around 300 to 500 m. For fish that moved south or southeast remaining closer to the coast, daytime depth actually decreased from 300 to as shallow as 90 m during the day. Nigh time depths were constrained to the mixed layer and increased significantly with lunar illumination. A third objective is to determine stock structure using otolith microchemistry. California is hypothesized to be a region of mixing of two potential stocks. The collection of otoliths was initiated in 2006 using specimens collected both from the drift gillnet fleet and the local harpoon fleet.

<u>Pelagic Sharks</u>

A wide range of biological studies are conducted in conjunction with the abundance surveys for juvenile shortfin mako, blue and common thresher sharks. Some past and ongoing efforts include conventional tagging for movement information, taking biopsies for genetics studies, marking with oxytetracycline (OTC) for age and growth studies, taking blood samples for condition factors caused by capture stress and/or injury, acoustic and satellite archival tagging for movement and physical habitat pattern descriptions, and a variety of physiological studies addressing cardiac function, swimming performance, and condition factors. During the 2006 surveys 272 blue sharks, 111 shortfin mako sharks, 2 common thresher sharks, 23 pelagic rays (*Dasyatis violacea*), 3 ocean sunfish (*Mola mola)* and 1 lancet fish *(Alepisaurus brevirostris)* were caught. One hundred and eleven sharks were tagged with conventional tags and sampled for DNA analysis and 93 were marked with OTC for age and growth studies. Satellite tags were deployed on 12 makos, one thresher, two blue sharks and three ocean sunfish. The satellite tagging is being conducted in collaboration with the TOPP (Tagging of Pacific Pelagics) program.

Studies of age and growth were initiated with mako sharks in 1997 and have since expanded to include thresher sharks as well. Since the beginning of the program, 948 OTC-marked individuals have been released during juvenile shark surveys. In 2006, 93 makos and 192 common thresher sharks were tagged and marked with OTC. As of January 2007, 50 mako sharks and 12 common thresher sharks have been recovered (6.2%). Of these, vertebrae were collected and returned from 28 sharks. Time at liberty ranged from 7 to 1,594 days with net movements of individual sharks as high as 2,648 nautical miles. Preliminary analyses of the labeled vertebrae from mako sharks indicate the formation and deposition of two band pairs (opaque and semi-translucent) per year. This is an extremely important finding as the question of whether the shortfin mako lays down one or two band pairs per year has been an ongoing uncertainty, with independent labs reporting conflicting results. The result has dramatic implications for age and productivity estimates incorporated into stock assessments. In addition, growth during the time at liberty from these recovered mako sharks combined with recapture information from a larger-scale conventional tagging effort, demonstrates average growth rates of 18 to 25 cm/year for juvenile makos (size range of roughly 90-160 cm FL at the time of tagging).

SWFSC scientists are also studying the movement and habitat use patterns of common thresher sharks, which are an important target species of the west coast based drift gillnet fishery. A satellite-tagging project was started in 1999 in the Southern California Bight during the spring-summer occupancy. Satellite tags have been deployed on 27 individuals during the years 1999, 2004, 2005 and 2006. While analyses are still ongoing, results provide important fishery-independent information about this species, previously known exclusively from catch data. Depth and temperature records demonstrate that common thresher sharks have a distinct diurnal pattern. Thresher sharks spend most of the day at depths around 200 m but remain close to the surface at night. The data are being examined with respect to oceanographic features (bathymetry, surface temperature, water column profile, and surface chlorophyll) in order to quantify the essential habitat of these sharks and determine how the physical environment influences movements and behaviors.

Since 1999, efforts at SWFSC have focused on the foraging ecology of pelagic sharks including blue, shortfin mako, common thresher and bigeye thresher sharks. A comparison of the first 12 prey items ranked by GII for each species reveals distinct diet differences among the species. The mako sharks fed on a combination of different taxa of teleosts and cephalopods. Blue sharks fed primarily on different squid species. The common threshers consumed mostly teleosts, especially coastal pelagic species, and very little squid. The bigeye thresher contained midwater and epipelagic species as well as some benthic species. Comparing across sharks, the bigeye thresher consumed taxa covering the broadest range of prey and habitat types suggesting that they are opportunistic feeders.

Fishery Management Research – A limited but important number of studies at the SWFSC falls into this category of fishery management research. SWFSC researchers are applying different economic models to understand the economics of fishing and factors contributing to overcapacity in tuna fisheries. Included in the studies is analysis of incentives for reducing sea turtles interaction in longline fisheries, such as in the North Pacific.

Pacific Islands Fisheries Science Center (PIFSC)

Studies are underway on stock assessment, biology, oceanography, economics, and methods to reduce the incidental catch and mortality of species that are particularly affected by longline fisheries. This research addresses fishery resource status and sustainability and fishery impacts on the ecosystem.

Fishery Monitoring and Socioeconomic Research-

Fishery Monitoring and Analysis

The Western Pacific Fishery Information Network (WPacFIN) completed the first phase of data integration between the Hawaii Division of Aquatic Resources (DAR) Commercial Fishing Report (FR) and the Commercial Marine Dealer Report (DR). In this phase, FR catch data by fishing trip were matched with DR daily sales data to create a complete database of fish sales and fish weight information. This database includes catch data from Federal Longline Logbooks (LL) and DAR FR data. Unmatched data and issues such as misidentified species in matched trips will be addressed during subsequent development phases. The integration work is an important aspect of improving reporting to the RFMO's because it incorporates the best estimates of the sizes of fish caught by area, information needed to convert U.S. catches in number of fish in the EPO and WCPO into catches in weight. The WPacFIN program also continued to improve data quality control for the DR data. DR data on longline landings were verified against Federal LL data to ensure that vessel names and captain Commercial Marine License (CML) numbers matched between the two datasets. This increases the success rate for data integration.

The PIFSC developed and implemented a real-time system for monitoring and forecasting U.S. longline catches of bigeye tuna in the Eastern Pacific Ocean (EPO). The system was created in collaboration with NMFS administrators, federal enforcement staff, NOAA Fisheries scientists in Hawaii and California, the Western Pacific and Pacific Fishery Management Councils, and the U.S. longline industry. The system enables the U.S. to stay within the U.S. longline fishery quota for bigeye tuna established by the IATTC to conserve the bigeye resource. New protocols for the system include dockside monitoring and manual tallying of EPO bigeye tuna catches and calculating catch rates from logbook data, daily vessel monitoring system counts of longline vessels present in the EPO as a proxy for daily real-time longline effort, market monitoring of bigeye tuna landed for area specific mean weight of fish, and in-season prediction of the date when the quota is expected to be reached. The latter predicted date is based on real-time catch and effort estimates that change in response to dynamics of the fishery. The system enabled the U.S. to keep its 2006 longline catch of bigeye tuna in the EPO within the established quota.

In other fishery monitoring research, statistical models of blue marlin catches by Hawaii-based longline vessels were developed. The new models increase predictive accuracy and comprehensibility with little loss of precision. Species misidentifications were corrected in the reported commercial logbook records for five species of billfishes taken as incidental catch by the Hawaii-based longline fleet from March 1994 through 2004. The study has provided a corrected catch database along with a 10-year time series of standardized catch rates.

Economic Research

A study is underway to estimate the economic value of opportunities to recreationally catch blue marlin in Hawaii. Data are being collected using a mail survey add-on to the Hawaii Marine Recreational Fishing Survey. Similar estimates may also be developed for tunas, mahimahi, and a variety of other pelagic species. Results will allow comparisons between recreational value and commercial values for these species. Data collection began in 2006 and is continuing into 2007.

A study was conducted on the adoption of new technology in the Hawaii-based longline fishery and resulting effects on fishing capacity and fishing productivity. A multiple linear regression model was computed to estimate the effects of technological factors on productivity. This model indicated, for example, that a 1% increase in hook numbers should yield a 0.9% increase in catch rates (catch per set). Other factors exerting positive effects on fishing capacity were vessel speed, vessel length, and use of sea surface temperature maps. It is expected that this work will be useful in determining the appropriate capacity of this fishery within the overall context of managing total fishing effort.

A bio-economic model was developed to explore tradeoffs between reductions in incidental interactions with sea turtles and economic returns by Hawaii-based longline vessels. Through simulation analysis of hypothetical time and area closures for the fishery, the study assessed possible policy options that allow the fleet to maximize fishing opportunity without exceeding federally enforced annual limits on sea turtle interactions. Several levels of fishing effort were employed in the simulations. The model provided a suite of policy options for consideration in managing the shallow-set Hawaii-based longline fishery that targets swordfish.

Fish Biology and Stock Assessment Research- The PIFSC conducts research on stock assessment, the biology and life history of exploited stocks and bycatch species, the selectivity of fishing gear for target species and bycatch. Staff also conduct fishing trials with alternative fishing gears with the objective of reducing bycatch of unwanted fish and protected species.

Blue Shark Stock Assessment

In 2006, the PIFSC collaborated with scientists from the JIMAR, Imperial College of London, and Japan's National Research Institute of Far Seas Fisheries and Fisheries Research Agency to revise and update a stock assessment of blue sharks in the North Pacific. The blue shark assessment will be confined to the North Pacific because of the relatively wide availability of data for the region, the purported separation of northern and southern hemisphere stocks of blue shark, and documented high catches and finning rates. The objectives of the study are to determine the degree to which the population has been affected by fishing activity and whether current fishing practices need to be managed to ensure continued viability and utilization of the resource. The study will update the blue shark assessment published by Kleiber et al. in 2001. In addition to re-estimating catch and effort data based on a longer time series of data, the current study will incorporate several new features. In particular, effort data will be provided by the Fisheries Administration of Taiwan and catches for the Japanese inshore longline fleet will be included. Catch estimates will be contrasted with harvest estimates from the shark fin trade, and catch per unit effort will be standardized using both a generalized linear model and a statistical habitat model. Two different stock assessment models will be applied.

