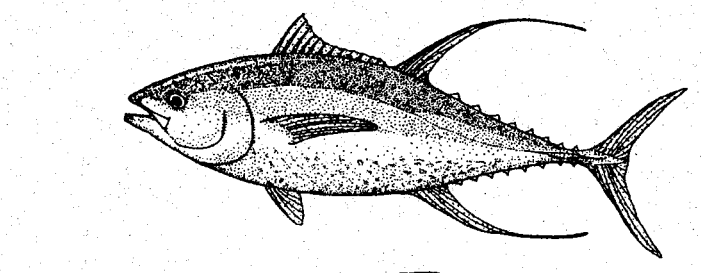
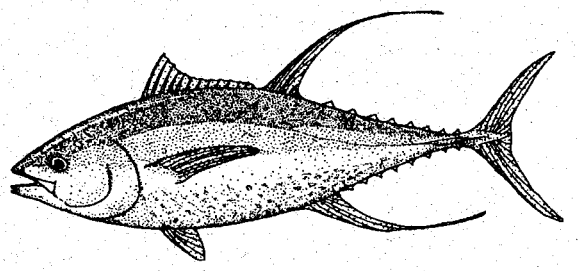
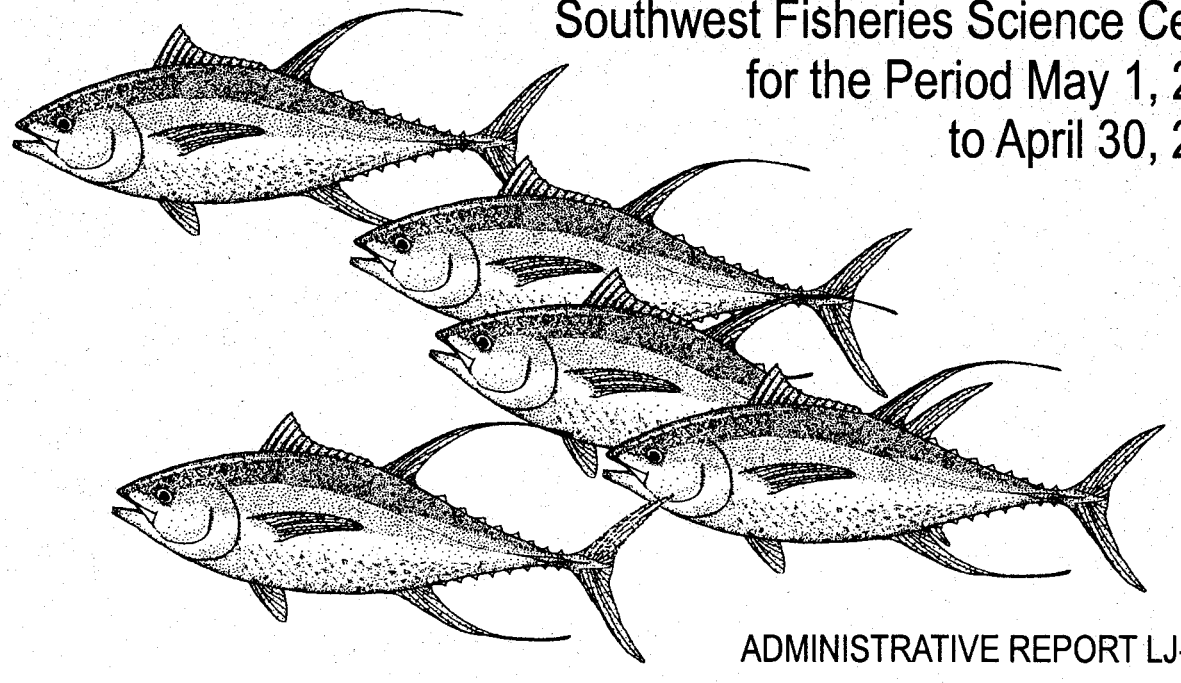
National Marine Fisheries Service
Southwest Fisheries Science Center

Director's Report to the 54th Tuna Conference





On Tuna and
Tuna-Related Activities at the
Southwest Fisheries Science Center
for the Period May 1, 2002
to April 30, 2003



ADMINISTRATIVE REPORT LJ-03-06

DIRECTOR'S REPORT TO THE 54th TUNA CONFERENCE ON TUNA AND TUNA-RELATED ACTIVITIES AT THE SOUTHWEST FISHERIES SCIENCE CENTER FOR THE PERIOD MAY 1, 2002–APRIL 30, 2003

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May 2003

ADMINISTRATIVE REPORT LJ-03-06

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INTRODUCTION

This report highlights research activities conducted by the Southwest Fisheries Science Center (SWFSC) 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 Honolulu and La Jolla Laboratories 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 (NMFS). 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, SWFSC 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 Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific.

