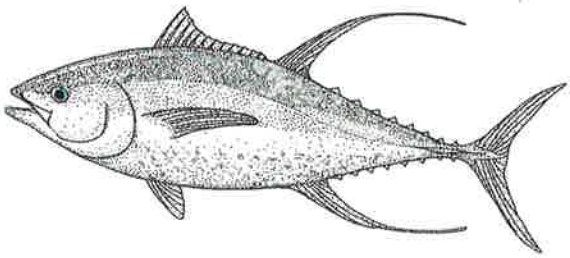
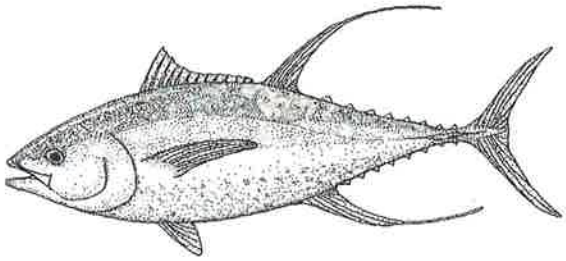
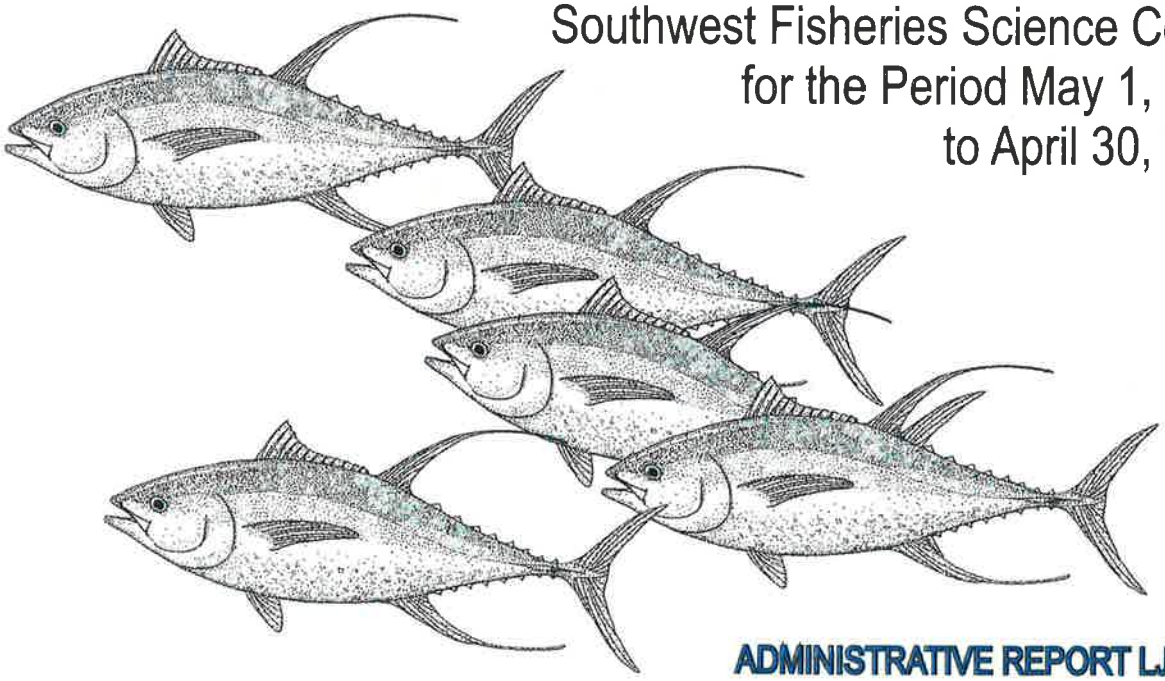
National Marine Fisheries Service
Southwest Fisheries Science Center

Director's Report to the 56th Tuna Conference





On Tuna and
Tuna-Related Activities at the
Southwest Fisheries Science Center
for the Period May 1, 2004
to April 30, 2005



ADMINISTRATIVE REPORT LJ-05-04

DIRECTOR'S REPORT TO THE 56th TUNA CONFERENCE ON TUNA AND TUNA-RELATED ACTIVITIES AT THE SOUTHWEST FISHERIES SCIENCE CENTER FOR THE PERIOD MAY 1, 2004 to APRIL 30, 2005

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ADMINISTRATIVE REPORT LJ-05-04

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Introduction

This report highlights research activities conducted by the Southwest Fisheries Science Center relating to tropical tunas, albacore, billfishes, oceanic sharks, and protected species associated with their fisheries. The sections that follow provide informal summaries of research activities that took place at the La Jolla Laboratory since last year's Tuna Conference. The biological, economic, and oceanographic research was focused on supporting the information needs of regional fishery management councils, international scientific working groups and committees, and the National Marine Fisheries Service. Major tuna-related activities included stock assessments, socio-economic research, research on interactions between fisheries and protected species, and mathematical modeling of fish movements and fishery interactions. The data collection and analysis were aimed at maintaining healthy U.S. and world fisheries, populations of protected marine species, and fish habitat, and ensuring that the most effective fishing regulations and international treaties are carried out. In addition, Center scientists were active 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 Tuna and Billfish, and the Western and Central Pacific Fisheries Commission.

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May 2005
La Jolla, California

I. U.S. FISHERIES FOR LARGE PELAGICS IN THE CENTRAL AND WESTERN PACIFIC

U.S. fisheries for pelagic fishes in the central-western Pacific Ocean continue to be important components of local and regional economies. Most of the fish stocks targeted by these fisheries appear to be healthy, unlike many exploited fish populations around the world. Recent assessments indicate that the stocks of bigeye, yellowfin, skipjack, and albacore tunas targeted by U.S. fisheries in the central-western Pacific are not overfished, although for some overfishing is occurring. The aggregate catch from some tuna stocks, however, may be approaching the maximum sustainable yield. Likewise, recent assessments for North Pacific swordfish and Pacific blue marlin, while preliminary, indicate that these stocks are not overexploited. The high level of cooperation among scientists of Pacific Island nations and distant-water fishing interests enhances the prospects for regular data sharing, stock assessments, and monitoring of the international fisheries for highly migratory fish stocks in the region.

U.S. Tuna Purse Seine Fishery in 2004 – The National Marine Fisheries Service (NMFS) collects and manages data from the U.S. purse seine fishery for tropical tunas in the central-western Pacific, as part of U.S. obligations under the South Pacific Regional Tuna Treaty. The NMFS Pacific Islands Region field office in American Samoa collects information from the U.S. vessels licensed to fish under the treaty. The data are transmitted to the Southwest Fisheries Science Center (SWFSC) in La Jolla, California, where scientists computerize logbook, landings, and biological data from the fleet to monitor the fishery's performance.

The U.S. fleet size in 2004 fell to the lowest level since the start of the treaty in 1988. Only 22 U.S. vessels obtained treaty fishing licenses in 2004 and of those, only 21 vessels actually fished. This is down from 49 licensed vessels at the peak in 1994. The decrease in fleet size in 2004 also contributed to the lowest recorded catch (67,400 metric tons, t) since the beginning of the treaty. The 2004 catch decreased 23% from levels reported in 2003 (87,900 t). Skipjack tuna dominated the 2004 catch (69%) as in previous years, followed by yellowfin tuna (24%), and bigeye tuna (7%).

Mild El Niño conditions affected fishing in 2004, causing the fleet to fish farther east and over a larger portion of the central-western Pacific than in 2003. Sets on floating objects (logs and fish aggregation devices) in 2004 were dominant at 73% of all sets, an increase from 50% of all sets recorded in 2003. Sets on free-swimming schools of tuna accounted for only 27% of the sets in 2004, a decrease from 50% in 2003.

Fishing was centered farther eastward in 2004 and this affected fleet performance. Days-at-sea per trip in 2004 were the highest recorded since the start of the treaty, as vessels had to travel farther to find fish. Because of longer trips at sea, the average number of trips per vessel was also the lowest recorded since 1988 and was 25% lower than in 2003. The overall catch rate declined to the lowest level (16 t per day) since the start of the treaty and 11% lower than the catch rate in 2003.

Biological samples collected from the tuna catch provided estimates of total landings on a species-by-species basis. Logbooks and landings data were collected from 100% of the U.S. purse seine fleet in 2004, and length measurements and species composition samples were taken from 21,100 yellowfin, skipjack, and bigeye tunas.

II. STANDING COMMITTEE ON TUNA AND BILLFISH

The 17 th meeting of the Standing Committee on Tuna and Billfish was held in Majuro, Marshall Islands, August 9-18, 2004. This meeting, hosted by the Marshall Islands government and organized by the Secretariat of the Pacific Community, was the last meeting in a series that began in 1988. Starting in 2005, the Scientific Committee of the new Western and Central Pacific Fisheries Commission will assume responsibilities of the Standing Committee on Tuna and Billfish.

Participants at the meeting were from 23 countries and five regional and international organizations. SWFSC Assistant Director Gary Sakagawa participated on the U.S. delegation. The main task of the meeting was to review stock assessment research results and information for determining the stock status of primarily yellowfin tuna, bigeye tuna, and skipjack tuna of the central-western Pacific and albacore of the South Pacific. The results of the review, which included comparison with biological reference points, indicated that both skipjack tuna and South Pacific albacore are at high biomass levels and not overfished. Fishing levels on these stocks are modest to moderate and overfishing is not taking place. Yellowfin tuna and bigeye tuna, on the other hand, are at high biomass levels owing to recent good recruitment, but fishing levels are also high, resulting in overfishing. Although these stocks are not in an overfished state, the participants advised that no increase in the fishing mortality rate (particularly on juvenile fish) from the current rate should be allowed.

III. INTERIM SCIENTIFIC COMMITTEE FOR TUNA AND TUNA-LIKE SPECIES IN THE NORTH PACIFIC OCEAN

The 5th meeting of the Interim Scientific Committee was held in Tokyo, Japan, March 28-30, 2005. Members in attendance were from Canada, China, Chinese-Taipei, Japan, Korea, Mexico, and the United States, as well as the Inter-American Tropical Tuna Commission and Secretariat of the Pacific Community. SWFSC Director William Fox led the U.S. delegation, which consisted of scientists from the NMFS Southwest and Pacific Islands Fisheries Science Centers and the Western Pacific Fishery Management Council and staff members from the NMFS Southwest and Pacific Islands Regions and the U.S. State Department. Participants reviewed fisheries information and progress with research by members. The status of albacore, bigeye tuna, and yellowfin tuna stocks was also reviewed. The review concluded that the current fishing mortality for all of these stocks is high and likely exceeding the rate desired for maximum sustainable yield. Furthermore, the bigeye tuna stock in the eastern Pacific appears to be in an overfished state and requires a reduction of about 38% in fishing mortality for recovery to a level that would produce maximum sustainable yield.

Among administrative matters agreed to by the participants was a name change for the organization. The new name is International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean. Because of concerns about increasing fishing in the North Pacific and the effects on the stocks, participants agreed that the Committee would meet annually, at least for the next few years, instead of every two years as specified in the Committee's rules and procedures. SWFSC Assistant Director Gary Sakagawa was elected to serve as the new Committee chairman and Jeong-Rack Koh of Korea was elected vice-chairman.

IV. ADVANCES MADE IN HIGHLY MIGRATORY SPECIES DATA COORDINATION

A data coordination team has been working since 2002 towards better coordination of highly migratory species (HMS) data collected and maintained at the NMFS Pacific Islands Fisheries Science Center, Pacific Islands Region, Southwest Region and SWFSC. The team is co-chaired by staff from the Southwest and Pacific Islands Fisheries Science Centers. During September 2004, the team met to discuss progress on resolving issues that were identified at its first annual meeting and to identify any new issues. Significant progress has been made on establishing a data portal (*http://swfscdata.nmfs.noaa.gov*) for sharing information and for allowing public access to summary information. The site contains an HMS data catalog with metadata descriptions and summaries of each data set maintained by the members. Meeting minutes, data submission guidelines, minimum requirements for data collection, and data management policies are also available on the site, which is still under development. Special working groups currently are looking at data management and collection guidelines and are continuing work on completing a data catalog. The next annual meeting of the HMS data coordination team is scheduled for August 2005 in Long Beach, California.