Billfish Stock Assessment

PIFSC collaborated with other members of the ISC Marlin Working Group (MARWG) and Swordfish Working Group (SWOWG) in 2006 to review data inputs and develop models for a North Pacific swordfish stock assessment and a North Pacific striped marlin stock assessment. North Pacific swordfish catch statistics were compiled and reviewed by ISC member countries.

Major issues to be considered in the assessment of swordfish in the North Pacific swordfish are its differential growth by sex and the possible existence of multiple stocks in the North Pacific Ocean. For striped marlin, standardized CPUE indices (1962-2005; Fig.11) declined over from the mid-1960's through mid-1970's; exhibited a relatively flat trend (with year-to-year fluctuation) over the next two decades; and then generally declined (with year-to-year fluctuation) from themid-1990's through mid-2000's. These CPUE indices – all derived from longline fisheries – can be considered roughly proportional to the number of spawners in the population (ages 5+); and should be highly influential in the population model, which is expected to completed in March, 2007.

Swordfish Age & Growth Study

A paper entitled "Age and Growth of Swordfish, *Xiphias gladius*, Caught by the Hawaii-based Pelagic Longline Fishery" was accepted for publication. Annuli observed using the cross-sectioned 2nd anal fin ray were corroborated by scanning electron microscopy (SEM) observations of daily microincrement formation within otoliths (sagittae) and also were consistent with the observed growth of three recaptured tagged fish at liberty from 1 to 4 yrs. Growth rates of swordfish in the central North Pacific were found to be similar those of swordfish caught off the coast of Chile and considerably higher than those of fish caught near Taiwan.

Age & Growth Study of Striped Marlin Initiated

The examination of bony hardparts from striped marlin was initiated to evaluate their feasibility as growth mark indicators for age estimation. Hardpart samples collected at the fish market included dorsal and anal fin rays, vertebrae, cleithrum, and otoliths. Each type of hardpart was examined for the presence of apparent annuli and evaluated for utility in age determination. Initial results indicated that cross-sections of vertebrae and cleithrum do not reveal distinct growth marks. Examination of various 1st dorsal fin and 1st anal fin ray cross-sections indicated that dorsal rays have smaller vascularized cores than anal rays, an advantage for age determination. Further work has indicated that cross-sections of rays 3-5 on 1st dorsal fins provide the best clarity in terms of visually identifying apparent annuli. Within the smaller sized specimens examined, sagittal otoliths were found to have structures presumed to be daily microincrements.

Collaboration on Blue Marlin Growth Study

PIFSC helped with a doctoral research project by a graduate student from University of the Ryukyus on the age and growth of blue marlin caught off Yonaguni Island, Japan. PIFSC staff described and demonstrated the Center's protocols for identifying annulus growth marks on swordfish dorsal fin ray sections and helped assemble digital images from a subsample of blue marlin spine sections, allowing several scientists to view and assign ages to the same sections, enabling a comparison between readers. It appeared that the first annulus mark in the blue marlin is formed at approximately 8 mm from the focus of spine sections. However, annulus marks observed in blue marlin were considerably less distinct than those in swordfish, making growth estimation for blue marlin difficult. Two sagittal otolith sections were examined and photographed under SEM at the University of Hawaii BEMF facility. Internal microincrements were visualized but there were unreadable gaps between the focus and edge of the otolith.

Early Life History Studies of Pelagic Species

Two research cruises by the NOAA Ship *Oscar Elton Sette* were conducted in 2006 off the Kona coast of the Island of Hawaii to learn about species-specific spawning dynamics of pelagic fishes and the oceanographic parameters associated with the presence/absence of their eggs and larvae.. The cruises focused on the surface net collection of eggs and larvae of billfishes and other species. An at-sea multiplex-PCR assay was used to confirm species identities of net-captured eggs and larvae of billfishes, wahoo, and mahimahi. A spring cruise collected primarily swordfish eggs and shortbill spearfish larvae while a late summer cruise collected primarily wahoo eggs and few billfish larvae. Environmental data indicated that billfish egg stages are present in surface waters along the Kona coast primarily when the sea surface is less saline (~34.5), warmer (25-27°C), and calm (low wind conditions). The first record of spawning (presence of larvae) for striped marlin in Hawaiian waters was published in Bulletin of Marine Science in 2006, based on observations during May 2005 research cruise.

Trace Element Study of Juvenile Swordfish Otoliths Initiated

In a new study trace element signatures of juvenile swordfish otoliths collected from distant nursery areas throughout the Pacific will be analyzed. Young-of-the-year juveniles caught seasonally in the warm water tuna longline fisheries of various regions and will be sampled by onboard observers or cooperating fishermen. The objective is to evaluate whether distinct trace element signatures exist that would serve as unique markers of nursery origin. The analysis will be conducted using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS). If successful, these markers will provide a basis for future studies to identify the origins of adult swordfish that typically inhabit the cooler higher latitude fishing grounds targeted by swordfish longline fleets in the Pacific. Juvenile swordfish otoliths were acquired from Ecuador and the western Pacific to supplement samples previously obtained from the central north Pacific and French Polynesia.

Wahoo and Dolpinfish Studies

A study documenting length-weight relationship for wahoo (*Acanthocybium solandri*) and mahimahi (*Coryphaena hippurus*) around Hawaii has been completed and submitted for publication. Histological sections of mahimahi ovaries are being studied to document oocyte development and spawning frequency in Hawaiian waters.

Shark bycatch research

Researchers have undertaken several projects to address shark bycatch on longline gear, including studies of chemical deterrents to bycatch. Experiments in early 2006 with demersal longline sets in South Bimini using the chemicals, and similar testing of magnets, were quite successful. In late 2006, the PIFSC began testing the ability of electropositive metals to deter sharks from biting freshly caught baits, observing the sharks at sea off the North Shore of Oahu.

The NMFS longline observer database is being used to compare shark bycatch rates under different operational factors (e.g., hook type, branch line material, bait type, the presence of light sticks, soak time, etc.). Preliminary results do not indicate that large circle hooks (size 18/0) increase the catch rate of sharks. This contrasts with results in other fisheries, where studies comparing smaller circle hooks with J shaped hooks found an increased shark catch on circle hooks.

Research is being conducted at sea to study the release and survivorship of shark bycatch, including the testing of dehookers and barbless hooks. In the Hawaiian longline fishery, sharks are generally released from the gear by one of the following methods, a) severing the branchline, b) hauling the shark to the vessel to slice the hook free, or c) dragging the shark from the stern until the hook pulls free. Fishermen are encouraged to use dehooking devices to minimize trauma and stress of by-catch by reducing handling time and to mitigate post-hooking mortality. In the current study, the effectiveness of barbed and barbless circle hooks was investigated by assessing catch rates and catch retention of both targeted and by-catch species (e.g., sharks). Results showed no difference between barbed and barbless hooks in the catch and catch rates of targeted species and sharks. Efficacy of the pigtail dehooker, a device required by U.S. regulations for releasing sea turtles, showed a 67% success rate in dehooking and releasing live sharks on barbless hooks, compared to a zero success rate when used with sharks caught on barbed hooks.

Alternative Longline Gear to Reduce Bycatch

An experiment with deep-set longline gear was conducted by PIFSC in coordination with the Secretariat of the Pacific Community (SPC) and JIMAR. The experiment altered current commercial tuna longline setting techniques by eliminating all shallow set hooks (less than 100 m depth) from tuna longline sets. The objective of eliminating all shallow set hooks, a method developed by SPC, was to maximize target catch of deeper dwelling species such as bigeye tuna, reduce bycatch of turtles and other protected species, and reduce incidental catch of many marketable by less desired species (e.g., billfish and sharks). A single vessel was contracted to perform 90 longline sets – 45 sets using the deep setting technique and 45 control sets using standard methods. A deep set was achieved by attaching paired 3 kg lead weights directly below paired floats on long portions of the mainline, thereby sinking the entire fishing portion of the line below the target depth of the shallowest hook (100 m). The deep setting technique was easily integrated into daily fishing activities with only minor adjustments in methodology. The main drawback for the crew was increased time to deploy and retrieve the gear. Catch totals on the deep set gear were greater for both bigeye tuna and moonfish; whereas catch of less valuable incidental fish (e.g., striped marlin and wahoo) was lower. Temperature-depth recorders placed on the gear verified that the deep set method achieved the goal of ensuring that all hooks sink below 100 m. Results have shown that the deep set technique works and would be practical to incorporate into existing fishing practices in Hawaii’s tuna longline fleet.

Marine Turtle Bycatch Mitigation

Research was conducted to track movements of longline-caught sea turtles after their release from a fisheries encounter by tagging them with pop-off satellite archival tags (PSATs) and platform terminal transmitters (PTTs). To maximize the number of turtles tagged, PIFSC worked with observers in several foreign longline fisheries with relatively high sea turtle encounter rates. During 2006, observers were trained in Hawaii, Brazil and Uruguay in the attachment of satellite transmitters and deployed about 10 tags.

