May 2000

Director's Report to the 51st Tuna Conference

On Tuna and
Tuna-Related Activities at the
Southwest Fisheries Science Center
for the Period May 1, 1999
to April 30, 2000

OUR SEAS AND OUR SKIES

OF EXCELLENCE AT NOAA

Administrative Report
LJ-00-05

National Marine Fisheries Service
Southwest Fisheries Science Center
P.O. Box 271
La Jolla, CA 92038

This annual report highlights research at the Southwest Fisheries Science Center relating to tropical tunas, albacore, billfishes, and sharks and protected species associated with their fisheries. The work was conducted from May 1999 through April 2000 by the Center's laboratories in La Jolla, California, and Honolulu, Hawaii.

During the past year, the Center's biological, economic, and oceanographic research concentrated on providing quality fishery analyses and management information to the regional fishery management councils, international scientific working groups and committees, and the National Marine Fisheries Service's Southwest Region and headquarters. Major tuna-related activities included stock assessments, socioeconomic research, research on interactions between fisheries and protected species, and mathematical modeling of fish movements and fishery interactions. This data collection and analysis is aimed at ensuring that U.S. and world fisheries, populations of protected marine species, and coastal and marine habitats remain at sustainable and healthy levels and that the most effective fishing regulations and international treaties are carried out.

Center scientists also were active during the year in tuna-related international forums, such as the Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific, the Standing Committee on Tunas and Billfish, the Multilateral High Level Conference on the Conservation and Management of Highly Migratory Species in the Western and Central Pacific, the South Pacific Albacore Research Group, and MEXUS-Pacifico.

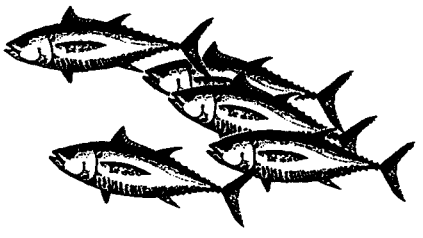
This year also marks the 30th anniversary of the National Oceanic and Atmospheric Administration (NOAA), which was created on October 3, 1970, in recognition of the importance of the oceans and atmosphere to our nation's welfare and economy. During this anniversary year, NOAA is celebrating past accomplishments and future endeavors to improve our understanding and stewardship of the environment which sustains us all.

As a key NOAA line office, the National Marine Fisheries Service (NOAA Fisheries) is dedicated to protecting and preserving our nation's living marine resources through scientific research, fisheries management, enforcement, and habitat conservation. I am proud of the Center's many outstanding contributions and achievements in support of this mission, particularly tuna-related research conducted by the Center that has contributed significantly to our understanding of the biology and ecology of tuna and billfish populations and fisheries.

Michael F. Tillman, Ph.D.

Science Director, Southwest Region
National Marine Fisheries Service

May 2000
La Jolla, California



This Administrative Report is issued as an informal document to ensure prompt dissemination of preliminary results, interim reports, and special studies. We recommend that it not be abstracted or cited.

CONTENTS

I. CENTRAL AND WESTERN PACIFIC TUNA FISHERIES

U.S. Purse-Seine Fishery Annual Report – The U.S. tuna purse-seine fishery in the central and western Pacific Ocean has operated under the South Pacific Regional Tuna Treaty since 1988. As part of the terms of the treaty, the National Marine Fisheries Service's (NMFS) Southwest Region and Southwest Fisheries Science Center (SWFSC) collect vessel logbook, landings, and biological data and monitor the fishery. In March 2000 at the annual meeting of treaty participants, the SWFSC presented a report on the 1999 U.S. central-western Pacific tropical tuna purse-seine fishery. Highlights of the report are given below.

Thirty-six U.S. purse seiners fished in the central-western Pacific in 1999 and caught about 182,000 metric tons (t) of tropical tunas. Skipjack tuna (*Katsuwonus pelamis*) dominated the catch at 131,000 t, with lesser quantities of yellowfin tuna (*Thunnus albacares*) (34,400 t) and bigeye tuna (*T. obesus*) (16,700 t). The 1999 tuna catch was only 4% greater than in 1998 but would have been higher had not many vessels stayed in port during the last half of the year to protest low cannery prices and long delays in unloading at the American Samoa canneries. These problems at the canneries caused vessels to unload 22% of the tuna catch in the Philippines, Fiji, and the Solomon Islands.

In past years, the U.S. fleet fished mainly on free-swimming schools of tuna. In 1999, however, the fleet made a significant switch to fishing most sets (>96%) on floating objects, 94% of which were fish aggregating devices (FADs). This change to FAD fishing led to a record high catch per unit of effort (CPUE) in 1999 (38.3 t per day fished), a record high bigeye tuna catch (more than 16,600 t), record low trip lengths (41.5 days per trip), and a record low number of sets per trip (21).

The NMFS Southwest Region and SWFSC collected and processed logbook and landings data from 100% of the U.S. fleet in 1999, measured lengths of nearly 64,000 fish, and identified 34,100 fish for species composition. In general, skipjack, yellowfin, and bigeye tunas measured in 1999 were slightly larger than those measured in 1998. Species composition sampling of the tuna catch in 1999 showed that about 33% of the landings labeled as yellowfin tuna were actually bigeye tuna. Also, 1999 landings labeled as skipjack tuna were actually composed of 5% yellowfin tuna and 2% bigeye tuna.

U.S. Tuna Fishery Information Presented at International Meeting – The 12th meeting of the Standing Committee on Tunas and Billfish was held in Papeete, Tahiti, in June 1999. More than 80 participants from 24 nations attended the meeting to review the status of tropical tuna and billfish stocks in the central-western Pacific. SWFSC scientists presented five papers at the meeting. The first paper, "U.S. fisheries for tropical tunas and billfish of the central-western Pacific and South Pacific albacore, 1994-98," presented statistics on catch, fishing effort, and size-frequency of the catches for the U.S. purse-seine, longline, troll, and pole-and-line fleets. The second, "The 1998 U.S. tropical tuna purse-seine fishery in the central-western Pacific Ocean," provided detailed analyses of logbook, landings, and size and species composition data collected from the U.S. purse-seine fleet in 1998. The third paper, "Comparisons of the Japanese and U.S. purse-seine fisheries in the central-western Pacific," was a joint paper between the United States and Japan that analyzed operational differences between these two fisheries in respect to areas, months, and set types fished and found that the current Standing Committee policy of using species composition sampling of the U.S. fleet to modify catches of the Japanese fleet is biased and should be changed. A fourth paper entitled "North

Pacific albacore catches and decadal-scale climatic shifts" analyzed correlations between albacore catches and sea surface temperatures and sea level atmospheric pressures and found good correlations among the data. The last paper, "Overview of the U.S. South Pacific albacore fishery for 1998," provided detailed analyses of logbook, landings, and size and species composition data collected from the U.S. troll fleet in 1998.

Use of FADs in U.S. Tuna Fishery Documented – The SWFSC presented a paper on the changing operations of the U.S. fleet and the use of FADs in the tropical tuna fishery in the Pacific Ocean during an October 1999 international FAD symposium in Martinique. The author discussed the U.S. purse-seine fleet's increasing dependence on drifting objects as a way to locate and catch tropical tunas. Since 1996, the U.S. fleet's use of drifting FADs and naturally occurring floating objects has increased significantly. These methods have become the dominant fishing techniques used in the central-western Pacific because of their higher success rate (>90%) in catching tunas compared to setting on free-swimming schools of tuna (50% success rate). Instead of randomly searching for free-swimming schools of tuna, vessels now place radio transmitter devices on FADs and other floating objects and then track and inspect them for fishable schools. This change in fishing methods has increased searching efficiency and improved the performance of the U.S. fleet. The author noted that these benefits, however, are at a cost of higher catches of small tunas and non-target species (bycatch). Further research is needed on ways to minimize small tuna discards and bycatch in the FAD fishery for tropical tunas.