The team has been also working closely with the national Fishery Information System (FIS) project in Washington, D.C. Several team members participated in the second annual FIS meeting in August 2004 in Seattle, Washington. With FIS financial support, the team has improved computer hardware and communication capabilities of facilities maintaining databases. A data reconciliation project has been started to reconcile logbook data with Pacific Coast Fisheries Information Network landings data and cannery receipts databases. Reconciliation of these data will increase data quality substantially. An observer database developed at the Pacific Islands Fisheries Science Center and used by the Pacific Islands Region is being transferred to the Southwest Region for its longline observer data. A permits system developed by the FIS also has been installed at the SWFSC and loaded with permits for the new West Coast HMS fishery management plan. Permits from this system will be issued beginning in April 2005. The FIS also has contributed funds to load central-western Pacific purse seine legacy logbook, landings, and length and species composition data, and applications to the new SWFSC Oracle database that is being used for storage of logbook, size measurement, tagging, catch and landing, and other types of fishery-related data. Twelve other legacy datasets are being loaded to the system with assistance from FIS Oracle contractors.

The SWFSC's HMS information technology specialists are also improving data collection methods. Electronic calipers (1.6 m) have been purchased that will capture length measurements electronically and archive the data on a handheld computer for later transmittal to the SWFSC. The prototype calipers and handheld computer will be tested during the 2005 North Pacific albacore season by port samplers in San Pedro, California. If tests go as planned, more calipers will be purchased and tested on a larger scale, commencing in Washington, Oregon, and California. This tool should increase sampling efficiency and eliminate transcription errors that are concerns in hard copy length-frequency collection procedures. HMS staff members have also developed a stand-alone electronic logbook software application that will be deployed and tested onboard a volunteer group of U.S. albacore troll vessels during the 2005 fishing season. Vessel captains will enter data directly to the application. The daily records will be stored on disk and transferred to the SWFSC upon completion of a trip.

V. PACIFIC ALBACORE FISHERIES

U.S. troll vessels have fished for North Pacific albacore since the early 1900s and for South Pacific albacore since 1986. North Pacific albacore fishing areas range from Vancouver Island to the coast of Baja California and from the U.S. West Coast to approximately 160°E. The fishing season begins in late April and can last into early November. The size of the troll fleet ranges from 500 to more than 1,000 vessels. Approximately 718 U.S. troll vessels fished for North Pacific albacore in 2003.

South Pacific albacore fishing areas extend from the east coast of New Zealand to approximately 110°W. This fishery begins in late December and continues until early April. The international troll fleet in the South Pacific consists of 20 to 60 vessels. Fourteen U.S. troll vessels fished for albacore in the South Pacific during the 2002-03 season. Bycatch is sometimes reported in vessel logbooks, including yellowtail, dolphinfish, and skipjack, yellowfin, bigeye and bluefin tunas.

Landings obtained from U.S. West Coast states, logbook data collected from cooperating fishermen, and length-frequency data obtained through port sampling from U.S. albacore troll and baitboat vessels operating in the Pacific Ocean are routinely processed by the NMFS for use in stock assessments and for fishery monitoring. Logbooks are provided by the SWFSC to fishermen, who record fishing information and return the logbooks to the SWFSC. Beginning in April 2005, logbooks will become mandatory under the requirements of a new HMS fishery management plan. Length-frequency data are collected through a Pacific States Marine Fisheries Commission contract to Washington, Oregon, and California state fisheries agencies and from the NMFS office in American Samoa. Statistics from these sources were analyzed during the year by SWFSC staff and summarized in a report issued in August 2004. Highlights of the report are given below.

Summary of U.S. North and South Pacific Albacore Troll Fisheries – U.S. troll vessels landed 17,237 t of North Pacific albacore in 2003, compared to 10,387 t landed in 2002. Annual catches over the last 10 years averaged 12,316 t. The most productive fishing areas in 2003 were in waters off Washington and Oregon and offshore near 170°E. U.S. catches of South Pacific albacore increased from 1,218 t in the 2001-02 season to 1,678 t in the 2002-03 season. South Pacific catches averaged 1,830 t over the past 10 years.

Catch per unit of effort (CPUE) in the North Pacific fishery has fluctuated greatly since 1995. CPUE increased from 67 fish per day in 2002 to 78 fish per day in 2003. Total effort remained the same as in 2002, at 25,398 days fished. CPUE for the South Pacific fishery increased from 46 fish per day in 2001-02 to 103 fish per day in 2002-03, while effort decreased from 3,602 days fished to 2,245 days fished during the same periods.

A total of 11,933 albacore were measured during the 2003 North Pacific season. The average fork length of sampled albacore in 2003 was 75 cm (19 lb or 8.6 kg), compared to 67 cm (14 lb or 6.7 kg) in 2002. Two size-class modes were evident at 65 cm (3 years old) and 81 cm (4 years old) fork length in the North Pacific length-frequency samples.

During the 2002-03 South Pacific season, a total of 1,229 albacore were measured. The average fork length of South Pacific albacore that were sampled was 71.0 cm (16 lb or 7.3 kg), the same as the 2001-02 season. Because of the low sample size, individual size-class modes were difficult to distinguish.

Cooperative Research with the American Fishermen's Research Foundation – SWFSC scientists are working in cooperation with the American Fishermen's Research Foundation on ongoing monitoring programs and other research efforts to improve knowledge of the biology of North Pacific albacore in the waters off the U.S. Pacific Coast. The cooperative research includes:

North Pacific Albacore Biological Data Sampling Program – Since 1961, a biological data collection program, or port sampling program, has been in place for collecting size data from albacore landings made by the U.S. and Canadian troll fleets at ports along the U.S. Pacific Coast. The biological data are collected by personnel from state fishery agencies (Washington, Oregon, and California) who follow sampling design and data processing instructions from the SWFSC, where the database is maintained. Roughly 189 fishing trips and 11,933 fish were sampled in 2003. In recent years, biological data have also been collected by fishermen during selected fishing trips to augment data collected through the port sampling program. After a training session, fishermen acted as biologists and provided a randomly selected length distribution for selected fishing trips which landed catches at ports in California, particularly northern California sites where no port sampling was in place. Participation in this program has not been high to date, with fewer than 500 length measurements taken. American Fishermen's Research Foundation members and SWFSC scientists designed new measurement kits in 2004 for the fishermen and began promoting increased participation in the coming seasons. The sample information provided by the fishermen was found to be generally similar to that collected through the port sampling program.

North Pacific Albacore Logbook Data Sampling Program – A logbook sampling program also has been in place since 1961, whereby albacore troll fishermen voluntarily submit their fishing records to the SWFSC. The implementation of a new HMS fishery management plan in 2005 will require the submission of a logbook from each trip that a participant in the fishery makes. These data are primarily used to develop relative indices of abundance, which subsequently provide valuable auxiliary information for fine-tuning stock assessment models. Fishing records are submitted to state fishery agency staff or directly to the SWFSC. In 2003, 342 logbooks were submitted by the U.S. troll fleet. A database for logbook data is also maintained at the SWFSC.

North Pacific Albacore Archival Tagging Project – A long-term archival tagging project was undertaken during the 2001 albacore fishing season to document details regarding North Pacific albacore biology that are currently only generally understood (i.e., to determine exact migration routes of juvenile fish, 2-5 years old, and to determine time, temperature, and depth characteristics of the migrating fish). The project was structured as a five-year program that entails tagging approximately 120 fish in each of the years 2002-05 for a total deployment of 500 tags.

In the pilot year (2001) of the project, 15 archival tags were deployed over a three-week period in October-November. Because of limited funding, only four archival tags were deployed in 2002. In 2003, program objectives were met with the deployment

of 43 dummy tags (similar to archival tags but without the internal electronics for recording data) and 97 archival tags during three tagging trips. All deployments were made off the coasts of southern California and northern Baja California, Mexico, during the months of July-November. In 2004, 118 archival tags were deployed during three tagging trips. All but 20 of the 2004 deployments were made in the waters off Oregon and Washington in areas where juveniles (ages 2-4) are targeted commercially. The fish, ranging from 57 to 110 cm fork length, were captured near the surface on hand lines or rod and reel. In total, 234 archival tags and 43 dummy tags have been deployed.

Ten archival tags were recovered by commercial and sport fishermen during summer 2004, bringing the number of archival tags returned to 11. The data are beginning to demonstrate areas of importance to animals visiting southern California waters in the summertime. Most fish remained near the coasts of southern California and Baja California, however, three albacore ventured offshore to an area near 27°N, 134°W during the same time period before returning to near-coast areas where they were recaptured. All fish exhibited a similar diurnal diving pattern of repetitive deep diving during the day while remaining near the surface at night. Dives routinely exceeded 200 m in depth. At the extreme, one fish dove to a depth of 1,200 m. The large number of tag recoveries within a short time period was an unexpected surprise.

The last two years of the tagging project have been very successful. As more tags are returned, the data will assist in refining our knowledge of the North Pacific albacore stock structure and habitat use patterns, information that is essential to improving stock assessments. During fiscal year 2005, the tagging team plans to deploy an additional 120 tags off the Oregon and Washington coasts.

International Collaboration on North Pacific Albacore Research – The SWFSC represented the United States at the 19th North Pacific Albacore Workshop, held in December 2004 in Nanaimo, B.C., Canada. Fifteen researchers from Japan, Taiwan, Canada, Mexico, the NMFS Pacific Islands Fisheries Science Center, the Inter-American Tropical Tuna Commission, and the Secretariat of the Pacific Community attended the meeting. Researchers from the SWFSC La Jolla Laboratory presented papers that addressed various topics, including formal stock assessments of the albacore population that inhabits the North Pacific Ocean, issues surrounding the Workshop's scientific information exchange and centralized databases, ongoing development of fishery statistics applicable to the U.S. troll and longline fisheries, and ongoing research regarding movement and distribution of juveniles based on archival tag deployments.

SWFSC researchers were integrally involved in a primary goal each year of the Workshop, namely, to provide estimates of important stock parameters based on fishery modeling efforts and ultimately, to develop Workshop consensus concerning the status of the stock at large. Estimates of historical abundance and fishing pressure associated with the albacore population were generated using fishery models based on 'backward-simulation' methods (virtual population analysis, VPA) and subsequently, determination of 'biological reference points' and projections involved uncertainty analysis based on four model configurations. That is, inherent uncertainty surrounding current levels of both stock 'productivity' (i.e., recruitment, *R*) and fishing pressure (i.e., fishing mortality, *F*) was evaluated as follows: (1) 'low productivity'/'low *F*'; (2) 'low productivity'/'high *F*'; (3) 'high productivity'/'low *F*'; and (4) 'high productivity'/'high *F*'.

'Low productivity' represented the mean recruitment for the period 1975-89 (R = 22.5 million recruits), whereas 'high productivity' was defined as the mean R for the period 1990-2000 (R = 31 million recruits; Fig. 1). For 'low F', fishing mortality was assumed to be 0.43 (i.e., arithmetic mean of ages 4-9+ in 2003), whereas the 'high F' hypothesis was based on an F of 0.68 (i.e., mean estimates of ages 7-9+ in 2003).