The PIFSC is leading studies on longline fishing vessels to test the efficacy of sea turtle bycatch mitigation methods. Specifically, we have coordinated field trials in Costa Rica, Brazil, Ecuador, and other countries to test effects of gear modifications (e.g., use of large circle hooks, appendage hooks, hook offsets) on the rates of hooking and entanglement of sea turtles in longline fisheries. The PIFSC is also conducting research on effects of shark shapes and light sticks on rates of sea turtle capture in a gillnet fishery in Baja California, Mexico. This work is conducted with the Aquatic Adventures Science Education Foundation with support from a NOAA Environmental Literacy Award. The PIFSC also hosted a meeting of the Sensory Physiology Working Group (Virginia, USA, September 2006), from which a NOAA Technical Memo has been drafted.

Ecosystem and Oceanographic Research- The PIFSC investigates oceanographic and ecosystem relationships that often have important influences on fish and protected species distribution, population dynamics, and vulnerability to fishing gear.

Pelagic Habitat of Loggerhead Sea Turtles

A satellite telemetry study of 43 juvenile loggerhead sea turtles (*Caretta caretta*) in the western North Pacific together with satellite-remotely sensed oceanographic data identified the Kuroshio Extension Current Bifurcation Region (KECBR) as a forage hotspot for these turtles. In the KECBR, juvenile loggerheads resided in Kuroshio Extension Current (KEC) meanders and associated anti-cyclonic (warm core) and cyclonic (cold core) eddies during the fall, winter, and spring when the KEC surface water contains high concentrations of chlorophyll. Turtles often remained at a specific feature for several months. However, in the summer when the KEC waters become vertically stratified and surface chlorophyll levels are low, the turtles moved north up to 600 km from the main axis of KEC to the Transition Zone Chlorophyll Front (TZCF).

In some instances, the loggerheads swam against geostrophic currents, and seasonally all turtles moved north and south across the strong zonal flow. Loggerhead turtles traveling westward in the KECBR had their directed westward movement reduced 50% by the opposing current, while those traveling eastward exhibited an increase in directed zonal movement. It appears, therefore, that these relatively weak-swimming juvenile loggerheads are not merely passive drifters in a major ocean current but are able to move east, west, north, and south through this very energetic and complex habitat. These results indicate that oceanic regions, specifically the KECBR, represent an important juvenile forage habitat for this threatened species. Interannual and decadal changes in productivity of the KECBR may be important to the species' population dynamics. Further, conservation efforts should focus on identifying and reducing threats to the survival of loggerhead turtles in the KECBR

Tagging of Longline-caught Opah

Data from 11 pop-up archival transmitting tags attached to opah (*Lampris guttatis*) in the central North Pacific were used to describe their vertical movement and habitat. The tags were deployed over the period 2002 to 2005 in the subtropical gyre northwest of the Hawaiian Islands. Based on the results, opah in the central North Pacific generally inhabit a 50–400 m depth range and a 8–22^{o}C temperature range. They are frequently found in shallower depths, between 50 and 150 m, during the night and in greater depths ranging from 100 to 400 m during the day. However, opah are constantly moving vertically within this broad habitat. During the day, they are very likely to spend some time in water shallower than 175 m, while at night, excursions occurring below 200 m are not uncommon. Speed of their vertical movements is generally less than 25 cm/s; however, a burst descent in excess of 4 m/s has been recorded. While the vertical extent of opah habitat can vary with local oceanographic conditions, over a 24-hour period the integrated temperature opah experience remains in a narrow range from about 14.7 to 16.5^{o}C.

Table 1. Number of vessels fishing in the North Pacific Ocean in various U.S. fisheries. Data for 2005 and 2006 are preliminary

Year	Purse Seine	Longline	Distant-water troll	Pole-and-Line	Troll & Handline	Gill Net	Harpoon
1985	110	36	792	27		210	99
1986	85	39	419	19		220	113
1987	85	37	486	18		210	98
1988	87	50	531	17		192	83
1989	84	88	338	18		158	44
1990	85	138	368	12		146	49
1991	65	141	172	12		123	32
1992	62	124	602	11	1,977	113	48
1993	62	122	608	13	1,987	105	44
1994	62	127	721	11	1,948	112	49
1995	55	116	471	11	2,020	127	39
1996	40	114	676	9	2,166	100	30
1997	38	117	1,172	9	2,149	104	31
1998	37	122	841	9	2,135	87	26
1999	25	140	776	9	2,127	78	30
2000	27	130	645	7	1,993	77	26
2001	29	125	860	9	1,937	64	23
2002	27	123	644	13	2,080	45	29
2003	29	128	729	14	2,094	37	34
2004	19	129	695	11	2,022	33	28
2005	23	126	541	10	1,988	37	21
2006	8	128	604	12	2,001	45	21

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 2005 and 2006 are preliminary. NEI = not included elsewhere. 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	BLZ	MLS	UNSPEC. BILLFISH	UNSPEC. TUNA	TOTAL
Purse Seine:													
1985	26	92,623	47,634	1,751	3,320	0	3,360	32	0	0	0	0	148,746
1986	47	102,736	52,817	264	4,851	5	171	87	0	0	0	132	161,109
1987	1	123,044	48,667	222	861	1	3,093	2	0	0	0	56	175,947
1988	17	88,302	78,250	1,120	923	34	3,416	4	0	0	0	9	172,075
1989	1	77,744	35,671	516	1,046	85	795	6	0	0	0	70	115,934
1990	71	63,722	53,213	674	1,380	260	3,687	0	0	0	0	39	123,046
1991	0	26,789	50,107	415	410	2	218	2	0	0	0	7	77,950
1992	0	29,668	74,234	3,709	1,928	2	770	13	0	0	0	0	110,324
1993	0	23,805	60,485	3,035	580	0	186	17	0	0	0	0	88,108
1994	0	10,516	30,183	2,472	906	30	75	0	0	0	0	8	44,191
1995	0	16,934	60,036	5,803	689	9	20	0	0	0	0	0	83,491
1996	11	6,653	20,646	6,884	4,523	39	202	0	0	0	0	0	38,959
1997	2	20,866	37,525	8,702	2,240	0	115	2	0	0	0	7	69,459
1998	33	20,831	25,258	3,645	1,771	34	418	1	0	0	0	0	51,991
1999	48	4,989	18,710	3,236	184	62	18	0	0	0	0	0	27,248
2000	4	1,670	5,508	454	693	0	32	0	0	0	0	0	8,361
2001	51	5,362	17,794	1,122	149	13	0	0	0	0	0	0	24,491
2002	4	6,612	4,002	580	0	37	0	1	0	0	0	0	11,236
2003	44	3,562	21,212	3,528	22	70	0	0	0	0	0	0	28,439
2004	1	3,810	6,860	1,437	0	78	0	0	0	0	0	0	12,186
2005	0	6,792	19,171	3,992	201	0	0	0	0	0	0	0	30,157
2006	0	768	3,918	498	0	0	0	0	0	0	0	0	5,184
Pole and Line :													
1985	1,498	472	1,328	0	3	0	0	68	0	0	0	0	3,369
1986	432	554	1,367	0	1	0	0	9	0	0	0	1	2,364
1987	158	1,861	2,087	0	0	0	1	22	0	0	0	0	4,129
1988	598	1,140	3,450	5	5	0	26	40	0	0	0	0	5,264
1989	54	1,318	2,456	0	9	0	1	26	0	0	0	3	3,867
1990	115	154	553	0	61	0	0	21	0	0	0	2	906
1991	0	942	1,840	0	0	0	0	22	0	0	0	0	2,804
1992	0	1,928	1,744	0	2	0	0	33	0	0	0	2	3,709
1993	0	2,636	2,850	0	5	0	0	139	0	0	0	5	5,635
1994	0	1,844	2,422	0	1	0	187	19	0	0	0	18	4,491
1995	80	394	2,393	0	1	0	0	21	0	0	0	0	2,889
1996	24	696	1,331	0	0	0	0	9	0	0	0	1	2,061
1997	73	468	1,755	0	1	0	0	1	0	0	0	0	2,298
1998	79	2,206	1,067	0	4	0	6	5	0	0	0	0	3,367
1999	60	57	601	4	2	0	0	17	0	0	0	0	741
2000	69	13	320	1	12	0	0	25	0	0	0	0	441
2001	139	4	448	0	1	0	0	19	0	0	0	0	611
2002	381	2	420	0	2	0	0	0	0	0	0	2	807
2003	59	35	587	0	3	0	1	1	0	0	0	0	686
2004	126	19	279	0	0	0	1	37	0	0	0	0	462
2005	66	68	353	0	0	0	0	0	0	0	0	0	487
2006	22	5	280	0	0	0	0	0	0	0	0	0	307

Table 2. Continued.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	BKJ	BEP	SWO	BLZ	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	8	0	0	1	0	0	0	0	10,137
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	2	0	0	2	0	0	0	0	10,391
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	12,590	0	0	0	0	0	0	0	0	0	0	0	12,590
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	504	68	0	2,843
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	351	136	0	7,814
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	304	721	90	4,977	0	0	0	1,609	348	517	215	0	8,781
2006	274	969	94	4,447	0	0	0	1,194	422	602	169	0	8,171

Table 2. Continued.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	BKJ	BEP	SWO	BLZ	MLS	UNSPEC. BILLFISH	UNSPEC. TUNA	TOTAL
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	442	0	0	0	1	450
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

Table 2. Continued.