The report also noted that during major El Niño-Southern Oscillation episodes, such as in 1997-98, yellowfin tuna become more vulnerable to purse-seine gear in the central-western Pacific. During an El Niño, the thermocline shoals from east to west, compressing the preferred, mixed-layer habitat of yellowfin tuna. The change in ocean conditions causes the yellowfin tuna to migrate up the water column, where they swim closer to the surface, in reach of the purse-seine fishery. Large yellowfin tuna (>75 cm fork length) are particularly affected by these climatic changes. Yellowfin tuna made up about 49% of the U.S. tuna catch in 1997, an El Niño year, compared to only 24% to 29% of the catch in 1993, a non-El Niño year.

New Fisheries Division at La Jolla – In October 1999, the La Jolla Laboratory's Coastal Fisheries Resources Division and Pelagic Fisheries Resources Division were combined into a new division headed by Dr. John Hunter. The new Fisheries Resources Division assesses the biomass of valuable coastal small pelagic fish stocks and evaluates biological and environmental factors that affect their distribution, abundance, and survival. The division also conducts basic fishery analysis and stock assessment research on tropical and temperate tunas, billfishes, and sharks. The work is in support of the U.S. commitment to international management of tuna fisheries and the regional management of fisheries for billfish and other large pelagic species.

Tuna-Related Fishery Database – Work continues on building an Oracle database for tuna and large pelagics fisheries data at the La Jolla Laboratory. U.N. Food and Agriculture Organization, International Commission for the Conservation of Atlantic Tunas, and Indian Ocean Commission catch data, Japanese, Taiwanese, and Korean longline catch and effort data, and Japanese baitboat catch and effort data have already been added to the database. Data managers are now adding U.S. Pacific albacore troll fishery logbook and length-frequency data and are preparing to add South Pacific Regional Tuna Treaty fishery data. Applications also have been developed to obtain reports of catch by species and gear

and catch-and-effort listings by area strata (1° and 5° squares). Future applications will provide for graphical display of the data.

II. PACIFIC ALBACORE FISHERIES

Albacore Fishery Data Summarized – La Jolla Laboratory staff analyzed fishery statistics collected from U.S. albacore troll vessels fishing in the North and South Pacific in 1998. The results were published in a report (Childers and Miller, 1999) and distributed to the public. The report summarizes logbook data collected from cooperating fishermen and length-frequency data obtained through port sampling of albacore catches.

U.S. troll vessels have fished for North Pacific albacore since the early 1900s and for South Pacific albacore since 1987. The North Pacific albacore fishing grounds range from the U.S. west coast to west of the International Date Line. The fishing season spans late April to early November, and the size of the fleet ranges from 500 to more than 1,000 vessels. Nearly 900 U.S. troll vessels fished for North Pacific albacore in 1998. The South Pacific fishing grounds extend from the east coast of New Zealand to approximately longitude 110°W. This fishery spans late December to early April and usually consists of 20 to 60 vessels. Thirty-five U.S. troll vessels fished for South Pacific albacore during the 1997-98 season. The U.S. troll fisheries occasionally catch other fish species, such as skipjack, yellowfin, and bluefin tunas, mahimahi (dolphinfish), yellowtail, and billfishes.

U.S. troll vessels landed 13,160 t of North Pacific albacore in 1998, slightly less than the 14,872 t landed in 1997. Annual landings over the last 10 years averaged 8,000 t. An excess supply of albacore at U.S. canneries in American Samoa (the regular buyers of albacore caught by U.S. troll vessels) limited the total amount of albacore that was landed in 1998. Many vessels remained in port for long periods or were forced to store their catch in freezer storage until buyers could be found. U.S. South Pacific albacore landings decreased slightly from the previous season's total of 1,865 t. South Pacific landings averaged 2,460 t over the past 10 years. A surplus of albacore at the canneries in American Samoa caused U.S. troll vessels to sell their catches in Fiji.

CPUE for the 1998 North Pacific fishery was 113 fish per day (40% sampling coverage), compared to 46 fish per day in the 1997 fishery. This is the highest CPUE recorded for the North Pacific fishery. The large increase in CPUE can be attributed to a large decline in total effort: 18,105 fishing days in 1998, compared to 46,614 fishing days in 1997. CPUE for the 1997-98 South Pacific fishery decreased to 52 fish per day from 79 fish per day in 1996-97 (64% sampling coverage).

High catch rates are often correlated with areas of strong temperature gradients where albacore tend to congregate. North Pacific albacore fishing areas generally occur in the North Pacific Transition Zone, where cool arctic waters meet the warmer mid-Pacific waters. Sea surface temperatures in these areas range from 15°C to 18°C. Likewise, South Pacific albacore fishing areas are located where cool antarctic waters meet the warmer mid-Pacific waters. Sea surface temperatures in these areas also range from 15°C to 18°C.

About 16,000 albacore were measured during the 1998 North Pacific season (0.8% sampling coverage). The average fork length of sampled albacore decreased in 1998 to 68 cm (13 lb or 5.9 kg) from 70 cm (15 lb or 7.0 kg) in 1997. Two size-class modes are evident at 65 cm and 83 cm fork length in the North Pacific length-frequency samples. Only 200 albacore were measured during the 1997-98 South Pacific season (0.1%

sampling coverage) because nearly all the troll vessels unloaded in Fiji, where no length-frequency sampling was done. The average fork length of sampled South Pacific albacore was 66 cm (13 lb or 5.9 kg), compared to 67 cm (14 lb or 6.2 kg) in the 1996-97 season. One conspicuous size-class mode is centered at 63 cm.

American Fishermen's Research Foundation Activities – Fisheries Resources Division scientists attended a meeting of the American Fishermen's Research Foundation board of directors that was held in Reno, Nevada, during March 2000. The non-profit foundation was established by the North Pacific albacore fishing industry to promote and support scientific research on Pacific albacore. At this meeting, the board of directors approved a research proposal from the SWFSC to enhance current monitoring programs of North Pacific albacore harvested by the U.S. trolling fleet. The research will involve collaborative work between the fleet and the SWFSC, and is expected to generate information that can be used (1) to develop accurate time series of size and age distributions of the exploited stocks for inclusion in assessment models; (2) to critically examine spatial and temporal details concerning the dynamics of the stocks that are at this time poorly understood; and (3) to begin preliminary efforts to generally define the total harvest generated by the troll fishery, including the catches of targeted and incidental fish species. The work will be completed by early fall 2000 and the results will be used in next year's Pacific albacore stock assessment.

Albacore Economic Research – The Fisheries Resources Division's economics program is developing a cost-and-earnings survey of the Pacific coast albacore fleet. The survey will be administered by the American Fisherman's Research Foundation through a contract with the Pacific States Marine Commission, which in turn received a contract from the NMFS. The survey, which covers 1996-99, will serve as a basis for economic research and for conducting regulatory impact reviews and flexibility analyses in support of the Pacific Fishery Management Council's proposed management plan for highly migratory pelagic species. SWFSC economists Dale Squires (team co-chair) and Sam Herrick are members of the council's fishery management plan development team.

North Pacific Albacore Workshop – The 16th North Pacific Albacore Workshop took place in Kesenuma, Japan, during November 1999. At the workshop, representatives from Canada, Japan, Mexico, Taiwan, and the United States discussed scientific research and the status of North Pacific albacore. The participants noted that the albacore population and fisheries have rebounded since the late 1980s, with present catches near 100,000 mt. Japanese pole-and-line catches increased to 20,000 to 30,000 t and their longline catches to 41,000 t by 1997, the latter due to expansion of coastal longlining. The U.S. albacore troll fishery now takes more than 16,000 t. Analyses of the albacore fisheries indicated that albacore biomass may have doubled since the late 1980s, and the population appears to still be increasing. The increase may have resulted from decadal environmental change, increased fishing power, or a response to recent reductions in fishing. Participants agreed that the sustainable catch or maximum sustainable yield (MSY) for albacore is in the range of 80,000 t to 110,000 t.

SWFSC personnel from the La Jolla and Honolulu laboratories presented three working papers at the workshop. "Summary of the 1998 U.S. North and South Pacific albacore troll fisheries" and "Catch of albacore by the Hawaii-based longline fishery" described the U.S. fisheries, including economic factors. "Perspective on sustainable yield production from North Pacific albacore" noted that an MSY of

80,000 t to 100,000 t was indicated regardless of assumptions concerning relative efficiency of different gears fishing the population.