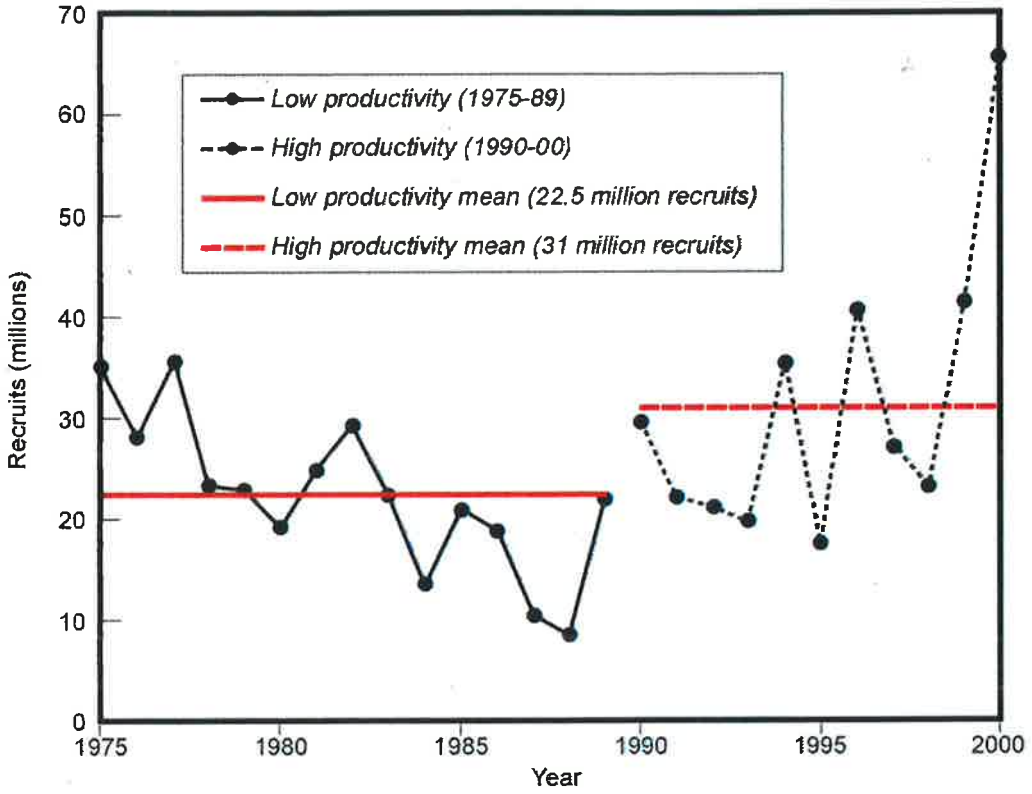

Figure 1. Recruitment (age-1 fish in millions) time series of North Pacific albacore generated from North Pacific Albacore Workshop stock assessment. Time series illustrate 'low' (1975-89) and 'high' (1990-2000) productivity scenarios assumed in uncertainty analysis. Mean recruitments for each period used in projection analysis are also presented.

Results from VPA-based (VPA-2BOX model) analyses indicated that albacore population abundance remains at relatively high levels (roughly, 450,000 t), particularly compared to levels observed during the late 1970s through the 1980s (Fig. 2). However, estimates of fishing pressure in recent years were relatively high, which translated to projected (2005-10) levels of both total stock biomass and spawning stock biomass that were generally not within (or at the lower end of) maximum sustainable yield ranges. Depending on the 'current' level of F assumed in the uncertainty analysis (see above), the population is being fished between roughly $F_{17\%}$ and $F_{30\%}$ (in general, spawning potential ratios considered 'minimum' biomass thresholds for many fisheries). However, it is important to note that strict management-based biological reference points have not been formally identified for North Pacific albacore at the present time, and thus it is likely that in the future, sustainable versus overfishing thresholds for this species, as well as for tuna stocks in general, will receive concerted attention.

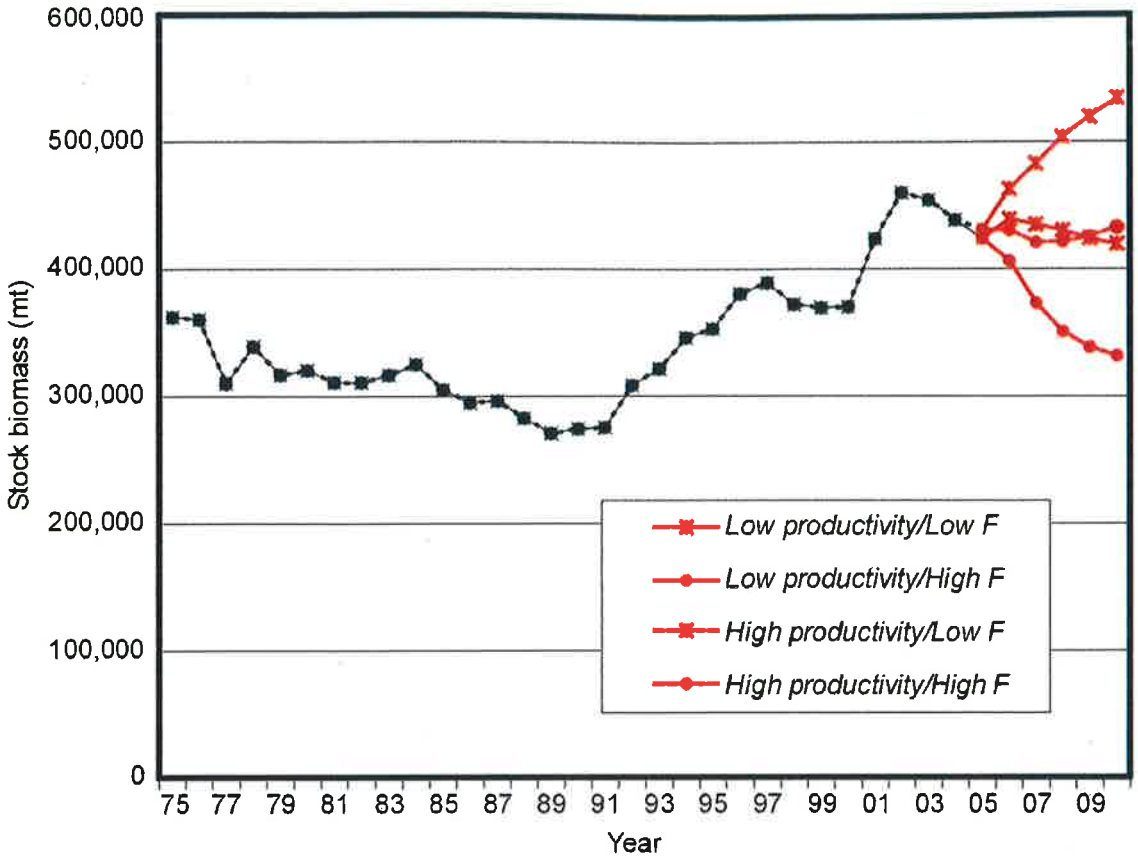

Figure 2. Total stock biomass (metric tons) time series (1975-2004) for North Pacific albacore generated from the North Pacific Albacore Workshop stock assessment. Projection estimation (2005-10) was based on uncertainty analysis involving productivity periods and assumptions regarding fishing mortality (*F*) within each productivity period: (1) 'low productivity'/'low *F*' scenario; (2) 'low productivity'/'high *F*' scenario; (3) 'high productivity'/'low *F*' scenario; and (4) 'high productivity'/'high *F*' scenario.

The SWFSC research team also presented preliminary results from statistical modeling research using 'forward-simulation' methods (ASAP and MULTIFAN-CL platforms). These models generally allow much greater flexibility than the VPA-based analysis described above. That is, these 'predictive' (versus 'historical') models accommodate detailed evaluations of each fishery's dynamics, including issues surrounding catchability and selectivity, as well as allowing recruitment to be more objectively examined than is generally possible using VPA methods. The alternative fishery models produced generally similar trends as the VPA-based models for important management stock parameters, such as biomass, spawning stock biomass, and recruitment. Although substantial progress has been made with these fully integrated models, further work is needed, including rigorous examination of underlying assumptions regarding stock structure, input data (including tag-related information), and comparison/contrast of results with Workshop-consensus VPA methods. Note that given the pan-Pacific Ocean distribution of this fish population and associated fisheries, all past and future stock assessment research is inherently a collaborative effort between a host of nations within the Workshop forum. In this context, the Workshop has recommended that its next formal meeting be held during fall 2006, with an intersessional meeting tentatively scheduled for fall 2005.

U.S.-Canada Albacore Treaty – A paper on the 2004 U.S. North Pacific albacore troll fishery was presented at the annual U.S.-Canada Albacore Treaty consultation in Long Beach, California, in April 2005. The SWFSC paper reviewed albacore landings, effort, CPUE, and fish size distribution in 2003, detailed U.S. catches in Canadian waters (<1%), and gave a brief status of the North Pacific albacore stock.

The NMFS published regulations necessary to implement treaty amendments agreed to by Canada and the United States to better regulate fishing for albacore tuna in the Pacific during the 2004 fishing season. The proposed rule established vessel marking, recordkeeping, and reporting requirements for U.S. albacore fishing vessel operators and vessel marking and reporting requirements for Canadian albacore fishing vessel operators under the treaty. The intended effect of this proposed rule is to allow the United States to carry out its obligations under the treaty by allowing fishing by both U.S. and Canadian vessels in the other country's exclusive economic zone (EEZ) as provided for in the treaty.

The revised treaty includes an initial three-year reciprocal fisheries limitation regime that would reduce the fishing effort each year until a level is reached in the third year that is slightly above the pre-1998 average level of fishing. The fishing limitation can be adjusted by agreement to accommodate changing conservation and fishery management needs. The mutually agreed upon fisheries limitation regime started June 1, 2004. During the first year, U.S. vessels fishing in Canadian waters and Canadian vessels fishing in U.S. waters were limited to 680 vessel-months or 170 vessels, each limited to four months. Vessels are to report entry and exit into the fishing zones. During 2004, U.S. vessels used less than 5% of their vessel-month allocation and Canadian vessels used all of theirs. The number of vessel-months will decrease to 560 during the 2005 season and to 500 in the 2006 season.

VI. EASTERN TROPICAL PACIFIC OCEAN TUNA FISHERIES

International Dolphin Conservation Program Act (IDCPA) research conducted by the SWFSC during 2005 was focused to determine the potential roles of the fishery and ecosystem in the lack of recovery by depleted eastern tropical Pacific (ETP) dolphin stocks. Activities included data analyses, processing and publication; initial planning with the Inter-American Tropical Tuna Commission for a pair of workshops on bycatch reduction; and longer-term research planning.

Data Analyses, Processing, and Publication – SWFSC investigations of dolphin stocks historically depleted by the ETP tuna purse seine fishery (pantropical spotted and spinner dolphins) are conducted with an ecosystem approach. In addition to investigating the status and trends of these dolphin stocks, auxiliary projects are conducted to improve our understanding of their surrounding environment. Data analyses, processing, and publications in 2004 included direct work on depleted ETP dolphin stocks, investigations of dolphin energetics, research on non-target and non-depleted ETP cetaceans, a review of ETP oceanography, and development of a data management system for our ecosystem data.

Depleted Dolphin Stocks – The SWFSC conducted line-transect research cruises in 1986 through 1990, 1998 through 2000, and 2003 to investigate pantropical spotted and spinner dolphin stocks. From data collected on these cruises, abundance

and trends of these stocks were estimated and evaluated through 2000. Line-transect sightings data from the 2003 monitoring cruise were carefully edited and processed, with analyses begun during 2004. Updated abundance estimates are being completed now in 2005.

In addition to the line-transect survey, aerial photogrammetry work was conducted on these cruises in order to calibrate observer estimates. Aerial photographs were also analyzed for calf production and length at independence for both spotted and spinner dolphins.