FISHERY/YEAR	ALB	YFT	SKJ	BET	PBF	BKJ	BEP	SWO	BLZ	MLS	UNSPEC. BILLFISH	UNSPEC. TUNA	TOTAL
Unclassified,other or recreational:													
1985	1,176	58	5	1	231	0	426	100	0	42	0	468	2,507
1986	196	227	0	6	309	0	28	105	0	19	0	6	896
1987	74	2,159	633	1	146	0	266	27	0	28	0	67	3,401
1988	74	936	372	1	79	0	335	58	0	30	0	2	1,887
1989	183	849	103	0	165	0	137	49	0	52	0	0	1,538
1990	28	508	147	0	158	0	227	38	0	23	0	1	1,130
1991	77	235	137	0	97	0	69	38	0	12	0	0	665
1992	74	1,119	1,014	0	191	0	78	46	0	25	0	2	2,549
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	156	0	0	4	0	21	0	0	1,283
1998	1,210	43	0	0	414	0	0	12	0	23	0	1	1,703
1999	3,622	0	0	0	441	0	0	18	0	12	0	0	4,093
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	291	0	0	0	96	0	0	0	0	0	0	0	387
HI 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	732	261	237	0	0	0	0	206	28	15	15	1,579
2004	160	732	253	279	0	0	0	0	178	22	20	44	1,688
2005	170	668	261	246	0	0	0	0	177	19	15	17	1,573
2006	86	454	286	222	0	0	0	0	144	25	13	11	1,241

Table 3. Discards of target and non-target fish species reported in Regional Purse Seine Logbooks by U.S. purse seine vessels fishing in the North and South Pacific Ocean during 2005 and 2006 (preliminary).

Species or species group	**Metric tons**	
	2005	**2006**
Target species discards		
Total:	**3900**	**1245**
Skipjack tuna (*Katsuwonus pelamis*)	3796	1190
Yellowfin tuna (*Thunnus albacares*)	104	55
Other discards		
Billfish:	**16.09**	**18.1**
Black marlin (*Makaira indica*)	0.17	0.34
Sailfish (*Istiophorus platypterus*)	0.08	0.12
Marlin (Istiophoridae)	15.84	17.64
Sharks/Rays:	**11.18**	**1.06**
Oceanic whitetip shark (*Carcharhinus longimanus)*	0	0.03
Silky shark (*Carcharhinus falciformis)*	0.23	1.03
Shark	10.76	0
Rays, skates, mantas (Rajiformes)	0.19	0
Other tunas/Tuna-like:	**10.13**	**3.87**
Albacore (*Thunnus alalunga*)	**4.50**	**0**
Tuna unspecified (tribe thunnini)	**2**	**0**
Mackerel (Scombridae)	**3.23**	**3.51**
Wahoo (*Acanthocybium solandri*)	**0.40**	**0.36**
Other fish:	**234.94**	**80.22**
Bait	**7.98**	**0.83**
Mahimahi (*Coryphaena hippurus*)	**0..69**	**0.62**
Ocean sunfish (*Mola mola*)	**0**	**0.02**
Rainbow runner (*Elagatis bipinnulatus*)	**2.65**	**5.02**
Triggerfish (Balistidae)	**0.69**	**0.58**
Yellowtail (*Seriola lalandi*)	**11.61**	**14.79**
Other unspecified	**212.01**	**58.36**

Table 4. Estimated total numbers of fishery interactions (not necessarily resulting in mortalities) with non-fish species (all of which is non-target, associated, or dependent species) by vessels in the Hawaii-based longline fishery, 2005 and 2006[2].

Species	**2005**	**2006**
Marine mammals		
Striped dolphin	0	6
Bottlenose dolphin	0	2
Risso's dolphin	4	7
Unidentified dolphin	0	9
Blainville's beaked whale	6	0
Bryde's whale	1	0
False killer whale	6	17
Humpback whale	0	1
Shortfinned pilot whale	6	6
Unidentified Whale	1	14
TOTAL MARINE MAMMALS	24	62
Sea turtles		
Loggerhead turtle	10	17
Leatherback turtle	12	11
Olive Ridley turtle	16	54
Green turtle	0	6
Unidentified hardshell turtle	0	2
TOTAL SEA TURTLES	38	90
Albatrosses		
Blackfooted albatross	89	73
Laysan albatross	105	15
TOTAL ALBATROSS	194	88
Observer Information		
Total trips	1,483	1,357
Observed trips	466	332
Proportion of trips observed	31.4%	24.5%
Observed sets	6,206	4,544
Observed hooks	10,689,477	8,285,411

[2] The estimates are made by raising the number of observed interactions by a factor determined according to the design of the observer sampling program. The species listed are those that have been observed. Sources: Pacific Islands Regional Office observer program reports and Pacific Islands Fisheries Science Center Internal Reports IR-06-006 and IR 07-006.

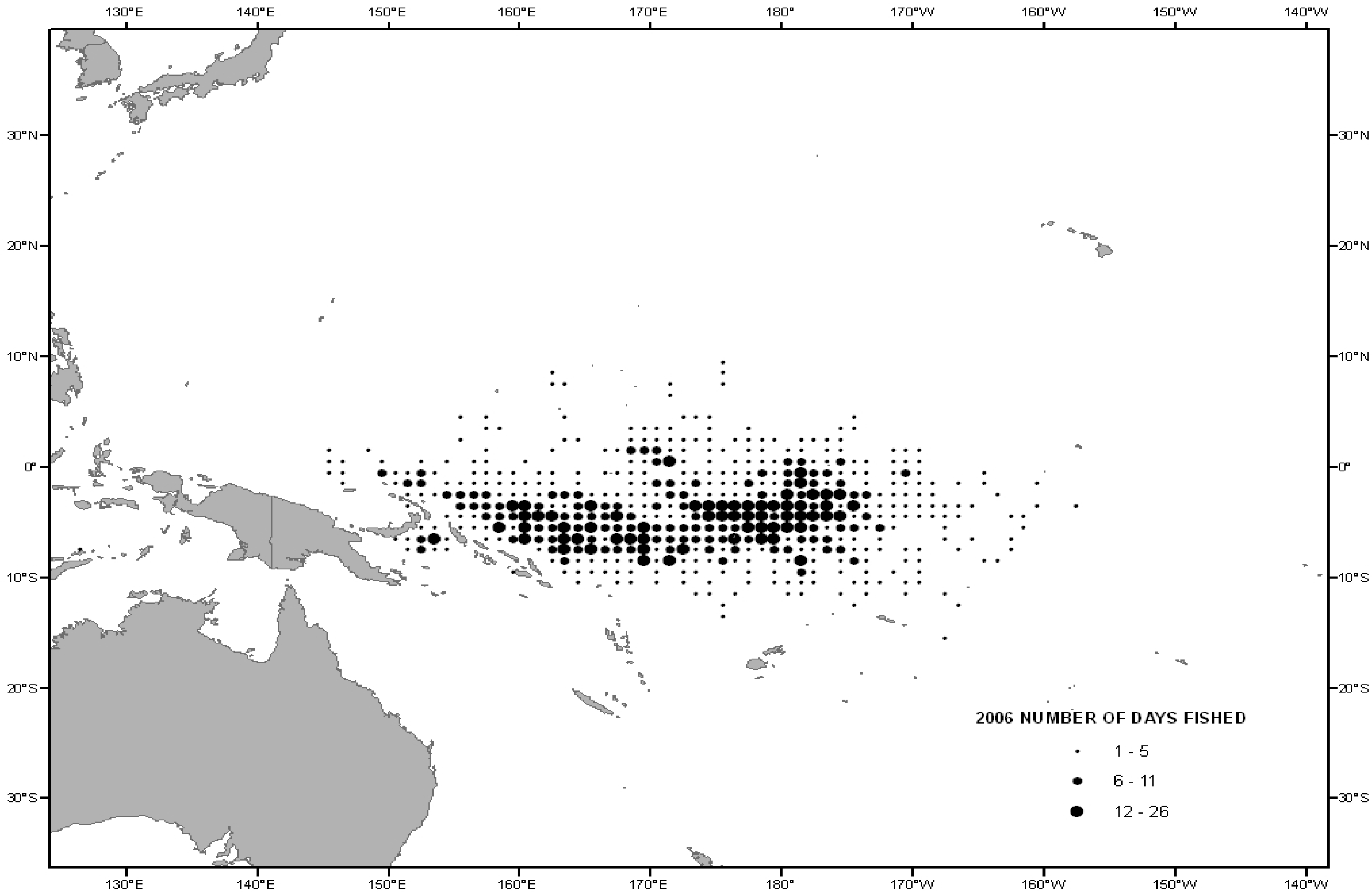

Figure 1. Distribution of nominal fishing effort (days fished) for the 2006 U.S. central-western Pacific purse seine fishery.