III. HAWAII LARGE PELAGIC FISHERIES

IMPORTANCE OF CENTRAL-WESTERN PACIFIC FISHERIES

Fisheries under U.S. jurisdiction in the central and western Pacific are healthy and viable, as well as economically and socially important. The condition of these fisheries appears to be among the best of all regions in the United States for which the NMFS is responsible. Great care and continued attention, however, must be taken to preserve this healthy state in the widest geographical jurisdiction in the United States.

Analysis of pelagic fisheries in the central Pacific shows no signs of overfishing, although some stocks may be near their sustainable yields. The Hawaii swordfish fishery has shown a complete recovery in CPUE (catch per 1,000 hooks) following a steep decline in 1994. Although swordfish landings have declined since 1993, this is primarily because some swordfish longliners left Hawaii in 1993 and 1994 and other swordfish boats shifted their fishing effort to the more lucrative bigeye tuna.

Longline catch of tunas, billfishes, and associated pelagics grew substantially in Hawaii from the mid-1980s through 1999 (record landings in weight but not in value), while the small-scale longline fishery operating out of American Samoa has grown dramatically.

Three western Pacific ports (Pago Pago, American Samoa; Agana, Guam; and Honolulu, Hawaii) rank among the top 10 most valuable fishing ports in the United States when distant-water landings are included.[1] The ex-vessel value of landings in these ports is about $350 million. U.S. canneries are the primary private-sector employer in American Samoa, while Guam has become a major hub for transhipping and airfreighting tuna for the Asian market. Local fisheries have grown substantially in American Samoa, Guam, and the Northern Mariana Islands over the past 10 years. Fisheries also have an important economic impact in Hawaii and are perhaps even more important socially and culturally. Growth in Hawaii's fisheries was dramatic in the 1980s and 1990s, leveling off in 1998.

TUNA AND BILLFISH RESEARCH AT THE HONOLULU LABORATORY

The mission of the Honolulu Laboratory includes providing scientific support for management decisions on fisheries for tunas, billfishes, and other highly migratory pelagic species in the Pacific. The laboratory conducts pelagic resource stock assessments and the biological and oceanographic research needed to improve stock assessment and management analysis. The laboratory's findings are provided to the Western Pacific Regional Fishery Management Council and are major ingredients of the council's fishery management plan for highly migratory species. The laboratory's research also provides support for multilateral assessment of pelagic resources and U.S. participation in the emerging international arrangements for the management of highly migratory species fisheries in the central and western Pacific, and for scientific cooperation on highly migratory species in the North Pacific.

The scope of the Honolulu Laboratory's pelagics research is defined by the important

[1]Landings by domestic and foreign purse-seine vessels in American Samoa and Guam are not reported in published statistics because of confidentiality restrictions. These estimates are based on reports from the governments of these island areas.

issues faced by the Western Pacific Regional Fishery Management Council and the international fisheries community. Currently, these issues include concerns about the status of swordfish targeted by Hawaii's longline fleet and the blue marlin population important to Hawaii's recreational and charter boat troll fleet. They also include concerns about the effects of longline fisheries, including Hawaii's fishery, on shark populations. Of secondary concern are the status of tuna populations important to U.S. fisheries and also exploited by foreign fleets, and populations of other pelagic species about which little is known, for example, ono (wahoo), opah (moonfish), and mahimahi (dolphinfish).

SWORDFISH RESEARCH

Swordfish (*Xiphias gladius*) research at the Honolulu Laboratory is guided by a comprehensive, multi-disciplinary research plan developed by the laboratory's swordfish research team. This plan is used to identify, prioritize, conduct, and coordinate swordfish research at the laboratory.

Swordfish Fishery Operational Model – Relatively little is known about swordfish in the North Pacific, and substantial uncertainty and incompleteness characterize the associated catch and effort statistics. During 1998-99, an operational model was designed at the NMFS Honolulu Laboratory to evaluate the performance of stock assessment and fishery management procedures in this 'data poor' context. This type of model is basically an amalgamation of data, parameter estimates, and hypotheses from various sources that best represents the fishery as we know it. The current version of the model is based on the results of morphometric studies, tracking and tagging operations, past International Commission for the Conservation of Atlantic Tunas, Inter-American Tropical Tuna Commission, and NMFS assessments, and oceanographic and ecological investigations. It incorporates key features of age-structured and length-based models and can account for growth, reproduction, mortality, recruitment, exploitation, and movement. The model can project trends in abundance, catch and stock composition, recruitment patterns, and spawning biomass for multiple stocks and fleets, under user-specified levels of process and observation error, sampling regimes, and exploitation patterns.

The operational model was used to test the performance of a modified Pella-Tomlinson, non-equilibrium production model used recently for swordfish stock-assessment. Time series of catch-effort data were generated and used as input to the production model analysis. The accuracy of the estimates was determined by comparing them to the 'known' values used to generate the data for different scenarios concerning stock productivity, exploitation patterns, sampling constraints, and observation errors. The production model was found to perform well under fairly complex conditions, with the estimates generally within 35% of the known value. However, the estimates were unreliable when the spatial coverage of the fishery expanded with time, when the catch-effort time series lacked contrast, and when various combinations of measurement errors contaminated the data series.

The operational model was also used to gain insight into the productive capacity of the North Pacific swordfish population. The potential yield associated with different levels of exploitation was forecasted over 150 years, assuming constant fishing patterns as observed in 1996. The results indicate that long-term potential yield is in the order of 57,000 t, or about 3.5 times greater than in 1996. At this level, the fishing mortality rate is about 0.26, which corresponds roughly to the hypothesized mean natural mortality rate for males and females. A long-term potential yield of 57,000 t is considered plausible and exceeds the peak North Pacific swordfish catch in 1960 of about 38,000 t. These

figures are characterized by considerable uncertainty, and the associated confidence intervals cannot be estimated by conventional means at this stage. Still, such facts are in agreement with the results of the production model analysis, which despite its shortcomings, suggested that the swordfish population has been subject to relatively low exploitation rates so far. Current plans are to update the assessment and tests as new information becomes available.

Swordfish Biology – Activities during the year included:

Diet Study–A study of the diet of central North Pacific swordfish is continuing as a cooperative effort between Honolulu Laboratory scientists and the NMFS Pacific Island Area Office longline observer program. The contents of 691 swordfish stomachs have been sorted, identified, weighed, and measured. Preliminary results are available.

Cephalopods were the dominant food items in swordfish >100 cm eye-to-fork length (EFL), making up about 60% to 70% of the diet by weight. Neon flying squid *(Ommastrephes bartramii)* was by far the dominant prey species at 50% to 60% of the prey weight except during the summer months. Fish were the other important general prey taxon, with crustaceans composing a minor part of the diet by weight. Of the fish, pomfrets (Bramidae) and particularly the genus *Brama* were the most important taxon at about 10% to 24% of the prey by weight. The contribution of squid relative to fish in the samples changed seasonally from winter to summer. The highest percentages of squid were found in samples collected during January-March when vessels were targeting swordfish at the Subtropical Front north of the Hawaiian Archipelago. Lower percentages of squid were found in samples collected during July-September, when swordfish were taken incidentally by vessels targeting tuna at the latitudes of the Hawaiian Islands and southward. An important difference between these results and results from studies of swordfish diet in other areas of the world was that in our studies the benthopelagic prey taxa found in swordfish stomachs collected at continental shelves and slopes elsewhere were rare. This reflects the oceanic habitat of swordfish in the central North Pacific as compared with other areas where diet studies have been conducted.

Swordfish <100 cm EFL ate a greater variety of food items in much greater numbers than did larger swordfish. Small fish constituted a greater proportion of the items found in the stomachs of smaller swordfish, although various small cephalopods were also important. Juvenile *Brama* were the dominant fish prey, but these smaller swordfish were also feeding on a variety of other epipelagic species such as flotsamfishes or driftfishes (Nomeidae), as well as vertically migrating, mesopelagic fishes such as barracudinas (Paralepididae) and hatchetfishes (Sternoptychidae).