Also of note, in late April 2003 the NMFS established a new regional office and science center in Honolulu to direct scientific research and management of the living marine resources in the western Pacific. The new Pacific Islands Fisheries Science Center (formerly known as the Honolulu Laboratory) and the SWFSC will continue to collaborate to study and provide fishery analysis and management information on large pelagic species in support of U.S. commitments to international management of tuna fisheries and regional management of fisheries for highly migratory species in the Pacific Ocean.

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May 2003
La Jolla, California

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

The U.S. fisheries for pelagic fishes in western and central Pacific Ocean are important components of the local and regional economies. Most 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 Pacific are not overfished, although the aggregate catch from some stocks may be approaching the maximum sustainable yield. Likewise, recent assessments of North Pacific swordfish and Pacific blue marlin indicate that these stocks are not overexploited. The prospects for maintaining healthy fisheries for tunas and billfishes in the region are enhanced by the high level of cooperation among scientists of Pacific island nations and distant-water fishing interests, regular data sharing and stock assessments, and rapid progress toward implementation of a multinational conservation and management arrangement for highly migratory fish stocks in the region.

U.S. Tuna Purse Seine Fishery in 2002 –The National Marine Fisheries Service (NMFS) monitors the U.S. purse seine fishery for tropical tunas in the central-western Pacific Ocean as part of U.S. obligations under the South Pacific Regional Tuna Treaty. The NMFS Pacific Islands Area Office and the Southwest Fisheries Science Center (SWFSC) collect and analyze logbook, landings, and biological data from the fishery to evaluate the fishery's performance and to assess the health of Pacific tropical tuna stocks. In March 2003, the SWFSC prepared a working paper for the annual meeting of treaty participants which reviewed data collected from the fishery and the fishery's impact on the skipjack, yellowfin, and bigeye tuna stocks in the area. Highlights of the paper are given below.

The U.S. fleet size in 2002 decreased to the lowest levels since the start of the treaty in 1988. Only 31 vessels obtained treaty fishing licenses in 2002 and of those only 29 actually fished. While fewer vessels fished in 2002 than in 2001, fewer of those fishing in 2002 lost days fishing due to tuna price disputes and long unloading delays that were prevalent in 2001. Even with the decrease in fleet size, the 2002 catch of 118,800 metric tons (t) increased a modest 3% from the record low levels reported in 2001 (115,500 t). As is typical in the western-central Pacific, skipjack tuna dominated the 2002 catch (73%), followed by yellowfin tuna (22%) and bigeye tuna (5%).

El Niño conditions affected fishing in 2002. These conditions were especially prevalent during the last half of the 2002 season and caused the fleet to fish further east than usual and on free-swimming schools of large-sized yellowfin tuna that were abundant in the eastern areas. However, sets on free-swimming schools of tuna are half as successful as sets on floating objects, and this weakened the fleet's performance. As a result, catch rates decreased to 22 t per day fished in 2002 from 23 t per day fished in 2001, and the average number of sets per trip increased 9% from those reported in 2001. The relatively high catch rates are consistent with stock assessment results indicating healthy tuna stocks in the region.

Sampling of the tuna catch continued during the year to provide 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 2002, and length measurements and species composition samples were taken from landings of 28,200 fish.

Hawaii-based Longline Fishery – The Hawaii-based longline fishery is the most productive and wide-ranging commercial fishery in Hawaii. The area fished ranged from 0° to 35°N and 145° to 175°W. This fishery is monitored with mandatory federal daily longline logbooks, an observer program, landings sampled at the United Fishing Agency auction in Honolulu, and a mandatory State of Hawaii commercial landings reporting system.

One hundred Hawaii-based longline vessels made 1,164 trips in 2002. Almost all of the trips made in 2002 targeted tunas (1,162), although two mixed-target trips were also made.

These vessels set a record 27.2 million hooks, with the highest proportion set on the high seas (44%) and in the main Hawaiian island exclusive economic zone (36%). Preliminary estimates of landings by this fishery totaled 8,000 metric tons (t) worth an ex-vessel value of $38 million. The major components of the landings were bigeye tuna (4,390 t, $27 million), yellowfin tuna (600 t, $3 million), marlins (600 t, $1 million), and albacore (500 t, $2 million). Preliminary estimates of landings and revenue for swordfish and shark were low in 2002 with 300 t worth $2 million and 200 t worth $0.1 million, respectively.

Regulations imposed on the Hawaii-based longline fishery to reduce the incidental capture of sea turtles strongly affected the fishery in 2001 into 2002. The fishery restrictions were brought about by a series of decisions by the Federal District Court in Honolulu in response to a February 1999 lawsuit brought against NMFS by the Earthjustice Legal Defense Fund on behalf of the Center for Marine Conservation and the Turtle Island Restoration Network. The restrictions had the greatest effects on swordfish and mixed target vessels because NMFS observer data had documented higher interaction rates for leatherback and loggerhead sea turtles with shallow-set longline operations targeting swordfish or mixed species rather than deep-set operations targeting tunas. A court order issued March 30, 2001, prohibited any vessel with a Hawaii longline limited access permit from using longline gear to target swordfish north of the equator. The court also adopted turtle take mitigation measures as outlined in the preferred alternative contained in the final environmental impact statement filed by the NMFS on that date. On June 12, 2001, the NMFS issued regulations implementing measures that included prohibition of shallow-set longline gear and light sticks aboard Hawaii longline vessels as well as several other measures.