Further research was conducted by the SWFSC on data collected by fishery observers on ETP tuna purse seine vessels. The unobserved kill of spotted dolphins in purse seine sets from 1973-90 and 1996-2000 was estimated annually. These estimates were based on mothers killed in sets without their calves, and they increased the reported kill of dolphins by about 14% in each year. The chase and capture of dolphins in the purse seine fishery may also lead to fetal mortality by physiological stress and/or energy depletion causing miscarriage. Fetal mortality was estimated for spotted and spinner dolphins and it was estimated that total mortality from conception to birth ranged from 78% to 87%. Stomach contents of spotted dolphins killed in the fishery were analyzed to model the weaning process of calves and to determine diet. A better understanding of the weaning process, especially quantifying the period of time when calves are nutritionally dependent on their mothers, may lead to a better evaluation of their potential vulnerability to the disturbance caused by the purse seine fishery. Additionally, age distributions were constructed for female eastern and whitebelly spinner dolphins incidentally killed in the purse seine fishery to better understand their life history.

Dolphin Energetics – Several studies on dolphin energetics (hydrodynamics and drafting) were conducted in 2004 to investigate the potential effects of high-speed chase by the purse seine fishery on dolphin mother and calf pairs. A study of dolphin calf hydrodynamics was initiated to examine the possibility that age-related constraints on calf swimming performance is a significant contributing factor in the calf deficit observed in tuna purse seine set mortality records. For this study, digital video was collected at Dolphin Quest in Hawaii of dolphin calves and mothers swimming together and alone at various velocities, for calf ages from birth through one year of age. The first mathematical examination of the physical basis for drafting by dolphin calves was completed and published. This analysis, backed by observations of free-swimming dolphin schools, indicates that hydrodynamic interactions with mothers play an important role in enabling dolphin calves to keep up with rapidly moving adult school members. A study estimating duration limits for sustained unassisted swimming at various speeds by spotted dolphin calves was submitted for publication. A review of dolphin behavioral and physiological ontogeny, with respect to potential effects on dolphin calf separation during chase by tuna purse seiners will be complete after final editing. Additionally, a proposal was developed to extend dolphin hydrodynamics work to examine the specific conditions likely to pertain during attempted escape from tuna purse seine sets, including the effects of high-speed maneuvering on dolphin calf drafting. The proposal is ready to implement, contingent upon funding.

Non-depleted ETP Cetaceans – Various data on ETP cetaceans not targeted by the tuna purse seine fishery were analyzed and submitted for publication in 2004. One such study was on the life history of ETP common dolphins, the third most frequently killed cetacean in the ETP tuna purse seine fishery. Prior to this study, a

comprehensive life history study of ETP common dolphins had not been done. This research utilized biological samples collected by fishery observers, with data going back to the early 1970s. Specifically, this study posed three primary questions: (1) can age estimations and archiving of tooth slides be improved through the use of an image analysis system; (2) what are the growth and reproductive parameters of central female common dolphins; and (3) does geographic variation occur in female common dolphins on both large and fine scales. These three questions are important for management because accuracy of age estimates directly affects reproductive parameter estimates, and understanding the basic reproductive parameters and their spatial variation provides essential information to improve management plans for each cetacean species/stock recognized.

ETP Oceanography – A "Review of Eastern Tropical Pacific Oceanography" is being edited by SWFSC scientist Paul Fiedler and Miguel Lavín of Mexico's Centro de Investigación Cientifica y de Educación Superior de Ensenada (CICESE) as a special issue of *Progress in Oceanography*. The goal of this effort is to update Klaus Wyrtki's seminal reviews (1966, 1967) by incorporating new data and published observational and modeling studies. The volume will include 10 papers reviewing topics of regional physical and biological oceanography: atmospheric forcing, hydrography, circulation, eddies and mesoscale processes, ENSO (El Niño/Southern Oscillation) variability, interdecadal variability and climate change, primary productivity and geochemical cycling, zooplankton, fisheries oceanography, and oceanographic influences on seabirds and cetaceans. Almost all of the papers have been submitted and reviewed. Publication is expected in late 2005 or early 2006.

Ecosystem Data Management – The SWFSC Ecosystem Studies Program completed the design of a new data management system and began its implementation. The system will ensure that all datasets (past, present, and future) collected by this program are more easily integrated, as well as properly edited, processed, documented, stored, and maintained. Data collection and maintenance is a primary function of the SWFSC, from which all other research products result. As a regular part of the periodic dolphin abundance research vessel cruises in the ETP, the Ecosystem Studies Program has been collecting an increasing number of datasets on ecosystem attributes (physical and biological oceanography, abundance and distribution of mid and top trophic-level species) to the point where each cruise now returns with up to 37 separate ecosystem data sets. These data sets represent a long-term (>2 decades) time series of species and environmental data which provide the basis for interpretation of the status and trends data on the depleted dolphin stocks. The new data management system will ensure that these data will be preserved and available to test hypotheses about ecosystem structure and function, with a view toward better understanding of the status of depleted dolphins.

Bycatch Reduction Workshops – The SWFSC and the Inter-American Tropical Tuna Commission are currently planning a pair of workshops (to take place in early summer) to discuss bycatch reduction in the ETP tuna purse seine fishery. The workshops, and follow up research and development, will address all types of bycatch in the purse seine fishery. The first workshop will be a scoping meeting to identify a subset of the most promising approaches to further reduce bycatch. In a follow-up workshop, experts in the identified approaches will be assembled to help draft detailed proposals. These proposals will be used to focus the application of funding and effort.

Research Planning – In late 2003 (early in fiscal year 2004), SWFSC staff with

expertise and interest in ETP dolphin research conducted a series of meetings to provide a longer-term focus for our activities to address possible fishery effects on the dolphins. A planning document was completed and issued as "A Research Plan to Investigate Fishery Effects on Reproduction and Post-Natal Mortality." The plan structures work under four headings: spatial-temporal patterns, population effects, individual effects, and data review. A synthesis phase is to be followed by formal external peer review of results.

During 2005, an expanded planning exercise is underway to draft detailed proposals for the fishery effects studies covered here, as well as the population monitoring studies and ecosystem studies that together comprise our overall program. It is intended to subject these proposals to formal external review and use them as the basis for guiding future research.

VII. PELAGIC SHARK RESEARCH

The SWFSC's shark research focuses on highly migratory pelagic sharks that occur along the U.S. Pacific Coast, including shortfin mako, blue shark, and three species of thresher shark. Researchers are studying the sharks' biology, distribution, movements, stock structure and status, and potential vulnerability to fishing pressure. This information is provided to international, national, and regional fisheries conservation and management bodies charged with ensuring that shark populations remain at sustainable levels. Some of the recently completed or ongoing shark research activities being carried out by the SWFSC are discussed below.

Shark Surveys and Tagging – Thresher and mako sharks are important commercial sharks in California and popular sport species, especially in highly populous southern California. Although the blue shark has little market importance, it is a leading bycatch species in the U.S. West Coast drift gillnet and high-seas longline fisheries. Surveys are carried out in the Southern California Bight to track trends in abundance of juvenile and sub-adult blue and shortfin mako sharks and neonate common thresher sharks. The commercial and sport catch of these species within U.S. Pacific Coast waters consists largely of juvenile sharks, although catches of adult blue and thresher sharks and a few adult shortfin mako sharks also occur. Efforts to determine abundance trends from commercial fishery data have so far been complicated by changes in fishing methods and areas and regulatory restriction over time, which have resulted in wide swings in both catch and distribution that are difficult to interpret. Therefore, consistent, fishery-independent sampling was needed, with slightly different survey strategies required for the more oceanic shortfin mako and blue shark compared to the more coastal common thresher shark.

Offshore longline surveys from relatively large research vessels have proved most appropriate for sampling and estimating abundance trends of the more oceanic species (shortfin mako and blue shark). The surveys have enabled the SWFSC to obtain a valuable abundance index for the shortfin mako, which can be linked to a historical time series of logbook and landings data from a former commercial mako longline fishery in the Southern California Bight during 1988-91. Abundance trend information is also obtained for the blue shark, which is compared to information obtained from observers in the drift gillnet and high-seas longline fisheries. The surveys are carried out cooperatively with the California Department of Fish and Game and Mexican researchers with CICESE in Ensenada, Mexico. Tagging is also carried out to

determine shark movements and obtain information on shark age and growth.

The juvenile shark abundance and thresher shark pre-recruit surveys were complemented with two additional surveys in 2004. The 16-day central California shark survey was conducted between Point Conception and Santa Cruz, California, to examine the extended distribution of mako, blue and thresher sharks, while a 20-day survey from Acapulco, Mexico, to California via Clipperton Island was conducted to examine abundance of pelagic ETP sharks.

Juvenile Mako and Blue Shark Abundance Survey – This survey began in 1994 and now provides an 11-year time series of fishery-independent CPUE, length frequency, and life history data for shortfin mako and blue sharks needed to address issues of stock condition. In 2004, the juvenile shark survey deployed a total of 6,692 hooks at 38 sampling stations off southern California. The index of relative abundance for juvenile sharks defines CPUE as catch per 100 hook-hours and summarized by set. Catch included 88 mako, 127 blue, and 2 common thresher sharks, and 59 pelagic rays. The catch-effort data indicate the overall catch rate was 0.40 per 100 hook-hours for shortfin mako and 0.50 per 100 hook-hours for blue sharks (Fig. 3). Catches of shortfin mako varied from 43 sharks in 2000 to 189 sharks in 2001, and catches of blue shark varied between 73 individuals sampled in 2002 to 903 individuals sampled in 2000. Since 1995, the 380 stations that sampled shortfin mako indicated a continued decline in mean CPUE from a high of 1.03 sharks in 1994 to 0.33 sharks in 2003. The CPUE trend for blue sharks likewise decreased over the period but with greater variability. These trends do not necessarily indicate a serious decline in abundance; however, further monitoring should continue.

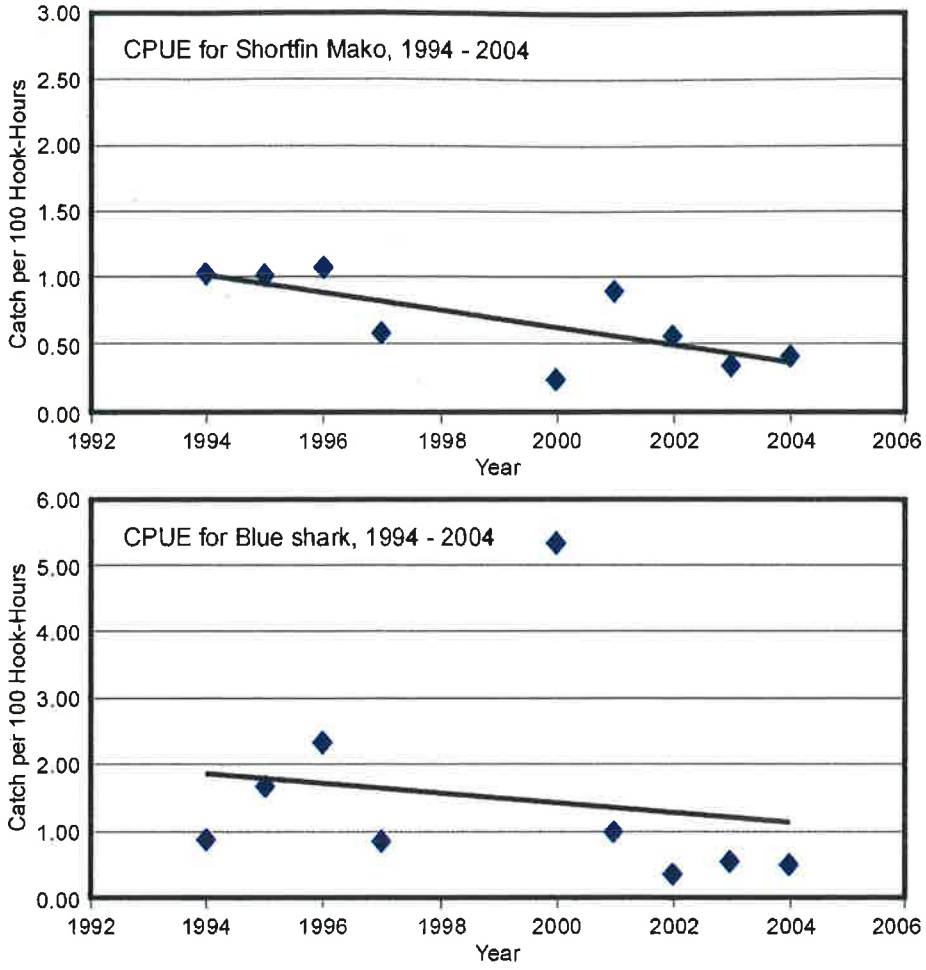

Figure 3. Catch per 100 hook-hours for shortfin mako and blue shark, 1994-2004.