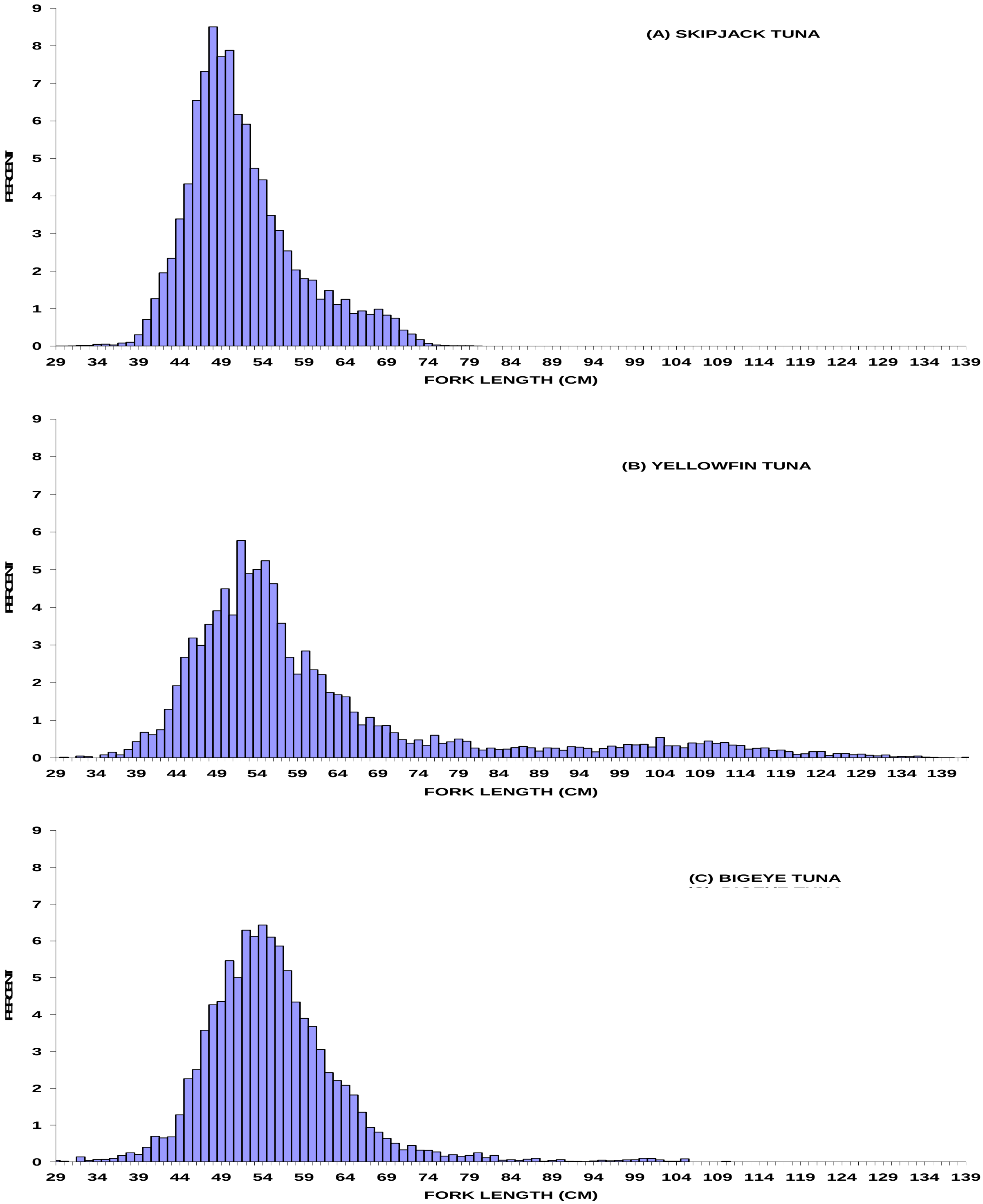

Figure 2. Size distribution of (A) skipjack tuna, (B) yellowfin tuna and (C) bigeye tuna caught by U.S. purse seiners fishing in the central-western Pacific Ocean in 2006.

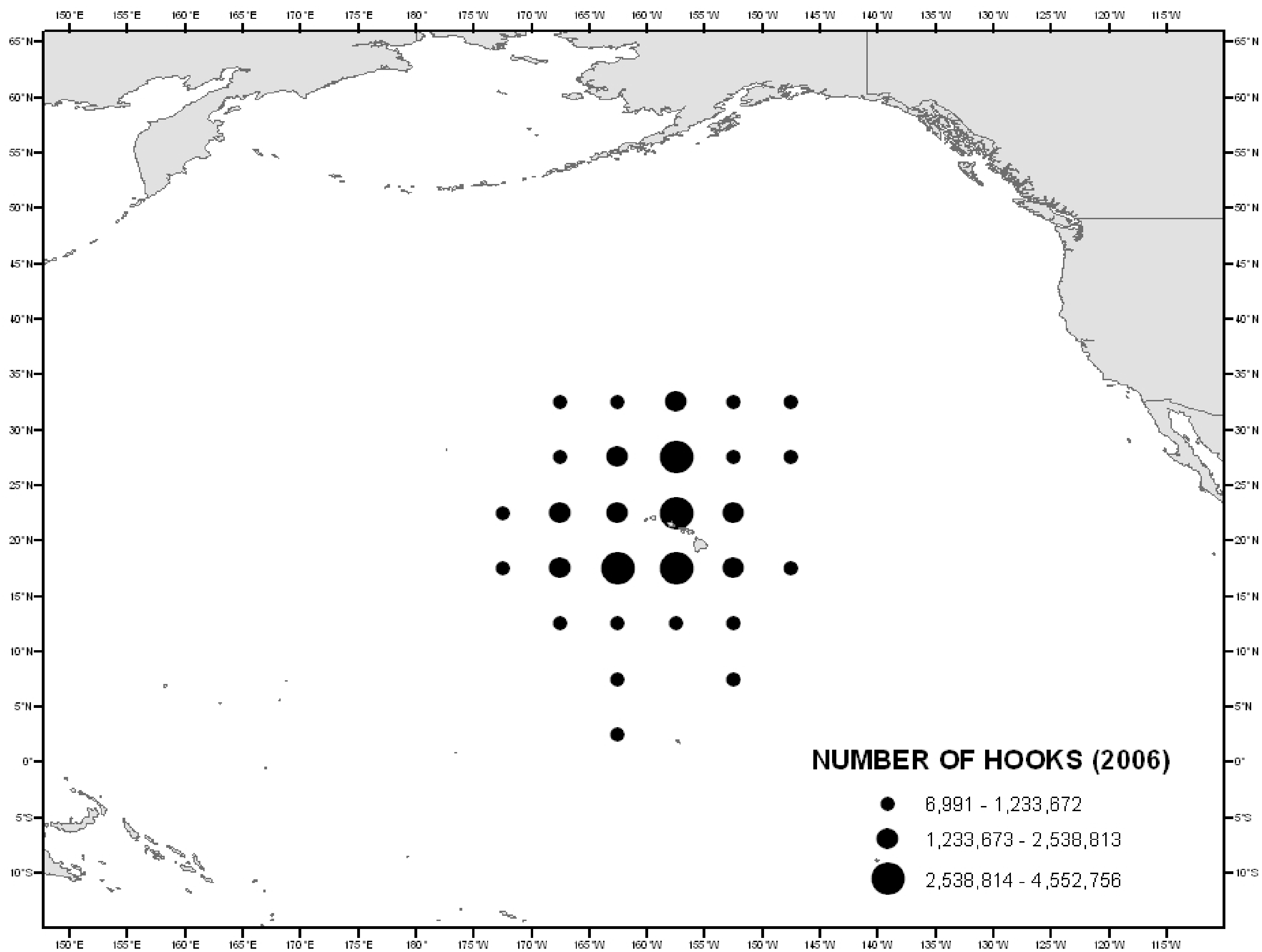

Figure 3. Distribution of nominal fishing effort (number of hooks) for the 2006 U.S. North Pacific longline fishery.