In response to restrictions on shallow-set longline operations, many Hawaii-based swordfish vessels either converted to deep-set tuna longline fishing or left to fish out of California in 2001. The California vessels continued to target swordfish because these vessels were not subject to the restrictions affecting the Hawaii-based vessels.

California-based Longline Fishery – The California-based longline fishery landed its catch at local markets in California. This fishery operated on the high seas since longline fishing is prohibited in the U.S. west coast exclusive economic zone. Data collected on this fishery include mandatory federal high-seas longline logbook data and State of California landing receipts submitted by seafood wholesalers to monitor total landings.

Twenty-one California-based longline vessels made 70 trips in 2002. Nearly all had previously participated in the Hawaii-based longline fishery, and as in Hawaii, these vessels targeted swordfish. Preliminary estimates of landings for 2002 are not yet available.

American Samoa Longline Fishery – The American Samoa longline fishery targets albacore for sale to the canneries in Pago Pago. The fishery operates mostly within the exclusive economic zone of American Samoa, though some larger vessels have agreements to fish in the zones of neighboring islands. Data used to monitor this fishery include mandatory federal longline logbooks and an offshore creel survey.

The American Samoa longline fishery began with small aluminum-hulled catamarans called *alias*. The fishery has grown not only with the addition of more *alias* but also with an influx of larger mono-hulled vessels. Preliminary logbook summaries show 59 vessels set a record 12.9 million hooks in 2002.

U.S. Longline Fisheries in Other Pacific Island Waters – Five U.S. longline vessels operated out of the Federated States of Micronesia and the Marshall Islands under arrangements with local fishery authorities in 2001. These vessels landed 102 t, including yellowfin tuna (31 t), albacore (27 t), bigeye tuna (21 t), and 21 t of unspecified tuna.

Troll and Handline Fishery – Small-scale and artisanal troll and handline fisheries exist in Hawaii, American Samoa, Guam, and the Northern Mariana Islands. The troll and handline fishery consists of relatively small vessels. In 2001, 1,858 vessels produced catches totaling 1,961 t. The Hawaii-based troll and handline fishery accounted for 74% of the catch. The catch was predominantly yellowfin tuna (44%) and skipjack tuna (27%). Yellowfin tuna dominated the Hawaii troll and handline catch, whereas skipjack tuna was the largest component of the troll catch in American Samoa, Guam, and the Northern Marianas. Catches for all fisheries were sold mainly at local markets. Composite data for 2002 are not yet available.

Pole-and-line Fishery – The pole-and-line fishery was based in Hawaii and operated exclusively within the main Hawaiian island exclusive economic zone. These vessels catch small live baitfish for chum to attract and hold feeding schools of fish. Six pole-and-line vessels caught 449 t in 2001. Catches were predominantly skipjack tuna with a very small quantity (<0.5%) of yellowfin tuna, all sold to local fish markets. Data for 2002 are not yet available.

Pelagic Fishery Data Collection and Database Management – A plan was developed to coordinate collection, processing, archiving, and distribution of highly migratory species (HMS) data through the NMFS Southwest Region and Center. The coordinated plan requires HMS staff to meet annually to review progress on various assignments made during the year and to identify new issues. The plan also set up a data coordination team made up of a member from the La Jolla and Honolulu Laboratories and the Southwest Region's Pacific Islands Area Office and regional office. The team will help the HMS data coordinator disseminate results, task staff at individual offices and laboratories, establish working groups to resolve issues, monitor the progress of working groups, and resolve disputes in the use of HMS data.

The HMS staff has identified nine HMS issues at their annual meeting: develop a data catalog; develop a data submissions catalog; investigate needed standards in the collection, handling, processing, management, and dissemination of HMS data; investigate needed protocols to obtain data required under the High-Seas Fishing Compliance Act; allow more access by HMS staff to information technology staff for help in designing databases; develop protocols for ensuring that policies developed by the coordination team are consistent NOAA and NMFS national policies; establish a dispute resolution panel; establish a panel to decide when data sets should be included in the HMS data system; and develop uniform data confidentiality and security policies. The data collection team has started to resolve these issues. Two working groups have been formed; one group will look at a data catalog and a submissions catalog and the other will look at standards.

International Activities – The Honolulu Laboratory organized the 53rd Annual Tuna Conference in Lake Arrowhead, California, May 2002, with assistance from the Inter-American Tropical Tuna Commission. The theme of the conference was ecosystem-based research in support of pelagic management plans. SWFSC personnel presented 12 papers at the conference.