The size of catch for shortfin mako and blue shark is apparently neither increasing nor decreasing. Total lengths of all sharks were measured throughout the survey period. Mean shortfin mako lengths ranged between 110 cm to 137 cm total length or TL (Fig. 4). Male shortfin mako reach maturity at about 200 cm TL and females reach maturity at 280 cm TL. Few mature males and no mature females were sampled during the survey. There was little size difference between males and females. Mean blue shark lengths ranged between 103 cm to 167 cm TL (Fig. 4). Lengths of mako and blue sharks may be slightly increasing. It is not known if this is because fewer young animals are entering the local population or the proportion of larger animals has increased from offshore immigration of mature individuals. The data do indicate the need for continued monitoring.

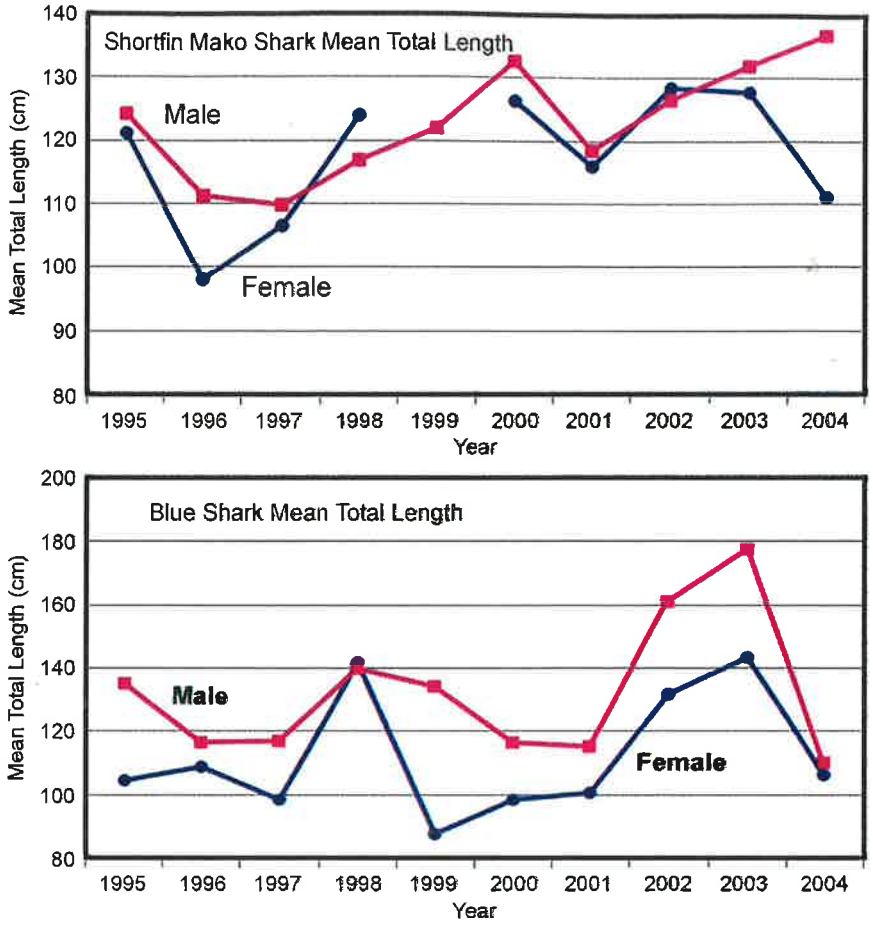

Figure 4. Mean total lengths for shortfin mako and blue sharks, 1995-2004.

Blue and mako sharks are caught in high-seas fisheries and in smaller-scale fisheries operating off the west coasts of the United States and Mexico. To properly manage and understand their oceanic and coastal distributions with respect to the fisheries, satellite telemetry was used to study the movements of 27 blue and 22 mako sharks for 7 to 257 days. Sharks were captured and released off California and were outfitted with transmitters (SPOT and PAT tags) between July 2002 and November 2004. Blue sharks ranged between 10-38°N and 105-150°W. Individual blue sharks made rapid directed long-range movements to the south and west, while other individuals remained within relatively small areas (Fig. 5). Mako sharks ranged between 13-46°N and 110-135°W. Movements of mako sharks, while rapid at times, tended to include more meandering (Fig. 6). Inter-annual differences in the movements of both species were apparent and likely driven by differences in sea surface temperature and prey availability. Both species encountered a wide range of sea surface temperatures throughout their migrations (14-27°C) and routinely dove to below 200 m. Important areas where both species concentrated include central California through the Southern California Bight, Bahia de Sebastian Vizcaino, and between Punta Eugenia and Isla Magdalena. These areas overlap with the California/Oregon drift gillnet fishery in U.S. waters and with artisanal and industrial longline and gillnet fisheries in Mexican waters. Consideration of the sharks' movements may provide reasonable alternatives for time and area closures while still enabling fishing for less vulnerable species. These data will also contribute toward efforts to improve population assessments based on habitat models and/or standardized CPUE indices.

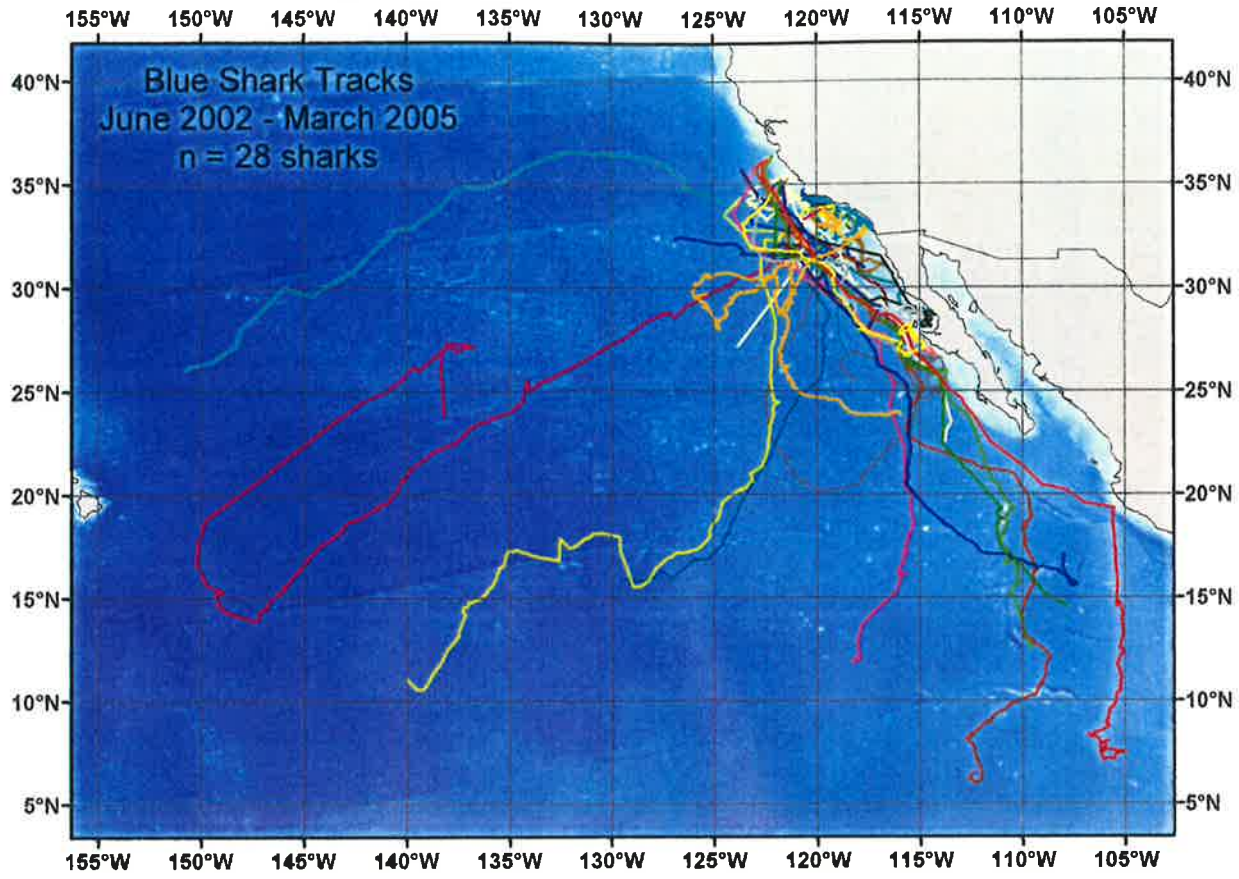

Figure 5. Movements of blue sharks as reported by satellite-linked tags deployed during the 2002-05 NMFS juvenile shark surveys.

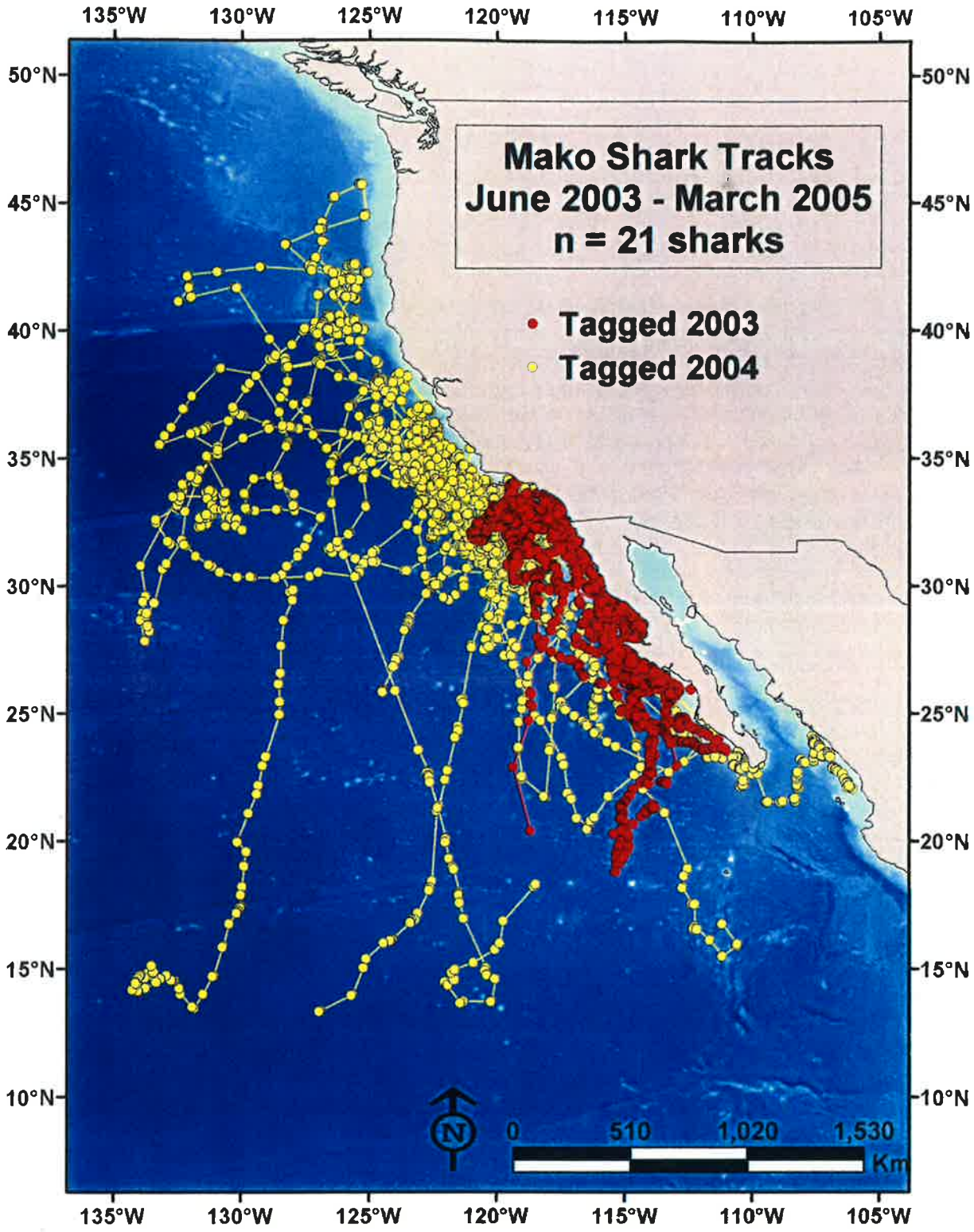

Figure 6. Movements of shortfin mako sharks as reported by satellite-linked tags deployed during the 2003-05 NMFS juvenile shark surveys.