Data collection and analysis for this study are ongoing. The cooperative work of the NMFS observers has enhanced the productivity of the Honolulu Laboratory in this research.

Sex Identification Study–In the Hawaii-based pelagic longline fishery, swordfish are headed and gutted before they are landed, and the sex of individual fish is indeterminable by conventional means such as gonad size or appearance. An unconventional indicator of sex is therefore required to provide the information on the sex of individuals that is needed for developing age-structured stock assessment models. During the past year, Drs. Gordon Grau and Malia Chow of the Hawaii Institute of Marine Biology at the University of Hawaii, using specimens provided by the Honolulu Laboratory, have been developing several sex markers for swordfish using liver and gonad tissue specimens collected by NMFS observers aboard commercial longline

vessels and complementary muscle tissues sampled from fish at a Honolulu fish auction by laboratory biologists. Matched gonad-sex marker tissue specimens were collected for 94 individual swordfish (80% female; 84-235 cm EFL) during the March-July 1999 spawning season in near-Hawaiian waters. Honolulu Laboratory researchers provided histological ground truth (sex identity and gonad developmental stage) for all specimens and gave these data to their University of Hawaii collaborators. Results of the sex marker analyses are still pending. Matched tissue specimens are being collected for additional male and female swordfish in nonspawning as well as spawning condition during the 2000 fishing season; histological verification of sex and characterizations of reproductive state are continuing.

Age and growth–Studies of swordfish size-at-age based on presumed daily growth increments (DGI) have continued. Due to the difficulty of processing swordfish otoliths for DGI and the sub-micron DGI widths encountered in the outer otolith region of large fish, efforts are concentrated on small swordfish (primarily <125 cm EFL). Currently, the focus is on refining estimates of sex-specific size at age 1 year. These results will complement the concurrent size-at-age study based on anal fin-ray cross sections in establishing the radius and band count in cross sections at age 1 year for which a corresponding DGI-derived age close to 365 days is available.

In a related study, researchers have developed laboratory viewing, counting, and measuring procedures for ageing swordfish using anal fin-ray cross sections and have prepared digitized images of representative fin-ray cross sections. These procedures and files will be sent to Dr. Chi-lu Sun's laboratory at the University of Taiwan and represent the beginning of an exchange of swordfish fin-ray specimens between the Honolulu Laboratory and the university. The specimen exchange is needed to distinguish differences in ageing protocols from possible regional variations in the growth rates of swordfish caught by the Taiwan-based and Hawaii-based longline fleets. Basal condyle measurements on a series of about 200 second anal fin-rays from swordfish <130 cm EFL were also completed. The series of measurements quantifies the condyle diameter-to-EFL relation for small swordfish caught by the Hawaii-based longline fishery. These data are needed for calibration between the Honolulu Laboratory and several international laboratories collaborating with the Honolulu Laboratory on ageing Pacific swordfish using fin-ray cross sections.

Swordfish Oceanographic Research – Results from Honolulu Laboratory swordfish oceanography research were presented at the American Geophysical Union's January 2000 Ocean Sciences Meeting in San Antonio, Texas. The presentation was titled "A physical-biological characterization of the central North Pacific Subtropical Frontal system during winter-spring." It described results from the combined assessment of a recent series of meridional shipboard hydrographic surveys, satellite remote sensing information, and fisheries catch data that elucidated structural patterns and coupling of the physics and the biology associated with the fishing grounds occupied by the Hawaii-based swordfish fleet.

During the January-May fishing season, multiple, individual planetary-scale fronts accentuate the central North Pacific Subtropical Frontal system. The most prominent fronts are climatologically located at latitudes 32° to 34°N (Subtropical Front, STF) and 28° to 30°N (South Subtropical Front, SSTF). However, there is considerable interannual variability in both position and intensity of these fronts. On synoptic time scales, geopositioning of the fronts may be systematically identified through surface outcropping of diagnostic thermohaline isopleths and therefore are

readily discerned from shipboard surveys and by spaceborne satellite sensors. The STF during winter-spring can be characterized by surface outcropping of the 34.8 isohaline and the 17°C isotherm within the frontal gradient. Biologically, the STF marks the transition from low-chlorophyll, nutrient-depleted surface waters to the south to a more productive regime to the north. To the south, the 21°C surface isotherm and 35.0 isohaline are characteristically embedded in the thermohaline gradients associated with the SSTF. A sharp increase in total chlorophyll is also observed at the SSTF and is ascribed to an increase in the concentration and thickness of the subsurface chlorophyll maximum prompted by the shoaling of the nutricline with the thermocline structure into the euphotic zone. The presence and position of the STF and SSTF play a key role with regard to distribution patterns observed among swordfish, their principle prey (flying squid), and incidentally caught loggerhead sea turtles, all of which exhibit strong affinities for waters associated with these fronts.

Studies of Larval Swordfish and Other Billfishes – Sampling of billfish larvae off the Kona coast of the island of Hawaii continued on cruises aboard the NOAA ship *Townsend Cromwell*. A total of 105 istiophorid larvae (mostly 1-2 cm EFL) were caught during 46 one-hour surface tows of a 6-ft trawl net. No swordfish larvae were encountered despite sea surface temperatures (about 25.6°C to 26.5°C) within the optimal range for swordfish larvae. Nearly one-half of all the istiophorid larvae caught were taken in the 16 net tows that remained in surface slicks for the entire duration of tow.

In a related study, 1,470 mahimahi (*Coryphaena hippurus*) stomachs were examined for the presence of small juvenile swordfish. These stomachs were sampled daily during May-September 1999 at a cooperating fish market in Honolulu. This survey yielded 44 early juvenile swordfish (10-33 cm EFL) and 14 early juvenile istiophorids (16-27 cm EFL) that are possibly shortbill spearfish (*Tetrapturus angustirostris*). Nearly all of the swordfish specimens were collected in the June-August period, and about 50% of the specimens appear to have intact otoliths useable for ageing. The swordfish specimens are being used to fill in gaps in juvenile swordfish age-length plots; the other specimens will provide some of the materials needed for future age-structured stock assessments of other billfish species.

Tissue samples taken from these larval billfishes, as well as samples from adult billfishes taken by the Hawaii-based longline fishery, have been shared with Drs. Michael Hinton (Inter-American Tropical Tuna Commission) and Jaime Alvarado-Bremer (now Texas A&M University). These specimens will prove invaluable for comparisons with the genetics of adult swordfish spawners sampled near Hawaii during the same months and years. Results of such a comparison could contribute importantly to our understanding of swordfish stock structure in the central North Pacific.

International Collaborative Research – During August 1999, five NMFS representatives met with about 25 Chilean fishery administrators and scientists for four days of swordfish talks in Valparaiso, Chile. The workshop agenda included presentations from both countries about their respective swordfish fisheries, fishery regulations, management, monitoring, and enforcement programs, and current scientific research. An overview of research being conducted by the Honolulu Laboratory and others on swordfish biology and satellite oceanography research relevant to stock assessment was presented. Government scientists from the Instituto de Fomento Pesquero and the Subsecretaria de Pesca and scientists from the Universidad Catolica de Valparaiso and Universidad de Concepcion were very interested in many of the research areas in which the Honolulu Laboratory is currently involved, including

swordfish age and growth studies, stock structure, satellite pop-up tag technology, fishery oceanography based on satellite-derived data, and stock assessment methods, particularly the use of spatially explicit models. Collaboration in some of these areas was discussed, particularly involving samples, techniques, and procedures that would help clarify questions regarding swordfish stock structure and age and growth.