The fifteenth meeting of the Standing Committee on Tuna and Billfish was held during July 2002 in Honolulu, Hawaii. The meeting was attended by more than 90 participants from 27 countries to review the population status of tuna and billfish stocks in the western and central Pacific. The meeting convened eight working groups: statistics, fishing technology, methods, skipjack, albacore, yellowfin, bigeye, and billfish and bycatch. Honolulu Laboratory scientists presented 14 papers at the meeting. Five presentations were in the billfish and bycatch group covering research to reduce sea turtle bycatch and mortality in pelagic longline fishing; dive-depth distribution of loggerhead and olive ridley turtles in the central North Pacific; determining survival, migration, and diving patterns of sea turtles released from longline fishing gear using pop-up satellite archival transmitters; an investigation of the life history and ecology of opah and monchong in the North Pacific; and a stock assessment of swordfish in the North Pacific using a statistical model. The tuna research groups presented research findings on the growth of yellowfin tuna in the equatorial western Pacific Ocean; characterization of the oceanography of the American Samoa longline fishing grounds for albacore; and the role of

oceanography in the aggregation and vulnerability of bigeye tuna in the Hawaii longline fishery from satellite, moored, and shipboard time series data. Additional presentations included an economic analysis and discussions of recent developments in the Hawaii and American Samoa longline fisheries; a summary of U.S. fisheries statistics for highly migratory species in the central-western Pacific, 1997-2001; the use of oceanographic data in longline effort standardization; and an application of an ADAPT virtual population analysis (VPA) model to simulated population data. La Jolla Laboratory researchers also presented three papers that summarized fishing by the U.S. purse seine fleet in 2001, investigated factors that may have affected catch rates of U.S. purse seiners fishing in the western-central Pacific, and evaluated the current species-composition sampling program for U.S. purse seine-landed tunas in the region.

A meeting of the Standing Committee's Skipjack Tuna Research Group, convened by the SWFSC senior scientist for highly migratory species, reviewed fishery data, advances in research, and information for stock assessment. Researchers showed that about 1 million t of skipjack tuna were landed annually in recent years. The 2001 catch was slightly more than 1.2 million t, the second highest catch on record. The purse seine fishery accounts for most of this catch (69%), and skipjack tuna was the dominant species caught in the western and central Pacific region. Stock status information indicated that recent stock biomass levels are the highest recorded and variation appears to be largely dependent on recruitment. The exploitation level is low, and the stock is healthy and capable of sustaining the current catch without adverse effects. This most recent information indicates the impact of fishing by the international fleet on the skipjack tuna stock is low and not a conservation threat.

In November 2002, the SWFSC senior scientist participated in a preparatory conference for the establishment of a Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific, held in Manila, Philippines. Progress on many issues was advanced at this session, including selection of the site Pohnpei, Federated States of Micronesia, for the Commission's secretariat, adoption of a resolution to assist in combating illegal, unregulated, and unreported fishing and to restrain growth in fishing capacity, and agreement on an organizational structure for the Commission.

II. 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 Mexican border and from the U.S. west coast to approximately 170°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 870 U.S. troll vessels fished for North Pacific albacore in 2001. 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 troll fleet in the South Pacific consists of 20 to 60 vessels. Thirty-three U.S. troll vessels fished for albacore in the South Pacific during the 2000-2001 season. Fifty-four logbooks (out of 442 logbooks received from the 2001 North and South Pacific fisheries) recorded catching other fish species while fishing for albacore. These species include skipjack, yellowfin, bigeye and bluefin tunas, mahimahi (dolphinfish), yellowtail, various shark species, salmon, pomfret, wahoo, and pompano.

Catch data 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 as well as for fishery monitoring under the Canada-U.S. Albacore Tuna Treaty. Logbooks are provided to fishermen who record fishing information and provide the information to the SWFSC. Length-frequency data are collected through a Pacific States Marine Fisheries Commission contract to Washington, Oregon, and California state

fisheries agencies and from NMFS offices in American Samoa and Hawaii. Statistics on the U.S. North and South Pacific albacore troll fisheries were analyzed during the year by La Jolla Laboratory staff. The information was summarized in a report (SWFSC Administrative Report LJ-02-05) issued June 2002 and is highlighted below.

Summary of U.S. North and South Pacific Albacore Troll Fisheries – U.S. troll vessels landed 11,210 metric tons (t) of North Pacific albacore in 2001 compared to 9,645 t landed in 2000. Annual catches over the last 10 years averaged 10,650 t. The most productive fishing areas in 2001 were in waters off Washington and Oregon and offshore near 170°E. U.S. catches of South Pacific albacore decreased to 2,128 t in the 2000-2001 season from 2,562 t in the 1999-2000 season. South Pacific catches averaged 1,953 t over the past 10 years.