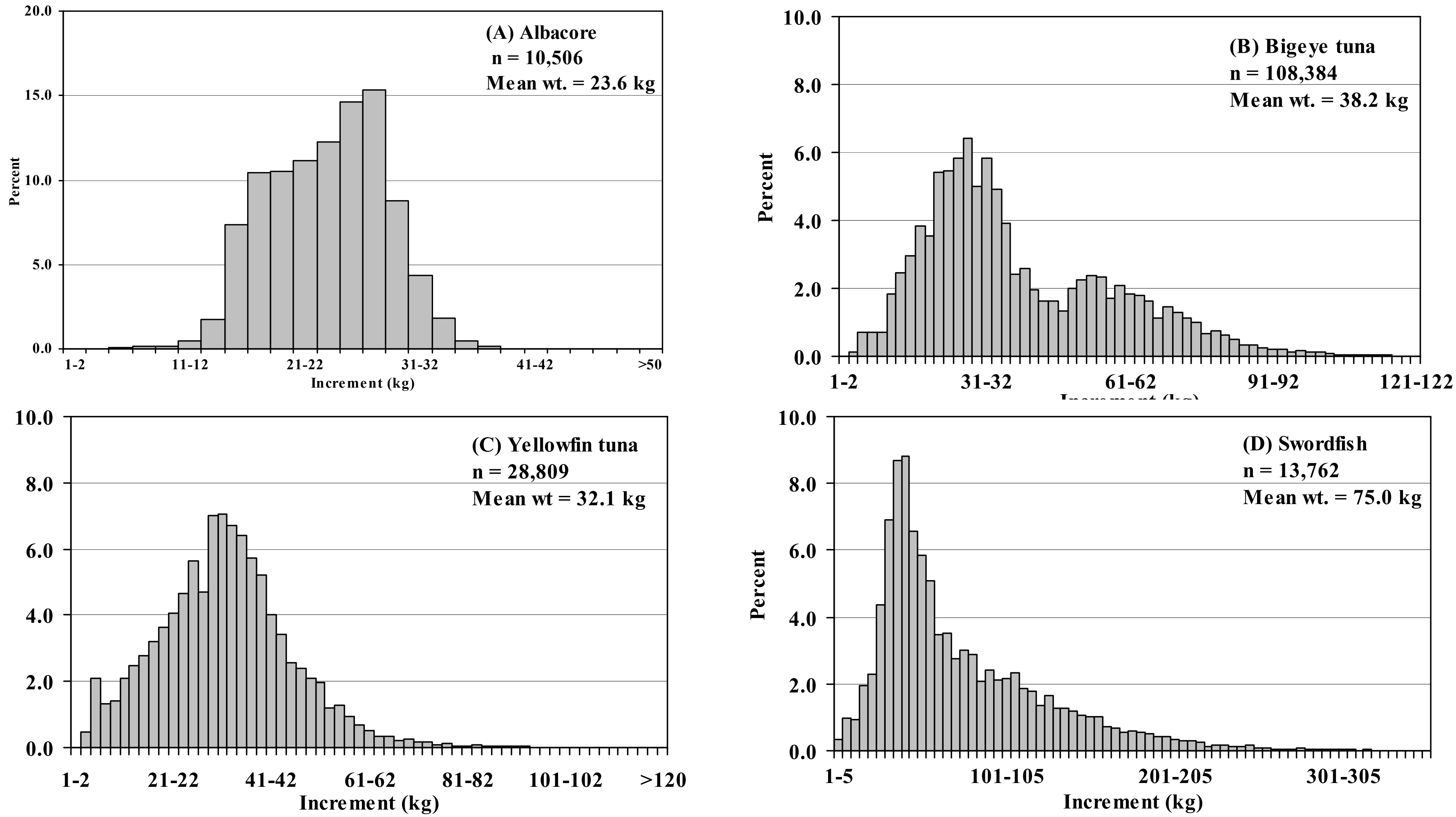

Figure 4. Size distribution of (A) albacore, (B) bigeye tuna, (C) yellowfin tuna and (D) swordfish caught by the Hawaii-based longline fishery, 2006.

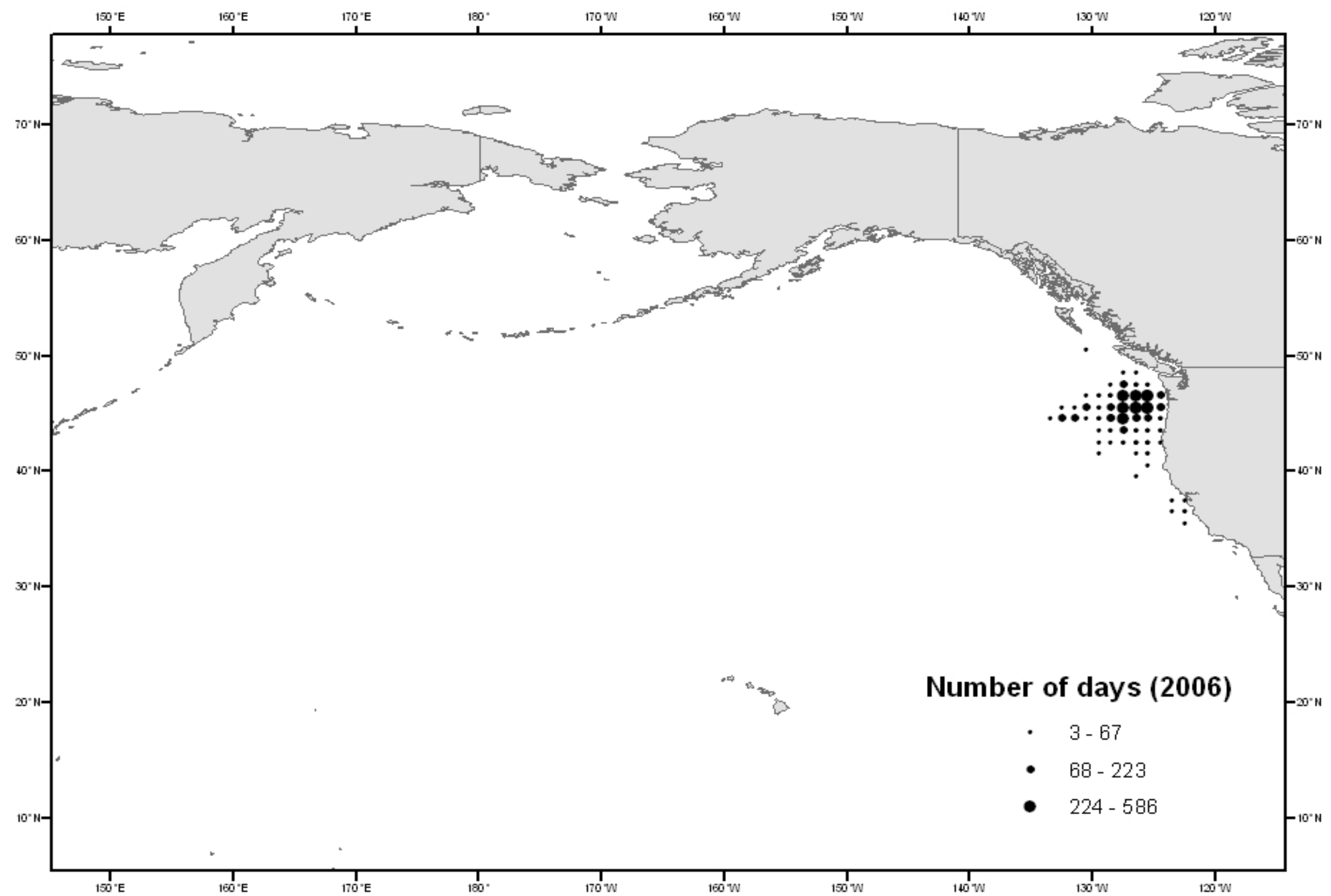

Figure 5. Distribution of nominal fishing effort (days fished) for the 2006 U.S. North Pacific troll fishery.

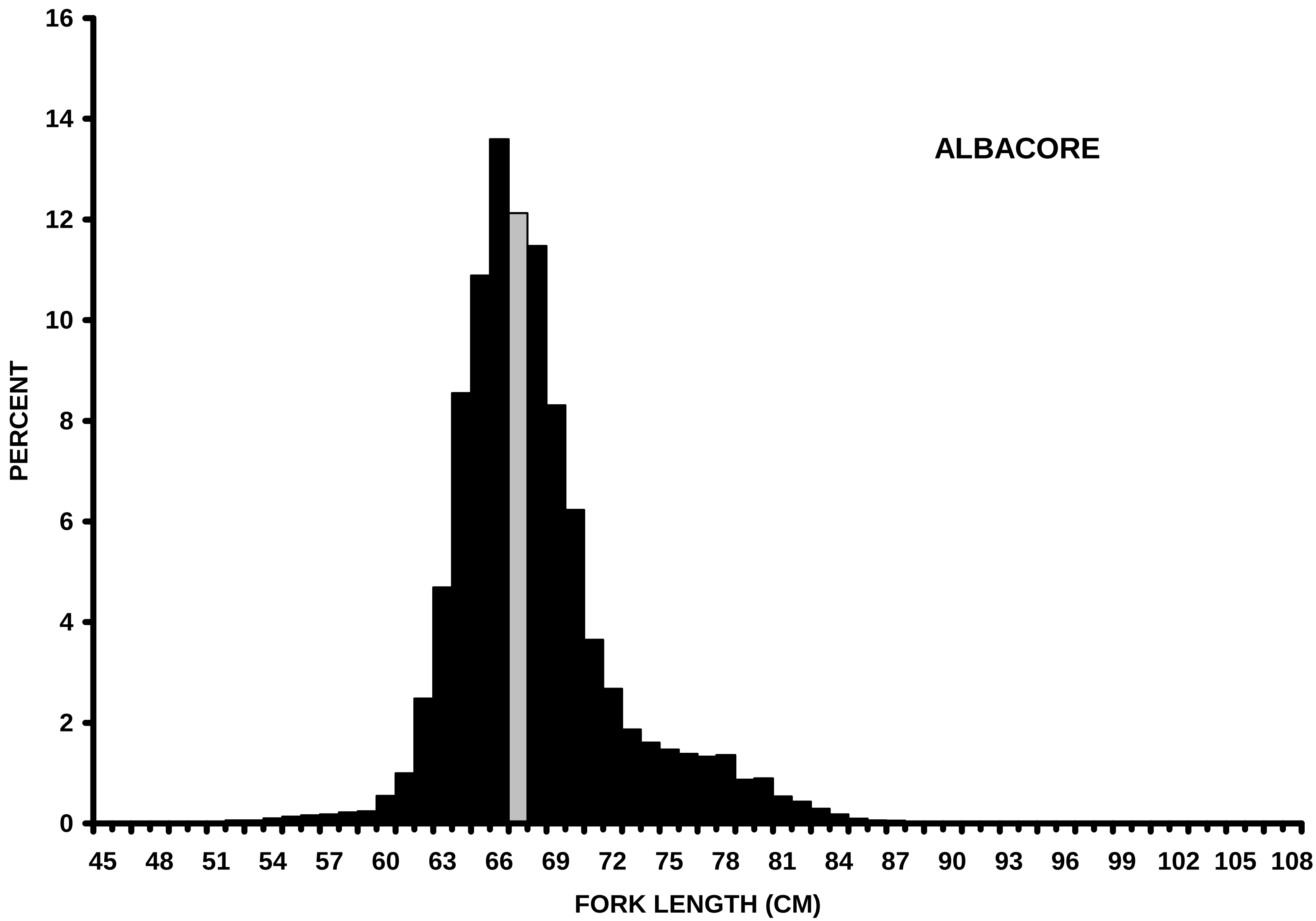

Figure 6. Size distribution of albacore caught by the U.S. North Pacific albacore troll fishery in 2006.