A system of standardized preparation and sharing of swordfish fin-ray cross-section specimens among the five Pacific Rim laboratories which either have aged or are in the process of ageing Pacific swordfish using these hard parts is currently being developed. These laboratories include the Honolulu Laboratory, the University of Taiwan (Dr. Chi-Lu Sun), Japan's National Research Institute of Far Seas Fisheries (Dr. Kotaro Yokawa), Mexico's Centro de Investigacion Cientifica y de Educacion Superior de Ensenada (Dr. Oscar Sosa-Nishizaki), and Chile's Instituto de Fomento Pesquero (Drs. Vilma Ojeda and Francisco Cerna). Fin-ray specimens have already been received from the laboratories of Drs. Sun and Sosa-Nishizaki. The ultimate objective of the program is to build consensus among laboratories to improve the accuracy and precision of age-length and growth estimates for Pacific swordfish.

Swordfish Cooperative Tagging with Industry – Honolulu Laboratory scientists are conducting a swordfish tagging program to investigate long-range movements of swordfish and to help validate growth rate estimates based on hard part aging studies. In addition to the swordfish tagged during research cruises, U.S. swordfish longline fishermen have been tagging and releasing about 100 swordfish per year. Out of about 500 swordfish tagged and released so far six have been recovered. The results suggest some long-range movements by the fish from the Hawaii area toward the American west coast, but most of the tags have been released and recovered in the fishing grounds north of Hawaii. A recent addition to the tagging program is the contracting of experienced swordfish longline fishermen to tag and release fish of commercially valuable sizes. Several dozen swordfish have been tagged under contract, with one tag recovery so far. The contract tag was recovered from a fish after 1.5 years at large, about 250 miles from the point of release in the fishing area north of Hawaii.

TUNA RESEARCH

Bigeye tuna oceanographic research – A new research initiative under the Joint Institute for Marine and Atmospheric Research (JIMAR) Pelagic Fisheries Research Program (University of Hawaii) is studying the role of the environment on bigeye tuna aggregation and vulnerability to fishing. This study is using the combined oceanographic information acquired from satellites (altimetry, temperature, ocean color), moored arrays, and shipboard platforms together with commercial and research fishery data for the assessment.

Initial phases of the study have principally involved field data collection. An oceanographic mooring was deployed in December 1999 from the NOAA ship *Ka'imimoana* at a site about 185 km (100 nautical miles, nmi) southwest of the island of Niihau. The site selection was based on information on bigeye tuna CPUE, variability of CPUE, proximity to TOPEX altimetric satellite crossover paths, variability of oceanographic structure, and linkages to other JIMAR Pelagic Fisheries Research Program projects. Information recorded by sensors will provide a time series of the vertical structure of temperature and velocity in the upper ocean. One objective of the shipboard surveys is to determine how the information acquired from the mooring is interpreted spatially with respect to adjacent waters. Two research cruises have been conducted so far aboard the NOAA ship

Townsend Cromwell: (1) an initial exploratory survey of the site before the mooring deployment of two 176 km-long (95 nmi) hydrographic and bathymetric transects (corresponding to the TOPEX satellite ascending and descending orbital passes) in May 1999; and (2) a survey of mesoscale dynamic variability and its influence on biology in November 1999. On the November cruise, successful navigation through the center of two eddy systems revealed marked differences in the vertical physical and biological structure through the water column between the features. Surface thermal gradients measured both by satellite and in situ were stronger at the more recently formed (about one month) eddy, but subsurface vertical structure (shoaling of isopleths, vertical nutrient flux) was considerably more developed at the older (about six months) cyclone. Consequently, substantial increases in chlorophyll at the surface and particularly within the subsurface chlorophyll maximum were measured within and at the periphery of the older eddy but not at the younger. A third survey that will revisit the mooring and its adjacent waters is scheduled for April 2000.

Archival tagging of bigeye tuna – To better understand harvest impacts and interactions among fisheries for populations of tuna and billfish across the Pacific, scientists need information on tuna and billfish migration patterns and environmental factors influencing distribution and vulnerability to specific fishing gears. Archival tags provide a powerful new tool for acquiring these data. The Honolulu Laboratory is conducting an archival tagging project on bigeye tuna and swordfish in collaboration with the JIMAR Pelagic Fisheries Research Program and the Commonwealth Scientific and Industrial Research Organization of Australia.

Since April 1998, archival tags have been deployed on 63 bigeye tuna (50-133 cm fork length) during research cruises aboard the NOAA ship *Townsend Cromwell*. Fish were caught both near the leeward (Kona) coast of the island of Hawaii and over Cross Seamount. Tags were implanted into either the dorsal musculature or the peritoneal cavity of the fish. An additional 14 tags were deployed during April 2000.

As of April 2000, six tagged fish have been recaptured and five archival tags have been returned. The fish were at liberty from several weeks to up to nine months. Preliminary calculations of position indicate the fish remained either within a few hundred miles of the leeward coast of the island of Hawaii or almost immediately adjacent to Cross Seamount. As observed during studies of bigeye tuna carrying ultrasonic transmitters, the fish spent daylight hours at depth and returned to the surface at night. Bigeye tuna are, however, able to descend deeper (up to 735 m), into much colder water (down to about 5°C), and to withstand much lower oxygen levels ($\approx$1 ml/l^{-1}) than yellowfin tuna in the same areas. During daylight, bigeye tuna make regular upward excursions into the warm surface layer in order to maintain body temperatures, which generally do not go below about 17°C.

The minimum depths reached during the night were also found to be strongly correlated with moon phase: fish would ascend to shallower depths during the new moon. These observations confirmed and explained the correlation between catch rates of bigeye tuna on longline gear and moon phase previously observed.

RESEARCH TO MITIGATE LONGLINE FISHERY INTERACTIONS WITH PROTECTED SPECIES

Sea Turtles – Honolulu Laboratory staff recently completed research on the pelagic habitat of loggerhead turtles that provides some insight into the overlap between the loggerhead foraging habitat and the fishing grounds of Hawaii-based longliners north of Hawaii. This work is described in a

manuscript to be published in *Fisheries Oceanography* entitled "Turtles on the edge: movement of loggerhead turtles (*Caretta caretta*) along oceanic fronts, spanning longline fishing grounds in the central North Pacific, 1997-1998" (Polovina et al., in press). The authors analyze movements of nine juvenile loggerhead sea turtles tracked by satellite telemetry during 1997 and 1998 in the central North Pacific in relation to satellite remotely sensed data on sea surface temperatures, chlorophyll, and geostrophic currents. The turtles all traveled westward along two convergent oceanic fronts, against prevailing currents. These fronts are characterized by gradients in sea surface height that produce an eastward geostrophic current, with gradients in surface chlorophyll and sea surface temperatures. Six of the turtles were associated with a front characterized by 17°C sea surface temperature, surface chlorophyll of about 0.2 mg/m^3, and eastward geostrophic current of about 4 cm/s, while the other three turtles were associated with a front with 20°C sea surface temperature, surface chlorophyll of about 0.1 mg/m^3, and eastward geostrophic current of about 7 cm/s. These results appear to explain why incidental catch rates of loggerhead turtles in the Hawaii-based longline fishery are highest when gear is set at sea surface temperatures of 17°C and 20°C. Further, from the seasonal distribution of longline effort relative to these fronts, it appears that the surface longline fishing ground lies largely between these two fronts during the first quarter and well to the south of the 17°C front, but including the 20°C front, during the second quarter. These findings suggest seasonal or area closures of the longline fishery that could be tested to reduce incidental catches of loggerhead turtles. Finally, these results illustrate the insights which can be achieved by combining data on movement of pelagic animals with concurrent remotely sensed environmental data.

Seabirds – Research on methods to reduce seabird interactions in the U.S. Hawaii-based pelagic longline fishery was conducted in 1999, culminating in a paper this year on "Deterring albatrosses from contacting baits during swordfish longline sets" (Boggs, in press) to be published in the Proceedings of the Symposium on Seabird Bycatch: Trends, Roadblocks, and Solutions by the Pacific Seabird Group. The results contributed to a set of fishery management measures by the Western Pacific Regional Fishery Management Council which are now under review. Annual incidental takes of 1,500 to 2,000 black-footed albatross and 1,000 to 1,800 Laysan albatross in 1994-98 are estimated for this fishery, with population sizes estimated at hundreds of thousands. Most of the albatross takes occur in fishing operations targeting swordfish or a mix of swordfish and tuna. Swordfish and mixed swordfish-tuna fishing areas are predominantly north of the main Hawaiian Islands, coinciding with the distribution of albatross habitat.