Catch per unit effort (CPUE) for the 2001 North Pacific fishery increased to 66 fish per day in 2001 from 40 fish per day in 2000. CPUEs in the North Pacific fishery have fluctuated greatly since1995. Total effort decreased by 29% to 26,248 days in 2001 from 37,072 days in 2000. CPUE for the 2000-2001 South Pacific fishery decreased to 47 fish per day from 71 fish per day in 1999-2000.

A total of 13,857 albacore was measured during the 2001 North Pacific season. The average fork length of sampled albacore is 68.1 cm (14.3 lb or 6.6 kg) compared to 68.9 cm (14.8 lb or 6.7 kg) in 2000. Two size-class modes are evident at 65 cm (3 yr old) and 75 cm (4 yr old) fork length in the North Pacific length-frequency samples. A total of 4,029 albacore were measured during the 2000-2001 South Pacific season. The average fork length of South Pacific albacore that were sampled is 71.0 cm (16.2 lb or 7.3 kg) compared to 72.0 cm (16.9 lb or 7.6 kg) in the 1999-2000 season. A single size-class mode is centered at 71 cm (4 to 5 yr old).

International Collaboration on North Pacific Albacore Research – In December 2002, the SWFSC hosted the Eighteenth North Pacific Albacore Workshop in La Jolla, California. Fifteen researchers from Japan, Taiwan, Canada, the SWFSC, and the Inter-American Tropical Tuna Commission attended the workshop. SWFSC researchers 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 data bases, ongoing development of fishery statistics applicable to the U.S. troll and longline fisheries, potential biological studies that would generate critical information for addressing reproductive parameters generally assumed in modeling efforts, and recent developments in a new archival tagging program.

Results from VPA-based assessments presented at the workshop indicated that albacore population abundance remains at relatively high levels, particularly compared to levels observed during the 1980s (**Fig. 1**). However, estimates of fishing pressure (F) have been relatively high, particularly for juvenile fish (ages 3 to 5), and prolonged periods of elevated F would likely lead to reduced abundance in the future; i.e., all estimates of projections resulted in decreased abundance, regardless of the assumptions concerning levels of recruitment in the future. Currently, the population is being fished at roughly an $F_{20\%}$ level, which is a rate generally considered to be a minimum biomass threshold for some fish populations; i.e., an exploitation level that could compromise the stock's ability to sustain its size over a long-term horizon. However, it is important to note that minimum biomass thresholds have not been objectively determined for the tuna stocks in general, and albacore is likely a relatively productive fish stock that can sustain elevated levels of fishing pressure for short periods of time given, of course, recruitment remains relatively high in the near future.

In terms of recent recruitment strength, the consensus from the workshop is that the population is still in a period of "high productivity," which is illustrated in the estimated time series of recruitment (**Fig. 2**). That is, generally speaking, all model configurations suggested that recruitment was generally lower during the mid-1970s through the late 1980s and subsequently has increased since then, albeit a highly variable index. In summary, stock size will likely remain

relatively constant over the next few years if recruitment remains at levels observed over the last decade. However, if recruitment levels decline to those observed during the 1970-80s, population biomass could decline markedly, given *F* remains at its current, elevated level.