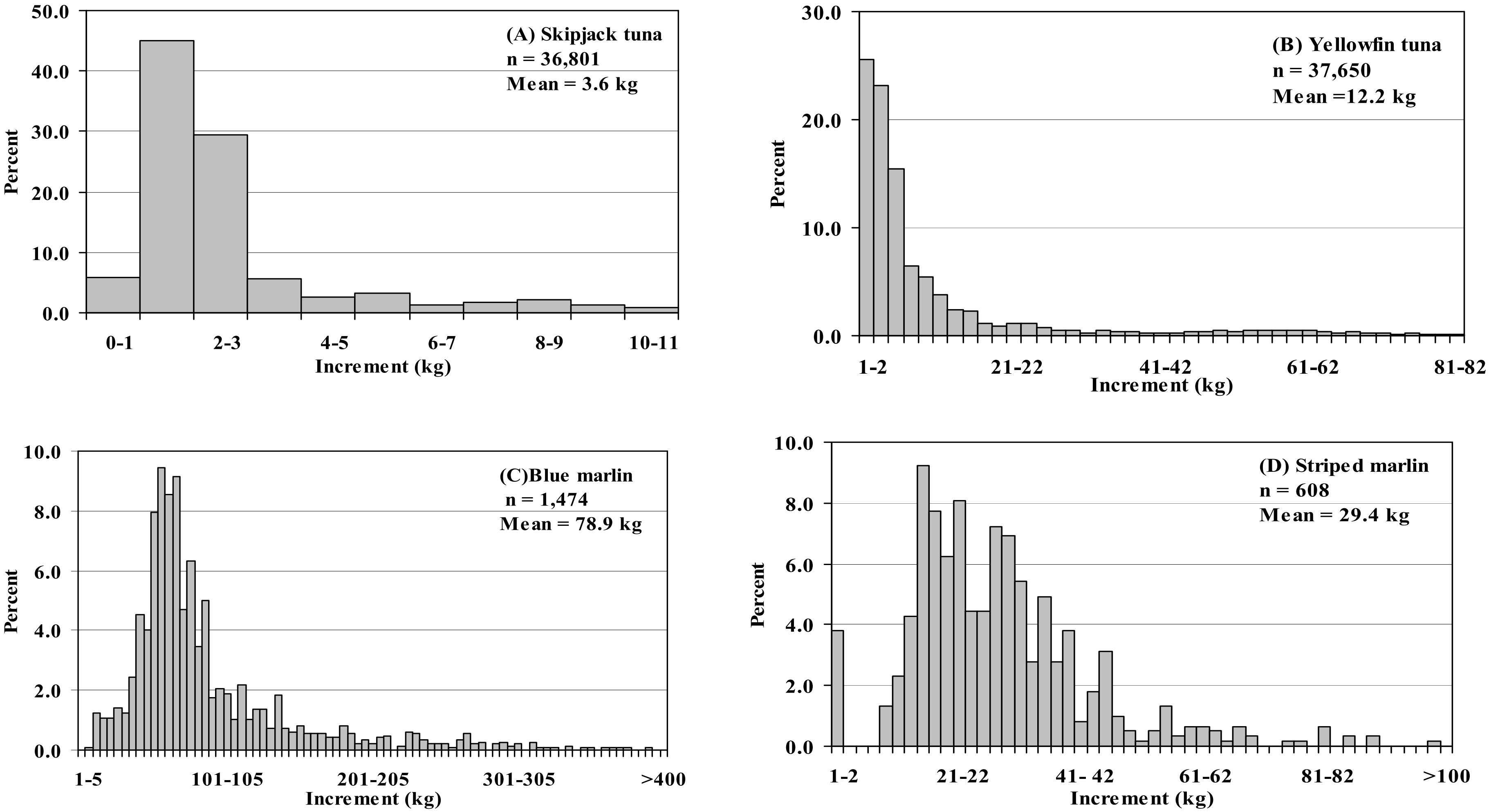

Figure 7. Size distribution of (A) skipjack tuna, (B) yellowfin tuna, (C) blue marlin and (D) striped marlin caught by the Hawaii-based troll and handline fishery, 2006.

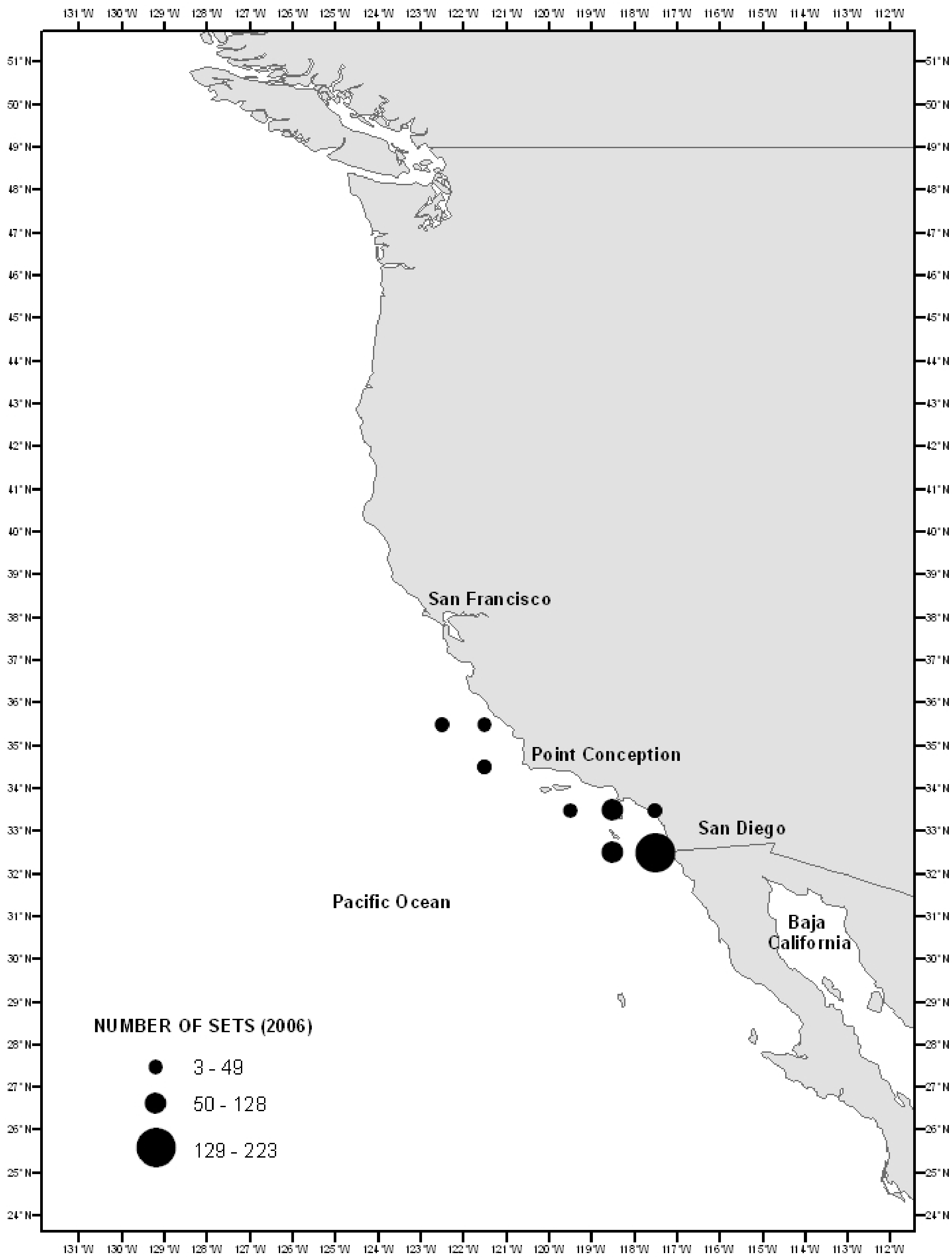

Figure 8. Distribution of nominal fishing effort (number of sets) for the 2006 U.S. North Pacific drift gill net fishery.