The research was conducted using the NOAA ship *Townsend Cromwell* in simulated fishing operations near the largest black-footed albatross colony at Laysan Island. Longline hooks were replaced by net pins so that no birds were hooked. The effectiveness of a bird-scaring line, weighted bait, and blue-dyed bait at reducing of albatross contacts with baits was tested in a balanced, controlled, experimental design. The results indicated each of these three deterrents was highly effective (70% to 90% effective) in reducing the number of contacts between seabirds and bait.

FISHERY MONITORING AND ECONOMICS

Summary of 1999 Western Pacific Longline Fishery – Preliminary figures show that the 1999 Hawaii longline season resulted in near record landings (by weight) and higher revenues than in 1998. Total landings (all species combined) in 1999 were 28.3 million pounds ($47.4 million ex-vessel), compared to 28.6 million pounds ($46.7

million ex-vessel) in 1998, which was the record year for landings. The record year for ex-vessel revenue ($53.4 million) was at the height of the swordfish fishery in 1993. In 1999, swordfish landings were 6.8 million pounds, down slightly from 1998. However, the average round weight of swordfish increased to 188.2 pounds per fish, and the average price also increased slightly, to $1.89 per pound (round weight). The latter may reflect some recovery from a boycott against Atlantic swordfish initiated in 1998. As a result, the ex-vessel value of swordfish landings increased in 1999 to $12.9 million. Bigeye tuna landings were 6.0 million pounds, down more than 10% from 1998 landings. Bigeye prices increased by about 30% to $3.34 per pound, reflecting the diminished supply. Bigeye tuna ex-vessel revenue decreased slightly to $20 million. Yellowfin tuna landings were 1 million pounds, down 50% from 1998 landings, but albacore landings were 3.25 million pounds, up 33% from 1998 landings. Yellowfin tuna average weights continue a downward trend begun in the early 1990s, but this may reflect the change in the industry's targeting patterns from swordfish to bigeye tuna and from northern fishing locations to more southerly fishing grounds. In addition to the Hawaii-based fleet, 29 California-based longline vessels also fished in this fishery at some point during 1999. Thirteen of these vessels that fished in late 1999 have moved back to Hawaii.

Summary of 1999 American Samoa Longline Fishery – The Honolulu Laboratory receives Federal longline logbook data from the NMFS Southwest Region field office in Pago Pago, American Samoa. The data are summarized by date of haul; preliminary results for 1999 are reported here. Twenty-two longline vessels operating in 1999 made 2,098 sets totaling 911,382 hooks. Fishing effort was at a record high for this relatively new domestic fishery (1996 to present). Catches of albacore, the target species, were down slightly in 1999, totaling 15,000 fish, as CPUE declined to 17.15 fish per 1,000 hooks, the lowest annual CPUE since the inception of the fishery. In contrast, skipjack, yellowfin, and bigeye tuna catches reached record highs in 1999, as did catches of billfishes, mahimahi, wahoo, and sharks. CPUE was higher for skipjack, yellowfin, and bigeye tuna in 1999, compared to 1998. However, yellowfin and bigeye tuna CPUE was highest in 1996.

Economic Research and Hawaii's Charter Fishing Boat Industry – Cooperating JIMAR researcher Edward Glazier presented an interim report on his Hawaii charter boat patron study to the Western Pacific Regional Fishery Management Council's recreational fisheries task force. Information from more than 200 charter boat patrons has been collected so far during the study, providing a broad look at cost and motivation in Hawaii's charter fishing industry. A final report should be available later in the year as another round of canvassing of patrons is completed. Glazier also presented a paper on the social aspects of Hawaii's troll fishery at the Pacific Sociological Association conference in San Diego, California.

IV. EASTERN TROPICAL PACIFIC TUNA FISHERIES

Dolphin-Safe Research Program Activities – Under its Dolphin-Safe Research Program, the La Jolla Laboratory's Protected Resources Division (formerly the Marine Mammal Division) completed its investigations focused on the development of acoustic and optical detection devices capable of detecting and tracking large yellowfin tuna at long ranges. These airborne optical and ship-towed acoustic devices may provide tuna fishermen in the eastern tropical Pacific Ocean (ETP) an alternative to locating tuna associated with dolphins. By concentrating on large yellowfin tuna not associated with dolphins, these optical and acoustic devices could provide a "dolphin-

safe" fishing method that would eliminate dolphin mortality and the bycatch of small tunas, billfishes, sharks, and other species.

Concern over the increase in the use of oceanographic lidar (light detection and ranging) prompted the Dolphin-Safe Research Program to determine its safety regarding marine mammals. A study addressing the potential impacts of the laser energy used in airborne lidar detection systems on marine mammals was completed in 1999 and the results were recently published (Zorn et al., 2000). Based upon an analysis of species-specific lens diameter, focal length, visual acuity, and commonly used laser energies, sensitivity ratios were calculated for several marine mammals. Comparison of these ratios with human eye-safety laser standards indicates that airborne lidar detection systems that the Dolphin-Safe Research Program has investigated do not pose a hazard to the marine mammals examined. Specimens are currently being obtained to expand the number of marine species examined for laser safety determination.

International Dolphin Conservation Program Act (IDCPA) Research – IDCPA research activities during the past year included (1) completion of the second year of research surveys to estimate current abundance of dolphin stocks affected by the tuna purse-seine fishery in the ETP; (2) initiation of a pilot necropsy program to collect tissue samples from dolphins killed during tuna fishing operations; and (3) continuation of an investigation of molecular genetics techniques to identify molecular-level effects of fishery-induced stress in ETP dolphins and to determine cow and calf relatedness in dolphin mortalities from single purse-seine sets. Work continued to complete estimates of abundance for all species of marine mammals sighted on the research cruises and to develop a decision analysis framework and population assessment model to quantify the likelihood that depleted stocks of ETP dolphins are or are not recovering as expected since a dramatic decrease in reported mortalities beginning in 1992.

The research surveys conducted in 1999, named the *Stenella* Abundance Research (STAR99) project, consisted of visual observations of nearly 30,000 nmi of vessel tracklines in the ETP. A total of 1,356 marine mammal sightings were made. In addition to marine mammal sightings, scientists recorded sightings of seabirds and sea turtles. The scientists also conducted helicopter operations to photograph dolphin schools. These photographs are used to calibrate observer estimates of marine mammal school size and for analysis of cetacean lengths and studies of pinniped and seabird colonies. Photographs of cetaceans were also taken from the research vessel and from small boats to verify stock identity and to document geographic variation. Acoustic recordings of cetaceans were made by deploying sonobuoys during sightings. Cetacean tissue samples were collected for genetic analysis as well. Daily sampling of flying fish and other surface organisms was also conducted. Micronekton biomass was sampled between 0 and 500 m depth using active acoustics. Concurrent with these activities, oceanographic data were collected several times a day.

Although the primary aim of these research surveys is to determine abundance of depleted dolphin stocks, this variety of ancillary research projects was included to aid in interpreting the results of the abundance estimation. In order to better evaluate the consistency between previous and current estimates of abundance, this ancillary research was designed to help determine if environmental conditions have changed substantially since previous abundance estimates were produced.

The necropsy program was designed to collect fresh samples from dolphins killed during routine fishing operations. Under the

current pilot program, several technicians have been trained to perform these procedures, and Mexico has agreed to allow these technicians on tuna seiners when space is available. To date, technicians have collected samples from eight specimens, which will be sent to various laboratories for analysis.

The first of the two molecular genetics projects is investigating the ability to assess stress levels from dolphin skin cells. A large historical data bank of dolphin skin samples from the fishery is available for analysis, and samples for these studies continue to be collected from both fishery-affected animals (biopsy samples of animals in the purse-seine net that are collected from fishing vessels) and fishery-unaffected animals (biopsy samples of animals that are collected from research vessels). The second genetics project estimates the potential effect of tuna fishery operations on dolphin cow and calf separation and differential mortality. Results of this study have been submitted for publication and will be included in a report on the NMFS's research program under the IDCPA in 2002.