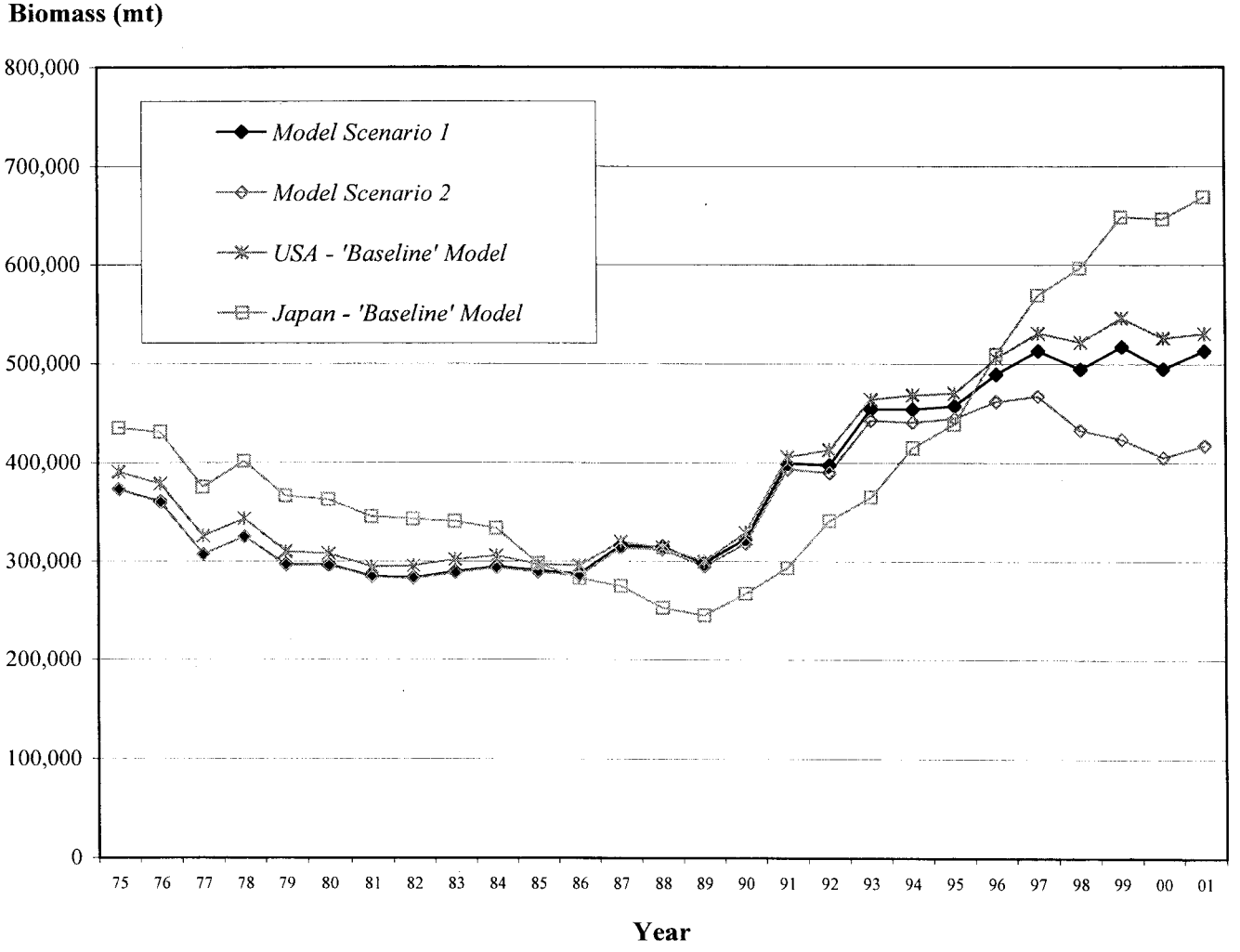

Figure 1. Estimated albacore total biomass (mt) time series generated from 'baseline' models (ADAPT Model Analysis) developed by the United States (USA) and Japan, and Model Scenarios 1 and 2 associated with the Eighteenth North Pacific Albacore Workshop (2002). Time series are based on January 1 estimates, except for the Japan time series, which is based on mid-year estimates.