Common Thresher Shark Survey – The common thresher shark stock off the U.S. West Coast is thought to be a regional and more coastal stock, migrating annually between Mexico and the three contiguous West Coast states. The stock utilizes southern California (and possibly northern Mexico) as a pupping and nursery area. This population was overfished in the 1980s and is now in a slow recovery phase after various area and season closures were imposed by the states of Washington, Oregon and California. The common thresher shark stock has a relatively low potential rate of population growth and an apparent dependence on inshore, high-use coastal areas as nursery grounds, especially during the first year of life. Population growth is estimated to be just above replacement; therefore, close recruitment monitoring is needed to ensure the stock's continued recovery from its former overfished condition.

The common thresher shark pre-recruit index and nursery ground survey was begun in 2003. Its primary purpose is to produce a relative abundance index for the West Coast population of the common thresher shark by periodically sampling 0-year pups in their core nursery grounds off southern California. Once the nursery area is defined, representative core areas will be identified and sampled annually. The resulting neonate index of abundance should mirror adult abundance since adult populations and recruitment are tightly linked in K-selected sharks. This study will complement the fishery-dependent data available through the observer program to provide measures of relative and absolute abundance of common thresher shark for stock assessment models.

During fiscal year 2004, the first year of the study, 16 trips were completed (6 gillnet and 10 longline). In 124 longline sets, 103 common thresher sharks were captured, 34 of which were neonates. In 29 gillnet sets, 83 common thresher sharks were captured, 37 of which were neonates. Neonates were captured in most sampled areas, including off of San Diego, Carlsbad, Gaviota, and Santa Barbara, California. Depth-stratified sampling revealed that over half the neonates were caught in shallow waters of 0-25 fathoms. During the first year, various longline gears (e.g., hook size, bait, hooks per set) were utilized in order to determine the most effective gear for sampling neonates. During the second year of the study, longline sets will be conducted with standardized gear. Gillnet sampling during the first year was conducted only in areas north of Laguna Beach, California. In 2005, gillnet sampling will focus in southern areas between Laguna Beach and the Mexico border, and close to the Channel Islands. The thresher shark pre-recruit survey provides the opportunity to enhance other ongoing studies of the SWFSC shark research group, such as age and growth, feeding, and habitat utilization studies.

Central California Shark Survey – The 2004 central California shark survey resulted from sea days made available on the NOAA ship *David Starr Jordan* by another SWFSC division. The objective of the survey was to investigate the near- and offshore abundance and distribution of juvenile pelagic sharks from Point Conception to Santa Cruz. One or two fishing sets were conducted during each day. A total of 4,773 hooks were fished at the 24 sampling stations. Catch included 10 mako, 411 blue, and 6 soupfin sharks. The preliminary data indicate the overall catch rate was 0.003 per 100 hook-hours for mako and 0.122 per 100 hook-hours for blue shark. Nine mako sharks were tagged with conventional tags for movement data studies and marked with oxytetracycline (OTC) for age and growth studies. Two mako sharks and 16 blue sharks were each tagged with satellite transmitting PAT and SPOT tags to define the physical habitat of these juvenile Pacific sharks.

ETP Shark Survey and Tagging – In fiscal year 2004, SWFSC scientists received funding from NOAA's Office of Ocean Exploration to study large pelagic sharks of the eastern tropical Pacific. Two cruises have been conducted in order to survey and tag sharks with electronic tags to study their depth and temperature preferences and migratory movements.

In September-October 2004, a longline survey took place aboard the NOAA ship *David Starr Jordan* in international and French waters roughly between 8-15°N and 100-112°W. During 30 sets, there was a disappointingly low catch of 25 sharks. Species encountered included silky, oceanic whitetip, pelagic thresher, and blue sharks. With the exception of the pelagic thresher sharks, all caught were neonates or juvenile sharks. With close to 16,000 hook-hours of effort, the CPUE for all shark species combined was 0.16 sharks per 100 hook-hours. Other species caught included sailfish, striped marlin, dorado, black skipjack, and yellowfin tuna. Conventional tags were deployed and DNA samples were collected from 27 fish. Seventeen sharks were injected with OTC for age and growth studies. Electronic tags (PAT and/or SPOT tags) were deployed on 4 silky and 3 oceanic whitetip sharks. The fin-mounted SPOT tags provided some locations from oceanic whitetip sharks, but the one deployed on a silky shark has not yet transmitted. A total of 227 days of depth, temperature, and location information was obtained from PAT tags deployed on 2 oceanic whitetip sharks and 3 silky sharks. In addition to the shark survey and tagging efforts, scientists collected fish tissue samples for the tissue bank at the San Diego Zoo's Conservation and Research for Endangered Species program and collected live specimens of several rare fish encountered near Clipperton Island for researchers at Scripps Institution of Oceanography and the Birch Aquarium.

In March 2005, another cruise was conducted in the waters off Costa Rica in collaboration with scientists from PRETOMA (Programa Restauración de Tortugas Marinas). In cooperation with a local longline fisherman, sharks were targeted in the northern area of the Guardian Banks (near 10°N, 88°W) to deploy electronic satellite-linked tags. No attempt was made to conduct a systematic abundance survey, but observers from PRETOMA are beginning to collect shark catch statistics from the longline fishery. During four days of fishing, 10 sharks were tagged with PAT and/or SPOT tags. Species tagged included silky and bigeye thresher sharks and a scalloped hammerhead shark. The hammerhead shark suffered a post-hooking mortality, but the other sharks appear to have survived. Locations are being transmitted from three silky sharks carrying SPOT tags. PAT tags are programmed to begin transmitting in June. The cruise was a success, and the SWFSC scientists hope to continue the collaboration with PRETOMA in order to expand their studies on tropical sharks.

Shark Demographic Analyses – SWFSC researchers use information on the vital rates of sharks and apply it to mathematical models to estimate and compare the rebound potentials of various shark species (i.e., their relative productivity and ability to rebound from fishing pressure or other sources of mortality). The researchers have developed a method which does not require large data sets and incorporates a density-dependent population response, which can be used to examine the relative productivity of a range of shark species, including most U.S. West Coast sharks. Two shark demographic papers have been published since the inception of the project.

Pelagic Shark Feeding Ecology – Since 1999, work has continued investigating the feeding ecology of the common thresher shark during various oceanic regime changes,

with recent work focusing on a comparison of blue, shortfin mako, and common thresher shark diets when these species co-occur in California Current waters off California and Oregon. One study on "Diet differences in the common thresher shark during transition from a warm to cool-water regime off California-Oregon, 1998-2000" was submitted for publication in *California Cooperative Oceanic Fisheries Investigations Reports*.

The paired food habits study on shortfin mako, blue, and thresher sharks when they co-occur in catch from the same set is in the third year of sampling and analysis. To date, 179 stomachs (57 blue, 41 thresher, and 81 mako) have been processed. The stomach contents have been identified to the lowest possible taxonomic level. Results and statistical analysis are not yet available but there is a noticeable difference in contents and feeding preference between the three species.

Mako and Thresher Shark Age, Growth and Maturity – Age and growth of mako and thresher sharks are being analyzed by ring formation in recaptured animals with OTC-marked vertebrae. Four hundred eighty-eight OTC-marked individuals have been released during the juvenile shark surveys and 28 have been recovered (5.7%). Of those 28, vertebrae were collected from 18 sharks. Time at liberty ranged from 7 to 1,594 days with net movements of individual sharks as high as 2,648 nautical miles (nmi). Preliminary results from shortfin mako vertebrae indicate that juvenile and sub-adults lay down two bands of unequal size each year; however, as they mature and transition from a more coastal distribution to more oceanic, the calcification pattern in the vertebrae appears to change with hyaline and calcified zones becoming narrower and more equal in relative size. This is an extremely interesting finding, since the question of whether the shortfin mako lays down one band or two bands per year has been an ongoing uncertainty, with two independent labs reporting conflicting results.

Thresher shark vertebrae are also being aged at the SWFSC using X-radiography techniques. The purpose is to expand and refine previous thresher shark ageing studies using a larger sample size from the driftnet fishery with accompanying information on sex and maturity stage. Tetracycline marking and release of tagged juvenile and sub-adult thresher sharks off California has begun to verify the timing of ring formation. Preliminary results from common thresher sharks indicate that they lay down one band per year.

Ageing studies are also underway to determine age and growth of shortfin mako sampled by Japanese longline from widely distributed localities in the Pacific and common thresher shark from the California/Oregon driftnet fishery. Mako shark growth rates and age are being examined using non-marked vertebrae collected from the California drift gillnet fishery and from Japanese longliners. The vertebrae are sectioned, X-rayed, and imaged using a Spot camera and microscope. The study will use the criteria developed in the validated (OTC-marked) ageing study for mako and thresher sharks along with the length-frequency distribution of the catches of the California drift gillnet fishery and the Japanese longline fleet. The derived ages and growth rates will be compared to determine differences in stock structures and to help elucidate migratory patterns. This project is being conducted cooperatively with Hideki Nakano of the National Research Institute of Far Seas Fisheries, Japan. Goals of this study include determining the mako and thresher sharks' size and age at maturity and defining the age structure of sharks caught off the U.S. West Coast.

The results from these studies should validate the age estimates of the shortfin mako and the common thresher shark and clarify how to interpret the formation of vertebral growth bands for these two species. The criteria for determining annual growth increments as determined by OTC validation will create the opportunity to obtain more accurate life history information which is needed for fisheries management. Several areas of uncertainty remain. For example, the growth model needs to be developed from a larger sample size with specimens that have made the transition from immature to mature.

Blue Shark Dynamics in the U.S. Pacific Coast EEZ – The objective of this project is to develop a model of blue shark preferred habitat based on longline and drift gillnet catch statistics and environmental data. A statistical model will be created to show how blue shark CPUE varies spatially and temporally. Secondarily, this model will attempt to validate Hideki Nakano's hypothesis, which states that blue sharks are segregated latitudinally by sex and age class, and verify whether it pertains within the U.S. EEZ. The capture rate of blue sharks in the California drift gillnet fishery is second highest after the ocean sunfish, yet their meat is not marketable. One targeted swordfish is caught for every 1.1 blue sharks. Finally, the predictive model will be compared to the distribution of swordfish catch in order to determine the degree to which they coincide. Determining the spatial and temporal distribution of these sharks with respect to remotely measured environmental variables such as sea surface temperature and chlorophyll may enable fisheries managers to apply appropriate measures to limit their bycatch.