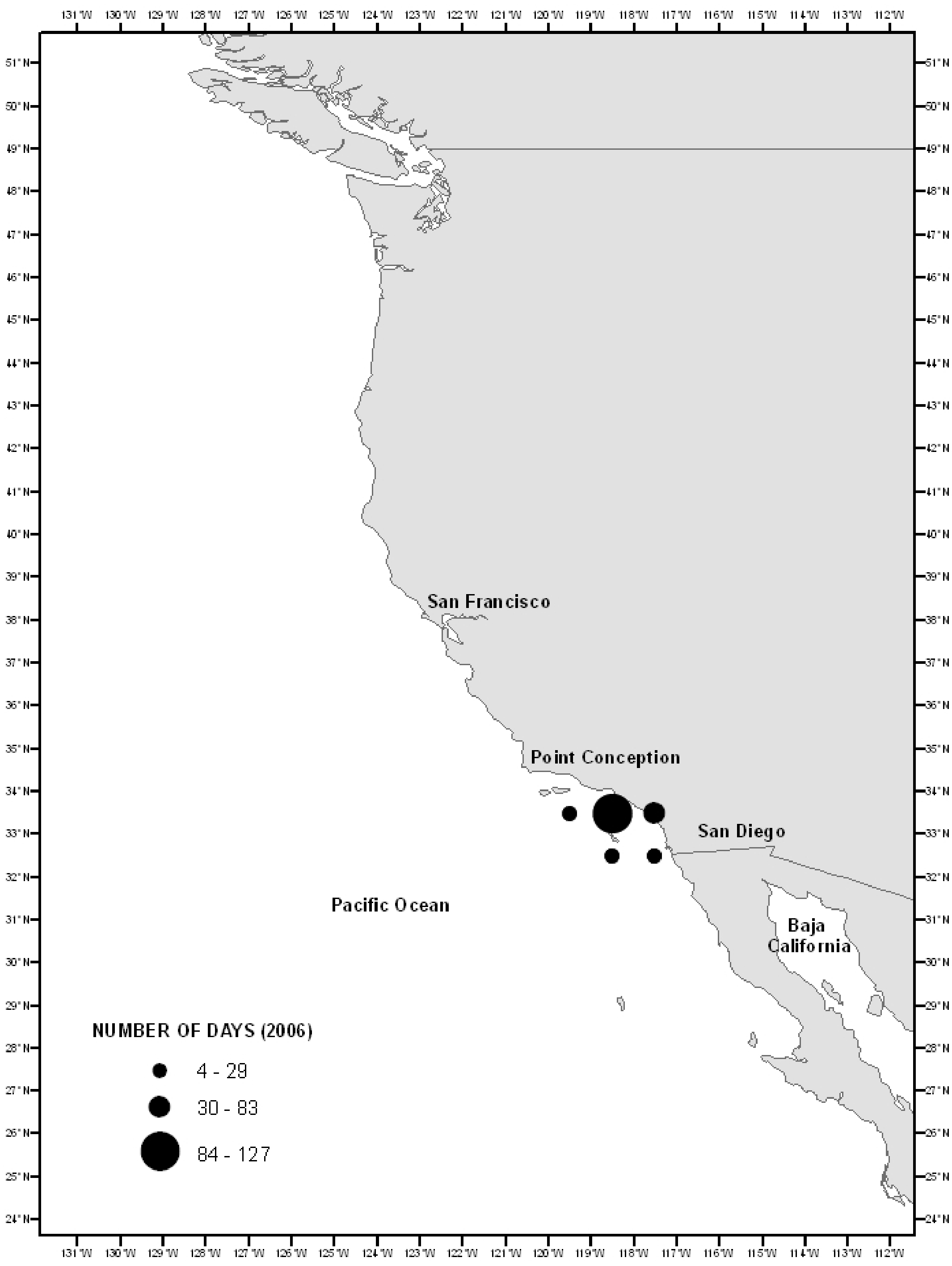

Figure 9. Distribution of nominal fishing effort (days fished) for the 2006 U.S. North Pacific harpoon fishery.

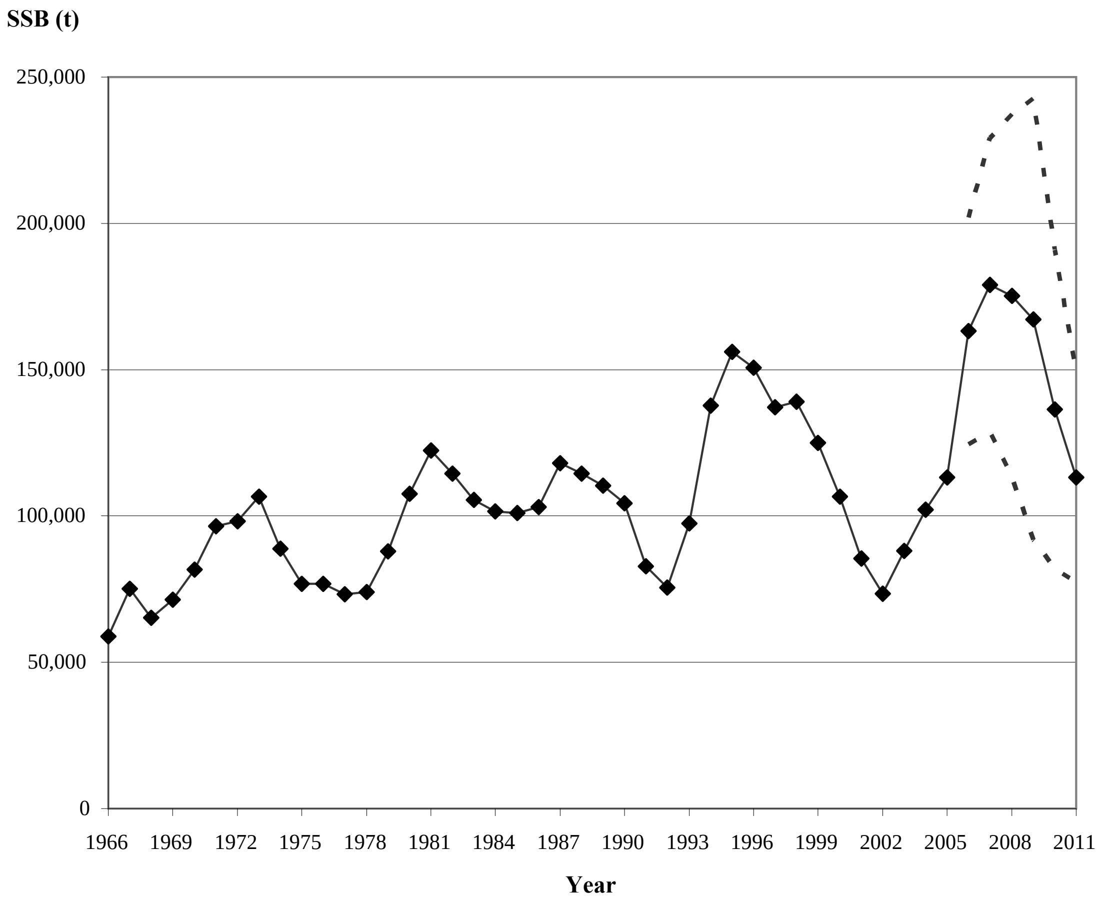

Figure 10. North Pacific albacore spawning stock biomass (SSB in mt) time series estimated from the VPA-based assessment conducted in 2006. Projected estimates from 2006-11 are bounded by an 80% confidence interval.

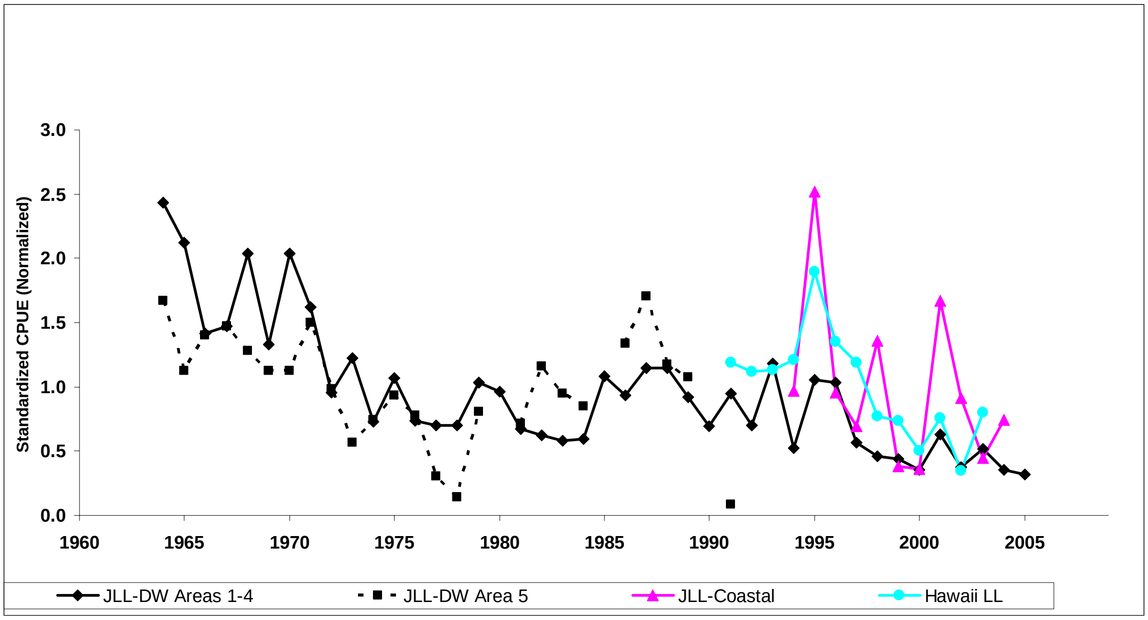

Figure 11. **Striped marlin standardized CPUE, 1964-2005.**