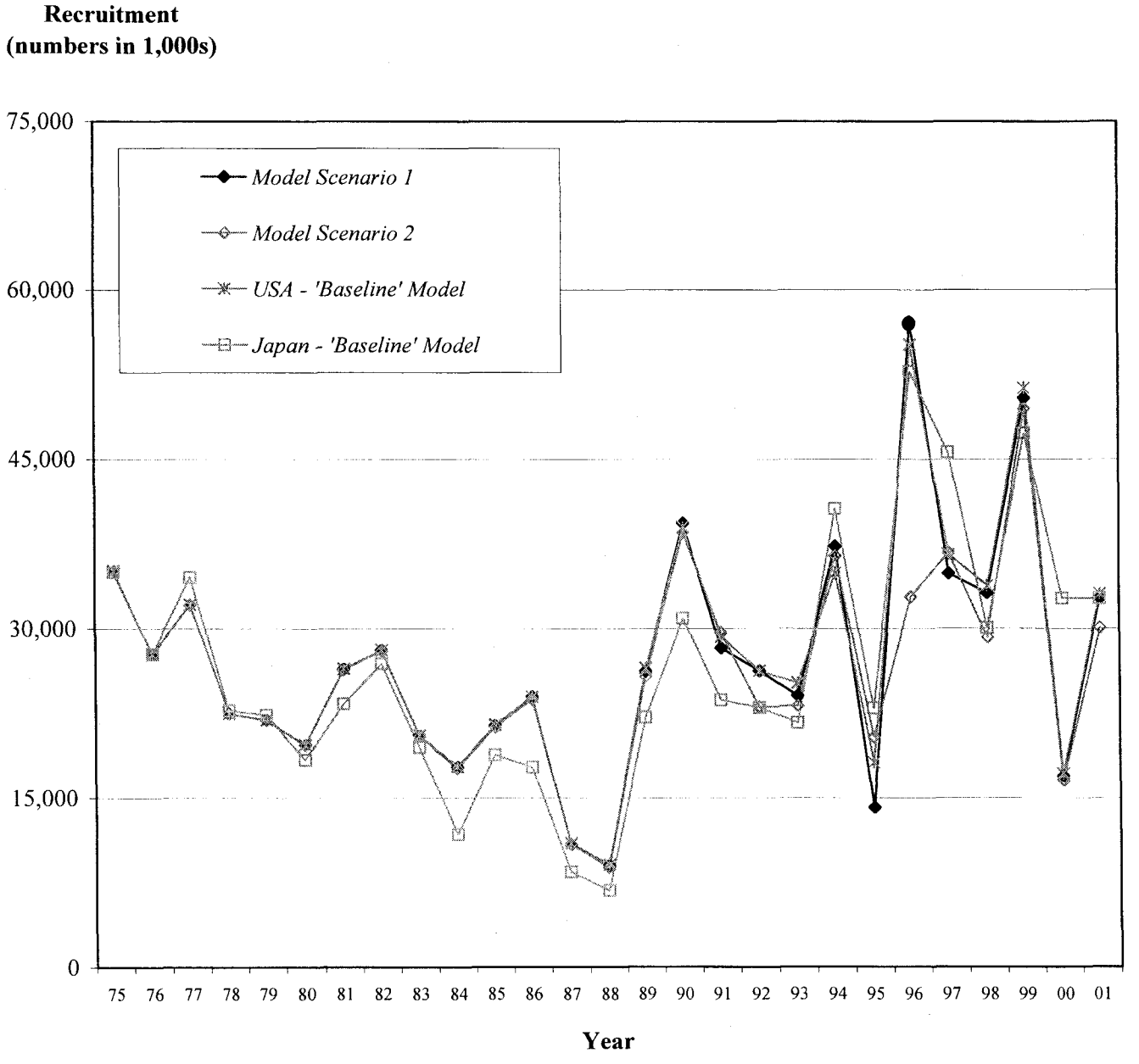

Figure 2. Estimated albacore recruitment (age-1 fish in 1,000s) time series generated from 'baseline' models (ADAPT Model Analysis) developed by the United States (USA) and Japan, and Model Scenarios 1 and 2 associated with the Eighteenth North Pacific Albacore Workshop (2002). Time series are based on January 1 estimates, except for the Japan time series, which is based on mid-year estimates.

III. PELAGIC FISHERY MONITORING, STOCK ASSESSMENT, AND RESEARCH AT THE HONOLULU LABORATORY

Many scientific activities are undertaken by the Honolulu Laboratory in support of U.S. domestic and international interests in Pacific highly migratory species. Activities include extensive support for monitoring of U.S. fisheries in Hawaii, American Samoa, Guam, the Northern Mariana Islands, and other U.S.-flag islands of the central and western Pacific. In addition, the laboratory conducts stock assessments of tunas, billfishes, and other highly migratory species and programs of biological, ecological, oceanographic, and economic research to improve our understanding of stock and fishery dynamics and to enable sound scientific advice for fishery managers. Much of the research is carried out in collaboration with other government or university science laboratories, both in the United States and abroad.

Pacific Swordfish Age and Growth Research – Size-at-age studies of young swordfish based on presumed daily growth increments are near completion. These studies employ an acid-etching technique to expose at the surface internal daily growth increments aligned along a path from the core to tip of the rostrum within the sagittal otolith. Processed sagittae are examined with a scanning electron microscope and overlapping digital photographs are taken under high magnification. Subsequent daily growth increment counts are conducted using image analysis software. Young-of-the-year (YOY) swordfish growth is rapid, attaining a length of approximately 97 cm eye-to-fork length (EFL) at age-1 (365 days). Based on the current daily growth increment processing technique, this method is limited to swordfish under age-2 due to the narrowing (to ~0.3 micron) of daily growth increment widths at the otolith edge, which increases the difficulty in properly processing these daily growth increments for subsequent scanning electron microscope examination.

Pacific Swordfish Stock Identification – As part of an ongoing investigation into the stock structure of Pacific swordfish, samples of muscle tissue were collected from larval and larger (50 to 80 cm EFL) YOY swordfish and sent to collaborative researchers at Stanford University and Texas A&M University for DNA population analysis. In addition to collections from around Hawaii, these samples also included YOY collected from equatorial waters directly south of Hawaii and also from Guam, Tahiti, and Australia. These tissue samples from YOY specimens will provide an opportunity to compare genetic results from individuals probably much less dispersed from their original nursery areas than samples derived from adults that were primarily collected from higher latitude fishing grounds.

In collaboration with a Bedford Institute of Oceanography researcher, the results of a trace element analysis of sagittal otoliths from YOY juvenile swordfish have been described in a paper recently submitted for publication. The objective of this preliminary study was to analyze a suite of elements using isotope dilution ICPMS to detect for the existence of elemental fingerprints within otoliths that could serve to identify geographically distinct nursery grounds. Differences in the concentration of Sr and Ba were detected between YOY swordfish collected around Hawaii and at the equator. With more comprehensive sampling of nursery grounds, it may be possible in the future to identify the nursery ground origin of individual adult swordfish by analyzing the core and adjacent juvenile portion of the otolith using a probe technique such as laser ablation ICPMS.