Capture Stress and Survival – SWFSC staff and colleagues at Scripps Institution of Oceanography and California State University–Long Beach have completed a four-year study on the effects of capture stress on juvenile sharks tagged and released during the SWFSC's juvenile shark survey. Sharks captured on longlines can suffer physical injury from hooks and traumatic stress and exhaustion from struggling to escape. Acute stress in sharks could dramatically increase circulating catecholamines, which has shown in other animals to result in altered cardiodynamics and gas exchange, leading to intense vasoconstriction and possible irreversible organ and tissue damage through acidosis or anoxia. Extremely high catecholamine levels ultimately may indicate a poor prognosis for survival.

This study examined plasma catecholamines and lactate levels in three species of shark to determine the effects of longline capture and tagging stress on long-term survival of released sharks. Blood samples were collected from 149 mako, 43 thresher, and 79 blue sharks between 1999 and 2002. All three shark species in this study had elevated catecholamine and lactate concentrations relative to resting (non-stressed aquarium) sharks. Sharks that were moribund at capture had the highest levels. However, the recapture rate of nearly 6% indicates most of these sharks are able to overcome the stress induced by longlining and tagging operations. A manuscript of the study is currently in review at *Fishery Bulletin*.

Bioaccumulation of Mercury in the Common Thresher and Shortfin Mako Shark – The common thresher and shortfin mako shark, being apex predators, have the potential to bioaccumulate high concentrations of methyl mercury in their tissues. These shark species are actively fished commercially along the U.S. West Coast and are marketed for human consumption. Despite this potential human health risk, there are no comprehensive published studies of the mercury levels in these fish. A 1991 preliminary study by the Hawaii Department of Health found high levels of mercury in the market

fillets of shortfin mako with an increase in fish size. The mean mercury level was 1.32 ppm, which exceeds the Food and Drug Administration's recommended safe human consumption levels of 1.0 ppm. The fish sampled in this study were generally larger than the mako sharks caught in the West Coast drift gillnet fishery. Similarly, the same preliminary study also found high levels of mercury (mean = 1.02 ppm) in two species of thresher shark (pelagic and bigeye).

The goal of this study is to describe the bioaccumulation of mercury with size and sex for the shortfin mako and common thresher shark in the eastern North Pacific and determine if mercury levels in West Coast market-size fish are a cause for concern for human consumption. We will also investigate for evidence of suspected ontogenetic diet shifts and the feasibility of utilizing mercury level as an indicator of trophic status complementing the stable isotope study (described below).

Preliminary results show low levels of mercury in the muscle tissue of small juvenile common thresher sharks. Tissue samples from larger individuals are now available and being analyzed. In contrast, the lone neonate shortfin mako analyzed to date shows a high mercury level (1.16 ppm) and three large adult makos had very high mercury levels (mean = 2.90 ppm).

Feeding Ecology and Trophic Status of the Common Thresher and Shortfin Mako Shark Inferred from Stable Isotope Analysis – The common thresher and shortfin mako shark are suspected of undergoing ontogenetic diet shifts but there is little quantitative evidence to support this. There is an ongoing SWFSC food habits study of these two shark species using stomach content analysis. Despite its high resolution, with the inherent snapshot view bias of stomach content analyses, it would take large sample sizes and sampling throughout the year if such feeding events are rare and/or localized spatially or temporally, to have a good chance capturing such differences in the feeding of these fish. Stable isotope signatures in a consumer reflect those of their diet with some fractionation (i.e., enrichment). Stable isotope signatures are a cumulative record of the feeding events of an individual fish and the temporal aspect of this depends on the isotopic turnover rate of the particular tissue examined.

The goal of this study is to infer aspects of the feeding ecology and trophic status of the common thresher and shortfin mako shark from the eastern North Pacific using stable isotope analysis of tissues and vertebral centra. This study will complement and supplement the SWFSC shark research group's pelagic shark food habits study.

Population Structure of Shortfin Mako – The shortfin mako is an extremely wide-ranging pelagic shark which is reported to occur throughout temperate and tropical waters worldwide. In the North Pacific, the shortfin mako is encountered in fisheries off the coasts of North America, Japan, and throughout the north central Pacific. In the South Pacific, makos are commonly encountered in fisheries operating off Australia, New Zealand, Peru, and Chile. Conventional tag returns have demonstrated that individual sharks tagged in southern California waters have migrated as far as Hawaii, Acapulco, Mexico, and Japan. In the North Atlantic, where conventional tagging of shortfin makos has a longer history, of 608 tags returned not a single shark was recaptured south of 10°N. This study will test the hypothesis that shortfin makos from the North and South Pacific are genetically distinct. Population structure of shortfin mako in the Pacific Ocean will be inferred through mitochondrial DNA analyses. Samples are being collected throughout the Pacific basin through cooperation with fisheries scientists in New Zealand, Australia, Chile, and Japan,

and by the shark research group at La Jolla through our surveys and fishery observers in southern California. DNA is being extracted and examined for mtDNA variability at the sequence level. In addition to examining distinctions between North and South Pacific populations, this study will address, based on the mtDNA sequences, if mako sharks are philopatric. Specifically, are the females returning to the same area to give birth each year as has recently been shown in other shark species through DNA analysis? A better understanding of stock structure is critical to developing accurate stock assessments and improves fisheries management of this species.

VIII. BILLFISH ANGLER CATCH RATES AND MOVEMENTS

This year marks the 40th year that NMFS and the billfish angling community have combined efforts to measure angler success for billfishing. These efforts have created one of the longest time series available for recreational billfishing, charting trends in relative abundance for key species. With highly migratory species management unfolding in both the eastern and western Pacific, data series such as these are key to assessing the health of the stocks. The SWFSC remains committed to monitoring recreational billfishing success. This research includes recreational and commercial fishery monitoring, stock assessments, biological research into the life history and ecology of specific billfish species, and determining the economic importance of billfish resources. Two major components of that research are the International Billfish Angling Survey and the Billfish Tagging Program. These programs produce essential information pertaining to the recreational billfish angling community for exploring conservation and management concerns.

Billfish Angler Survey – The Billfish Angler Survey provides the only estimates of billfish angling activities in the Pacific and Indian Oceans. This collection of recreational billfish catch-and-effort data began in 1969 and now provides a 36-year index of fishing success in many key Pacific tourist locations. CPUE is measured in catch of billfish per angler fishing day. This measure of angler success, tracked over time, can indicate changes in stock size caused by overfishing, changing environmental conditions, or local economic and political events. This index of CPUE is important in stock assessments and in developing management options.

In 2003, 832 billfish anglers reported catching 5,845 Pacific billfish during 6,732 fishing days. Table 1 indicates fishing effort, in angler days, and CPUE (measured in catch per day fishing) for all billfish reported by location for the year 2003. The annual mean catch-per-effort for all billfish was 0.87 billfish per day in 2003, up from 0.50 in 2002. The current mean catch rate of 0.87 is a new record high and well above the prior five-year average of 0.58 (1999-2003). The second highest rate in CPUE occurred in 2000. This is a new all-time mean high catch rate and slightly greater than during the first years of this survey (1969-71). The lowest catch rates (0.33) resulted from large international fisheries during the late 1970s.

Table 1. Results of all billfish catches reported for the 2003 Billfish Angler Survey. Numbers indicate total days fished by location and catch per fishing day. Data in parentheses are values recorded in 2002. Major species in each location are indicated: striped marlin (SM), blue marlin (BLM), black marlin (BKM) and sailfish (SF).

LOCATION	ANGLER FISHING DAYS	BILLFISH PER FISHING DAY (CPUE)	MAJOR SPECIES
PACIFIC OCEAN			
Hawaii, U.S.A.	3,309 (2,960)	0.50 (0.37)	BLM
Southern California, U.S.A.	1,065 (1,314)	0.12 (0.04)	SM
Baja California, Mexico	959 (903)	0.81 (0.82)	SM
Panama	275 (120)	4.92 (3.33)	SF
Australia	168 (94)	0.80 (1.06)	BKM
Acapulco, Ixtapa, Zihuatanejo, Mexico	147 (44)	1.65 (1.66)	SF
Costa Rica	120 (56)	5.90 (3.04)	SF
Manzanillo, Mexico	112 (21)	0.46 (1.14)	SF
Tahiti	80 (21)	0.20 (0.19)	BLM
Guaymas, Mexico	63 (175)	0.079 (0.33)	SF
Mazatlan, Mexico	34 (24)	1.059 (0.96)	SF
Puerto Vallarta, Mexico	33 (2)	0.61 (1.00)	SF
Guatemala	22 (21)	7.05 (7.14)	SF
Fiji	20 (12)	0.00 (0.08)	NA
Japan	18 (42)	0.44 (0.02)	BLM
Galapagos Islands	12 (0)	0.25 (0.00)	SM
Marshall Islands	12 (11)	0.25 (0.09)	SF
New Zealand	6 (32)	1.167 (0.09)	SM
New Guinea	5 (0)	0.20 (0.00)	BLM
Kiribati	4 (8)	0.25 (0.50)	SF
Ecuador	3 (0)	2.33 (0.00)	SF
French Polynesia	2 (0)	0.50 (0.00)	BLM
Guam, U.S.A.	1 (0)	1.00 (0.00)	BLM
INDIAN OCEAN			
Dubai / United Arab Emirates	235 (180)	2.26 (3.47)	SF
ATLANTIC OCEAN			
Atlantic Total	139 (21)	1.78 (1.05)	SF

Billfish Tagging Program – The angler-based Billfish Tagging Program has provided tagging supplies to billfish anglers for 40 years, providing data on the biology, distribution, and migration patterns of billfish. Recapture data indicate that blue marlin, striped marlin, sailfish, and swordfish move extensively throughout the Pacific but without an apparent specific pattern of migration. These transpacific movements, whether

seasonal migrations, nomadic wanderings or generally dispersive, expose billfish to high-seas commercial and coastal recreational fisheries. Billfish tagged and released by anglers and commercial fishers in the North Pacific are recaptured throughout the North and South Pacific by vessels operating in coastal and international waters.

Striped marlin are widely distributed in the Pacific and generally move in a directed yet dispersive manner away from core areas of high abundance, including the Hawaiian archipelago and the central coast of Mexico. Striped marlin tag and releases total 21,852 since 1963, with 336 recaptures, yielding a 1.54% recapture rate (Table 2). The majority of tagged striped marlin were tagged and released from Hawaii, southern California, and Baja California Sur, Mexico. Recaptures indicate movement from southern California to Baja California Sur but show little movement in the reverse direction. Striped marlin tagged off southern California and Baja California Sur generally move south and offshore to the east. Several have been recaptured after moving great distances, including to Hawaii, Peru, and the South Pacific. There is little indication of direct movement from Hawaii to the U.S. West Coast, although fish arriving off Baja California and Southern California are thought to be from the central North Pacific.

Table 2. Summary of billfish, tuna and other fish tagged in 2004 with releases and recoveries for 1963-2004.

Species Name	Release 2004	Release Total	Return Total	Rate %
Striped Marlin	147	21,852	336	1.54
Sailfish	217	8,713	48	0.55
Pacific Blue Marlin	522	7,351	73	0.99
Billfish, other/unid.	9	4,348	6	0.14
Black Marlin	6	3,361	69	2.05
Mako Shark	131	1,597	43	2.69
Short-billed Spearfish	137	1,584	2	0.13
Other Fish	1	1,257	45	3.58
Broadbill Swordfish		521	17	3.26
Yellowtail		496	36	7.26
Dolphinfish		413	3	0.73
Blue Shark	38	372	5	1.34
Yellowfin Tuna		347	24	6.92
Thresher Shark	98	234	10	4.27
Rays	0	224	0	0.00
Sharks, other/unid.	18	117	4	3.42
Skipjack Tuna		97	2	2.06
Albacore Tuna		87	1	1.15
Bigeye Tuna		79	2	2.53
Bluefin Tuna		57	7	12.28
Hammerhead Shark		53	2	3.77
Other Tunas	0	53	1	1.89
Bronze Whaler		50	1	2.00
Whitetip Shark	3	43	1	2.33
Marlin, Atlantic Blue		42		0.00
Leopard Shark		39	1	2.56
Wahoo		39	3	7.69
TOTALS	1,327	53,426	742	1.39

A total of 7,351 blue marlin have been reported tagged with 73 recaptures, resulting in a 0.99% recapture rate (Table 2). Nearly half of these marlin were released and recaptured within 200 nmi of Hawaii, indicating considerable inter-island movement and residence times. Other billfish released off Hawaii moved west and offshore from 200 to 600 nmi. One blue marlin was recaptured after traveling to the Marquesas Islands (2,357 nmi), another to the South China Sea (4,450 nmi), and a third to New Caledonia (3,508 nmi). Blue marlin tagged off Baja California Sur also traveled west to Hawaii and to the Marquesas Islands in the South Pacific. Blue marlin are infrequent visitors to southern California, with few releases, and no recaptures exist.