In 1999, the NMFS completed an initial Report to Congress containing details of the dolphin abundance survey and stress studies completed in 1998. Based on this report, the Department of Commerce made an initial finding, as required by the IDCPA, and determined that there was not enough evidence to show that chase and encirclement by tuna purse-seine fishing significantly harms depleted ETP dolphin stocks (eastern spinner, northeastern offshore spotted, coastal spotted). Accordingly, the IDCPA required the Commerce Department to change the U.S. tuna labeling standard to allow the use of the dolphin-safe label on tuna caught with dolphins if no dolphins were observed killed or seriously injured during the set. In April 2000, however, a federal judge stopped the Commerce Department from loosening the U.S. tuna labeling standard, ruling that the department did not adequately consider preliminary results from stress studies on ETP dolphins before releasing the initial finding. The Commerce Department is reviewing the judge's decision for a possible appeal.

Information about the Report to Congress, IDCPA research results, and the tuna labeling standard is available on the Internet at http://swfsc.ucsd.edu/mm_res.html and http://www.nmfs.gov/prot_res/mammals/tunadolph/tunadolphin.html.

V. SHARK RESEARCH

Satellite Pop-up Tagging of Common Thresher Shark – La Jolla Laboratory scientists conducted a pop-up satellite tagging experiment to track the seasonal migratory pattern and range of the common thresher shark (*Alopias vulpinus*). In June 1999, satellite tags were successfully deployed on eight large thresher sharks released in the Southern California Bight. The tags were pre-programmed to release 60, 120, 210, and 300 days after the deployment date. As of March 2000, five tags have successfully released from their host fish and transmitted location and archival temperature data to an orbiting Argos satellite. Two more tags are scheduled to pop up around mid-April (only one tag so far has failed). The first two tags popped up on schedule two months after tagging, in August 1999—one released from a 246-cm tail length (TL) male thresher shark near the tagging location off Oceanside, California, another from a 240-cm TL female thresher shark 79 nmi off Point Conception, California. Two months later, in October 1999, another tag released from a 260-cm TL male near Oceanside, and a fourth tag released from a 237-cm TL female 290 nmi west of Magdalena, Baja California, Mexico. In January 2000, a fifth tag released from a 255-cm female 540 nmi southwest of La Paz,

Mexico, about 160 miles west of Clarion Island. These results confirm transboundary migration in this species and indicate a more offshore distribution than previously thought for the common thresher shark. This is the first deployment of satellite pop-up tags on a shark species, and the results are especially encouraging, considering this species was once thought to be too large and too delicate to land, tag, and release in good condition. The research will help scientists to better understand the stock structure and migration of this species.

Thresher Shark Food Habits – Last fall contract work began on a common thresher shark food habit study, and as of March 2000, the contract biologist (Antonella Preti) has almost completed examining stomach samples collected from the California and Oregon driftnet fishery during 1998-99. To date, 185 stomach samples have been processed and the following prey items have been identified: northern anchovy, Pacific sardine, Pacific mackerel, California barracuda, Pacific hake, pelagic red crab, louvar, grunion, jack mackerel, shortbelly rockfish, market squid, and euphausiids.

Plans Made for Shark Abundance Survey – La Jolla Laboratory biologists conducted planning sessions during the year to resume the annual fishery-independent mako shark abundance survey in 2000 and to expand it to include a survey of common thresher shark. The shark survey will be part of a multi-project cruise to be conducted by the Fisheries Resources Division during June-July 2000. Changing target methods, fishing areas, and regulatory restrictions over time have resulted in wide swings in catch and distribution effort in the pelagic shark fisheries off California which have previously hampered attempts to determine trends in mako shark abundance. The mako shark index survey is linked to a historical time series of logbook and landings data from a former commercial longline fishery in the Southern California Bight during 1988-91.

Mako Shark Ageing – Work continues on ageing shortfin mako sharks sampled by Japanese longline from widely distributed localities in the Pacific. The purpose of the study is to help clarify age-differentiated movements and the effects of exploitation on the high seas and to help resolve existing problems in interpreting annual periodicity of vertebral circuli. This is a joint study between scientists from Japan's National Research Institute of Far Seas Fisheries and the NMFS La Jolla Laboratory to independently age a sample of about 250 individual mako sharks, mainly subadults and adults, sampled by longline from Japanese research ships in the western and central North Pacific. The data include size, sex, and maturity condition. Preliminary aging has been completed in Shimizu, Japan. At La Jolla, about 60 specimens have been processed by X-ray and acid etching techniques. Tetracycline marking of juvenile sharks off La Jolla has begun as a time calibration (age "validation") experiment to apply to the North Pacific specimens.

International Pelagic Shark Workshop Participation – The Fisheries Research Division's shark research staff was well represented at the February 2000 International Pelagic Shark Workshop that was held in Pacific Grove, California, and sponsored by the Ocean Wildlife Campaign. In addition to four papers presented by division staff, the report "Solving for intrinsic rebound potentials with the Solver program" (Show, 2000) was prepared and made available to researchers at the conference. This publication describes a personal computer, user-friendly method for calculating a variant of the Lotka demographic equation using Microsoft's Excel Solver program and includes a spreadsheet and start-up diskette.

The two demographic papers, "Review of shark intrinsic rates of increase with emphasis on pelagic sharks" and "Shark rebound potentials and reproductive protection for ensuring population viability,"

are part of the Fisheries Research Division's continuing investigation and refinement of the density-dependent demographic method developed at the SWFSC in 1997 to measure the intrinsic rates of increase (*r*) of various shark species under a uniform harvest condition. Each *r*-value or rebound rate represents an estimate of maximum potential growth in a population hypothetically exposed to an estimated level of MSY harvest then allowed to rebound from that condition. In the former paper, rates were calculated for 10 pelagic shark species and one pelagic stingray and compared to other shark species. It was learned that pelagic elasmobranchs have a wider range of rebound capabilities than previously thought, with some of the least productive species ranking with the large coastal sharks in having a very low rebound potential. Although most remaining pelagics fell within the mid-range of the shark productivity spectrum, all values were still low compared to many teleosts. In the latter paper, rebound rates were calculated to compare productivities among sharks and certain large pelagic teleosts such as billfishes and tunas. The paper also showed how shark rebound rates can be used to calculate certain biological reference points and how protecting female sharks, by raising the age at fishery entry, can prevent population collapse while under different exploitation rates. The paper also proposes that an estimated level of MSY harvest of Z_{msy}=1.5M is a mortality level beyond which overfishing would likely occur for most sharks. Some of the small coastal sharks were found to be similar in productivity to certain billfishes and tunas (but not tropical tunas). Protecting female sharks to allow 2-3 reproductive seasons before the beginning of exploitation is shown to substantially protect the more productive sharks (some pelagic and small coastal species) against collapse under high exploitation rates. The reproductive importance of young adults to a population is brought out by the analysis of how their protection can prevent collapse.

The paper "Abundance trends for three exploited pelagic sharks off the U.S. west coast" describes trends in relative abundance of common thresher, shortfin mako, and blue sharks in the California-based driftnet fishery, using data from fisher bridge logs, onboard observer records, and an NMFS fishery-independent relative abundance survey. Results indicate that local thresher shark stocks may be rebuilding after having been overfished during the 1980s. Trends in relative abundance of shortfin mako and blue sharks show a slightly decreasing trend in abundance along with decreased fish size in the catch over the same period.

The paper "Occurrence of the pelagic thresher shark (*Alopias pelagicus*) in the eastern Pacific Ocean" documents the occurrence of the pelagic thresher shark off southern California as evidenced from commercial landing receipts, onboard observer records, specimen collections, and genetic analysis. The pelagic thresher shark is generally more abundant off the Pacific coast of northern Mexico but moves into California waters during periodic warm-water episodes relating to El Niño conditions.

VI. BILLFISH INVESTIGATIONS

The goal of the SWFSC's Billfish Research Program is to provide information for the conservation and rational management of Pacific billfish resources, including sound fishery data analysis and fishery management information and advice for the U.S. fishery management councils and international agencies. The primary objectives for SWFSC billfish research are to monitor recreational and commercial fisheries, to conduct research into the biology and ecology of specific billfish species, to conduct stock assessments, and to determine the economic importance of billfish resources.

The International Billfish Angler Survey and the Billfish Tagging Program produce

essential information about the recreational billfish angling community that is used to explore management concerns. The Angler Survey provides catch and angler effort information from the recreational fisheries. The Billfish Tagging Program provides much-needed data on the biology, distribution, and migration rates of these far-ranging species. Both investigations rely on continued cooperation from billfish anglers, sportfishing clubs, commercial fishers, and agencies affiliated with the Center.

The International Billfish Survey – The *International Billfish Angler Survey* began in 1969 and now provides a 31-year time series on recreational anglers' billfish catch and fishing effort. The information developed from this survey is used to indicate trends in angler catch rates in specific areas in the Pacific and Indian Oceans. Trends produced by the survey help us monitor the impact of pelagic fisheries and highlight the importance of recreational fishing for billfish.

In 1999, 617 billfish anglers reported catching 3,738 billfish during 8,013 fishing days. The overall CPUE (measured in catch per day fished) was 0.47 billfish per angler-day in 1999, compared to 0.42 billfish per angler-day in 1998. The total number of angler-days reported for 1999 was nearly the same as in 1998, when anglers reported catching 3,715 billfish during 8,748 days of fishing. The 1999 overall catch rate equals the prior five-year average catch rate of 0.47 billfish per angler-day (1994 to 1998). The highest reported catch rate (0.57 billfish per angler-day) occurred during the first years of this survey (1969 to 1971). The lowest catch rates occurred in the mid-1970s and averaged about 0.34 billfish per angler-day.

The Billfish Tagging Program – The Billfish Tagging Program began as the Cooperative Marine Gamefish Tagging Program in 1963. Release and recapture data from tagged billfish are used to determine movement, distribution, and growth patterns of billfish. This angler-based tagging program depends on the participation and cooperation of recreational anglers, sportfishing organizations, and commercial fishers. According to billfish tagging report cards received in 1999, a total of 641 billfish were tagged and released by 486 anglers and 158 fishing captains. This is 3% more tag releases than in 1998. The number of striped marlin and sailfish tagged in 1999 decreased, while the number of blue marlin and shortbill spearfish tagged increased. Increased tagging was also noted for bluefin tuna.

Each year the tagging program gratefully recognizes the anglers, captains, and fishers who tag and release billfish. Individual recognition of each angler who reported tagging two or more billfish in 1999 will be published in the annual Billfish Newsletter. Captains of charter and private boats who tagged significant numbers of billfish in 1999 also will be recognized in the newsletter.

Billfish Tag Recoveries in 1999 – Thirteen recaptures of billfish were reported in 1999, including one striped marlin, four blue marlin, seven sailfish, and, for the first time, one shortbill spearfish. Two bluefin tuna and two common thresher sharks were also recaptured. All four blue marlin recaptured in 1999 were tagged in Hawaii; they were at liberty from 21 to 25 days and moved less than 368 nmi. All of the sailfish were tagged and recaptured in the Persian Gulf; they had moved northwest from near Abu Dhabi, United Arab Emirates, and were at liberty for up to 481 days. The shortbill spearfish was tagged off Kona, Hawaii, and recaptured a month later 173 nmi to the north.

The Center's Billfish Tagging Program participates with AFTCO's Pacific Tag-Flag Tournament and now supports tagging of bluefin tuna. Two tagged bluefin tuna were recaptured last year. One tuna traveled north from Cedros Island, Baja California, Mexico, to Monterey, California, a distance of 612 nmi in 66 days. The second tuna moved 57 nmi

in 28 days.

Pacific Federal Angler Affiliation for Pacific Billfish (PacFAAB) – Pacific billfish will soon be included in an international fisheries convention and U.S. fishery management plans. Information on vital rates, trends in abundance, and stock boundaries is crucial for the effective management of Pacific billfish resources. Stock assessments have not been conducted for most billfish species since 1989, however, and little progress has since been made because of research costs associated with gaining access to the resource. The rarity of billfish encounters and difficulties of capture dictate that an alliance between fishermen and scientists is the only way to improve knowledge of these stocks. Billfish anglers have the greatest access to the fish and are in a position to help in the collection of fishery-independent data and biological specimens needed to assess Pacific billfish resources.

The SWFSC started the PacFAAB to improve stock assessments of Pacific billfish by increasing baseline data on billfish movements, growth, reproduction, and tagging mortality through a research collaboration between recreational billfish anglers, Mexican fishery scientists, the California Department of Fish and Game, and the SWFSC. A workshop was held at the Balboa Angling Club in Newport Beach, California, during August 1999 to define needed billfish research activities and to develop a research plan for conducting a new billfish stock analysis. The consensus of the workshop was that a cooperative program between California billfish anglers and their organizations and the governments of Mexico and the United States has great potential for improving the level of knowledge on Pacific billfish and reducing the risk of ineffective management. Partnership with Mexico is important because most of the U.S. west coast recreational catch of billfish is taken in Mexican waters.

The resulting report (Hunter and Holts, 1999) summarizes the workshop presentations and recommendations and provides a draft research plan based on this information. The plan describes how such a cooperative, angler-based research program could improve Pacific billfish stock assessments by providing new information on vital rates, trends in abundance, stock boundaries, and tagging stress. The scientific approach would build upon and greatly expand the kinds of information collected by the SWFSC's successful angler tag and release program while preserving the strong conservation ethic of the program.

VII. OTHER ACTIVITIES

Highly Migratory Species Management Plan – The Pacific Fishery Management Council began work during the past year on a management plan for highly migratory pelagic species fisheries off the west coast. Highly migratory pelagic species include tuna, swordfish, and marlin, and some species of sharks.

In its June 1999 decision to proceed with development of a management plan, the council acknowledged that there were no clearly identifiable fishery conservation problems for highly migratory species that warranted immediate new Federal regulations, but recognized that there may be coastwide problems in the future that would warrant such regulations. The plan will provide a mechanism for effective interstate action to resolve west coast highly migratory species fishery conservation and management problems as well as a framework for interstate and regional cooperation in the collection, management, and analysis of information to monitor the highly migratory species fisheries and to identify fishery problems. At the international level, the plan will provide a mechanism to furnish information and advice needed by the U.S. State Department for international

negotiations and conservation decision-making affecting U.S. highly migratory species fishery interests.

Commercial fisheries for highly migratory species off the U.S. west coast or based on the west coast target several species using different types of fishing gear: (1) albacore, using troll, driftnet, longline, and set net gears; (2) tropical tunas (yellowfin, skipjack, and bigeye tuna), using purse-seine, pole-and-line, and longline gears; (3) swordfish and sharks, using driftnet, longline, and harpoon gears; and (4) northern bluefin tuna, using purse-seine gear. Moreover, west coast-based vessels fish for these species beyond the U.S. 200-mile Exclusive Economic Zone.

West coast recreational fisheries for highly migratory species target albacore, yellowfin, skipjack, bigeye, and bluefin tunas, striped marlin, and mako, blue, and thresher sharks. The recreational fisheries are composed of private angler vessels and charter vessels (also known as head boats and commercial passenger fishing vessels).

The Pacific Council has assembled a team made up of scientists from the state fisheries agencies of Washington, Oregon, and California and the NMFS La Jolla Laboratory to develop a management plan for highly migratory species. The team has held regular public meetings since December 1999 and, with direction from the council and input from an advisory panel and interested parties, has made considerable progress on an outline and draft sections of a fishery management plan that address the requirements of the Magnuson-Stevens Fishery Conservation and Management Act and other laws. The team is developing a list of species to be included in the fishery management plan and is compiling life history and essential fish habitat information on these species, as well as information about landings by species and fishing gears. Progress reports on the highly migratory pelagic species plan development process can be found on the Internet at http://www.pcouncil.org.

VIII. SWFSC PUBLICATIONS ON TUNA AND TUNA-RELATED SUBJECTS

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