Cooperating billfish anglers and U.S. commercial fishers have tagged a total of 521 broadbill swordfish. Recaptures total 17 for a return rate of 3.26% (Table 2). Swordfish tagged north off Hawaii on U.S. longline vessels moved northeast toward the west coast of North America and were recaptured by other commercial fishing vessels. One swordfish tagged northeast of Hawaii by a commercial longline vessel was recovered near San Clemente Island, California, by a drift gillnet vessel fishing for swordfish.

Adopt-A-Billfish Program – The Adopt-A-Billfish tagging program seeks to determine the survival rate of large billfish caught and released during international tournaments and to evaluate site fidelity off Central America and Mexico. The program is coordinated by a team of NMFS scientists from the Southwest and Southeast Fisheries Science Centers in cooperation with the University of Miami's Center for Sustainable Fisheries. In the Pacific, researchers are collaborating with the Presidential Challenge tournament series off the coast of Central America. From 2002 to 2004, Adopt-A-Billfish collaborators traveled to the Tropic Star Lodge in Panama, Los Sueños resort in Costa Rica, Fins and Feathers Lodge in Guatemala, and to Ixtapa, Mexico, where they tagged 39 sailfish, 2 blue marlin, and 1 black marlin with data archiving satellite tags.

The satellite tags were programmed to record depth, temperature, and light level data for periods of 30 to 120 days and then detach from the fish and transmit the data via satellites to SWFSC biologists. Results to date indicate that billfish survive being caught and released only when proper tagging protocols are followed. Although 92.5% of these billfish survived the tagging event, a blue marlin and two sailfish died within one day of capture and release. Survival is greatest when the fish are revived (resuscitated) by slowly being towed through the water before release. This allows them to regain their energy and strength before release, as indicated by the return of their normal color.

Satellite tag data showed significant movement across all international boundaries from Mexico to Panama (Fig. 7). Nearly all tagged sailfish either moved along shore into the exclusive economic zones of adjacent countries or moved offshore into international waters. The time sailfish spent at depth and temperature is still being analyzed but the data clearly show that sailfish spend most of their time in the mixed layer above the thermocline. The black marlin moved west from Panama into Costa Rica in 28 days and spent 80% of its time above 50 m depth and in water temperatures ranging from 22 to 24°C. The longest time at liberty for a conventionally tagged Pacific sailfish was 1,717 days tagged and recaptured near Cabo San Lucas, Mexico.

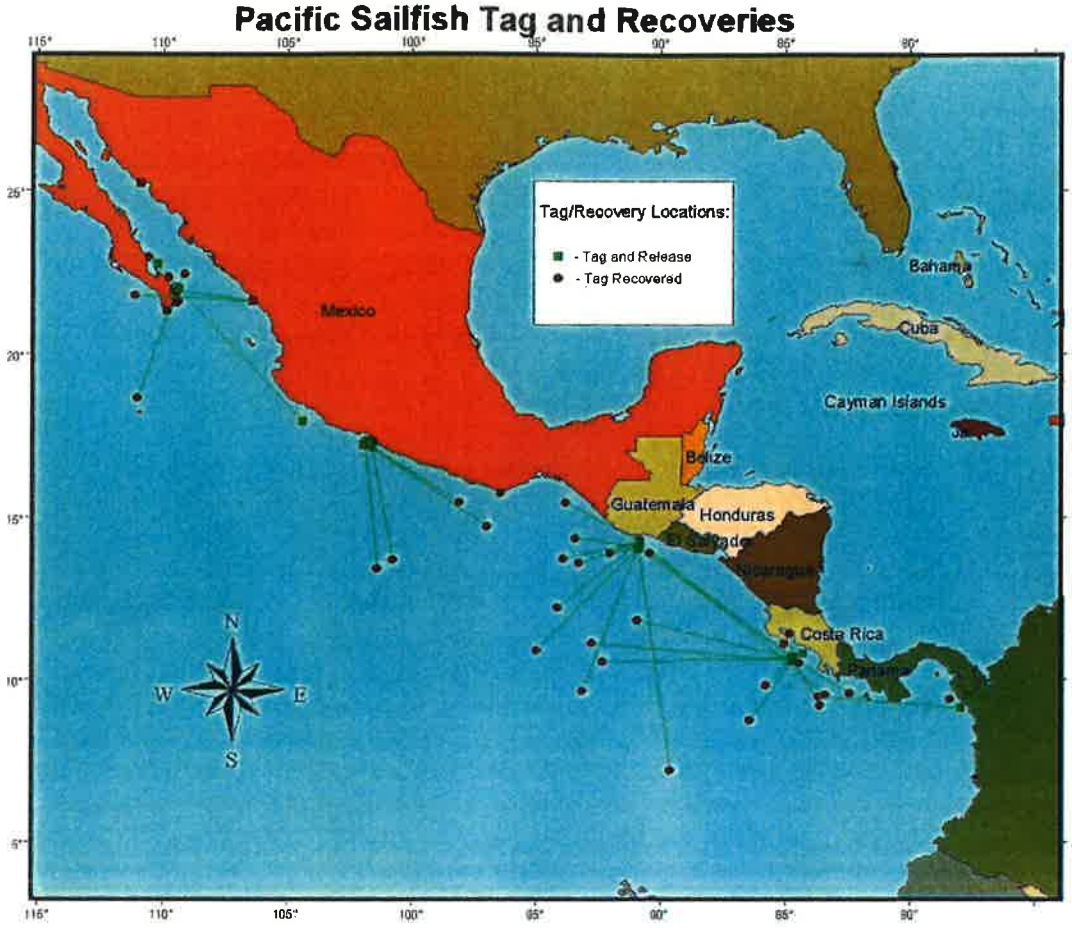

Figure 7. Pacific sailfish initial tag and recovery locations as reported by satellite tags used in the Adopt-A-Billfish program (2002-04).

Molecular Identification of Billfish Eggs and Larvae – Ichthyoplankton samples are collected on most SWFSC cruises and have been collected at least yearly since 1951. These samples provide an excellent time series and are good indicators of environmental shifts and trends in distribution and abundance of a variety of species. Traditionally, samples are collected at sea, preserved in formalin, and are brought back to the lab for sorting and identification. Identifications are generally made using a microscope and are based solely on morphology and pigmentation. This is an extremely labor intensive process, and few scientists possess the requisite expertise to identify eggs and larvae. In addition, one survey can take four to six months to process, with 90% of the samples remaining unidentifiable.

The SWFSC Fisheries Resources Division has pioneered a new technique to not only improve our ability to identify ichthyoplankton samples, but to do so in real time, at sea. Samples can be collected using net tows or the continuous underway fish egg sampler (Fig. 8). With an automated molecular technique, eggs and larvae are processed and identified on board the ship, within hours of collection.

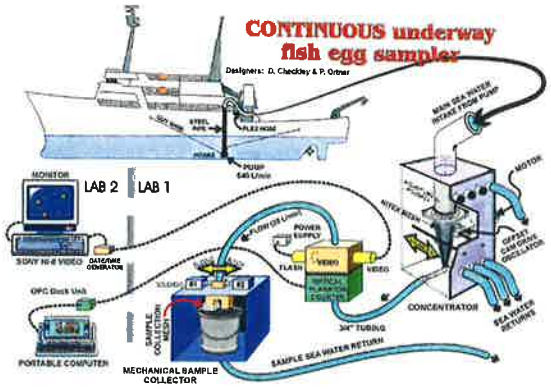

Figure 8. Schematic diagram of the continuous underway fish egg sampler.

In collaboration with the Pacific Islands Fisheries Science Center, this new method has been field tested on three cruises during July and September 2004 and March 2005 off the Kona coast of Hawaii, a putative spawning "hot spot" for istiophorid and xiphiid billfish. A species-specific multiplex PCR assay was designed to amplify a single, unique size fragment of the mitochondrial cytochrome *b* gene for all six species of Indo-Pacific billfish, both dolphinfish species, and the monospecific wahoo. Eggs and larvae were successfully identified to species within three hours of acquisition (Fig. 9). This study provided the first description of the eggs of blue marlin, shortbill spearfish, and wahoo, and is helping to determine the spatial and temporal dimension of spawning and nursery habitats of these highly valuable but poorly known species.

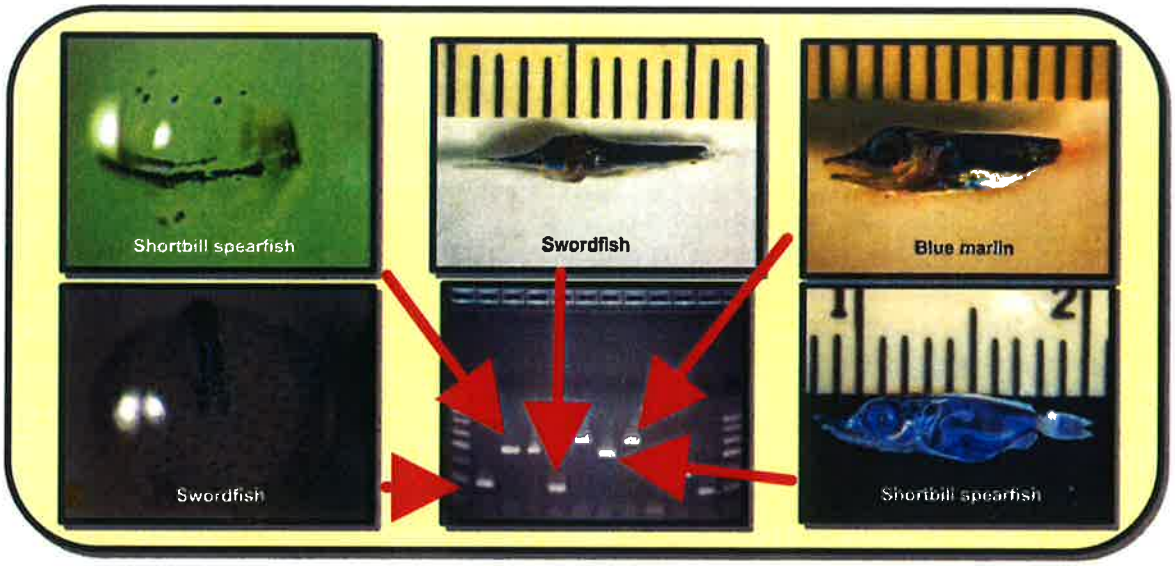

Figure 9. DNA-specific probes and optical detection identify eggs and larvae.

IX. PACIFIC COUNCIL HIGHLY MIGRATORY SPECIES ACTIVITIES

The Pacific Fishery Management Council's HMS Management Team was mostly inactive during 2004 due to inadequate funding. The team met initially to develop a limited entry program for the pelagic longline and drift gillnet fisheries in which the factor determining the number of vessels was the number of takes and mortalities of loggerhead and leatherback sea turtles. After initial work developing databases and preliminary discussions, all action was concluded when the funding was terminated, because public participation was not possible. In April 2005, funding for the West Coast HMS fishery management plan was reinstated. The Council subsequently reactivated both the HMS advisory subpanel and management team, and outlined tasks that require addressing over the next 6 to 12 months.

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56th Tuna Conference Notes

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