Studies of Larval Swordfish and Other Billfishes – Larval billfish sampling off the Kona coast of the island of Hawaii was conducted from NOAA ship *Townsend Cromwell* in May 2002. Sampling was conducted using a 6-ft Issacs-Kidd trawl and neuston nets towed from the ship's small boat, both targeting surface slicks 1 to 10 nmi offshore. These tows yielded 15 swordfish larvae and 70 istiophorid larvae during the five-day sampling period. In an ongoing effort to definitively identify istiophorid larvae and billfish eggs, the La Jolla Laboratory continues its collaboration with the Honolulu Laboratory in taking the research lead at sea to test and refine a polymerase chain reaction (PCR)-based technique that would definitively identify billfish larvae and eggs to species. During the cruise, a restriction fragment length polymorphism technique

was tested that would provide near real-time species identifications. Such at-sea identifications are important in allowing Honolulu Laboratory researchers to employ adaptive sampling methods while at sea to better delineate species-specific habitat extent and associated environmental parameters. Further testing by the La Jolla Laboratory of a more rapid and reliable at-sea PCR-based identification technique is planned for an upcoming Kona cruise scheduled in May 2003.

International Collaborative Research – An ongoing collaboration in swordfish life history research between the Instituto de Fomento Pesquero in Chile and the Honolulu Laboratory began in 1999. Current collaboration involves larval surveys to identify swordfish spawning areas within Chilean waters. Swordfish larvae would be used in an investigation of stock structure to determine the natal origins of the adult swordfish captured in the Chilean swordfish fishery. Chilean research surveys have focused on waters adjacent to Easter Island as this is the only location where seasonal sea surface temperature exceeds the lower limit of 24°C associated with swordfish spawning. Larval specimens have been sent to the Honolulu Laboratory for identification; thus far only istiophorid larvae have been collected. Another Chilean collection survey in February-March 2003 will attempt to employ similar techniques used off the Kona coast to capture swordfish larvae.

Recreational Meta Data Project – The University of Hawaii-Joint Institute for Marine and Atmospheric Research (JIMAR) recreational meta data project was initiated to document and compile all sources of pelagic recreational and sports fishing information in Hawaii over the past 50 years. To date, there has been no centralized, systematic documentation of Hawaii's recreational fishery, though information does exist in the form of previous studies, surveys, tournament and club records, newspaper articles, and fishing logbooks. We have organized these sources into database formats, so that they are easily accessible to researchers and fishery managers.

Our sources of information fall into two categories – literature and catch records. The literature consists of nearly 80 documents, including published and unpublished papers, technical reports, books, surveys, and project summaries. Copies of the literature and associated tables will be made available via the Honolulu Laboratory Web site by May 2003. The catch records have been provided by various clubs, tournaments, and fishermen and contain some or all of the following: date, time, boat, species, number, weight, tackle used, area, condition of fish, and tag number. Annual catch records from 31 tournaments, provided by seven clubs and three tournament organizers, and daily catch records from two harbors specializing in charter boat fishing have been incorporated into the database. The tournaments, which range in size from six to 260 boats, are held at approximately the same time each year. Though one tournament provided 42 consecutive years of data, the mean is six nonconsecutive years. This database is available to scientists and other interested parties upon request.

Information on effort, catch, and tournament totals reflects the unique nature of each tournament's reporting procedures. Most tournaments do not differentiate between bigeye tuna (*Thunnus obsesus*) and yellowfin tuna (*T. albacares*), listing both as "ahi." Likewise, "marlin" may refer generally to any billfish species. Skipjack tuna (*Katsuwonus pelamis*) may or may not be reported. The potential for constructing weight frequency charts was investigated, but it was confounded by species identification problems and the estimation of weight used in radio log catch records. Despite these limitations, this information does provide insight into hooking rates, catch composition, average weight of catch, and fish aggregating device use.

Tuna Growth Study – Determinations of the von Bertalanffy model growth coefficients were calculated for the bigeye and yellowfin tunas caught in the western-central Pacific Ocean. Monthly size-frequency distributions were developed on the landings of foreign longliners participating in the Guam fishery where fresh fish were transshipped to sashimi markets in Japan. Modal progression method was used to determine the growth coefficient for each individual age class. From the 1989 to the 1998 landings, seven year classes of bigeye tuna were identified. From the time of entry into the fishery, each recruiting year class could be

tracked for four or five years, to near asymptotic size. The values of *K* for each year class ranged from 0.201 to 0.465 yr^{-1} and were found to be positively correlated to the Southern Oscillation Index, such that the year classes with higher *K* values were hatched during El Niño and those with lower values during La Niña. Additionally, the strength of the year classes was also positively correlated to *K*. This would suggest that survivalship increases when the critical period in the life history is reduced.

From the 1989 to 2001 landings, nine year classes of yellowfin tuna were identified. Estimates of the growth coefficient ranged from 0.334 to 0.775 yr^{-1} and were well within the range of previous yellowfin tuna growth studies in the Pacific. Except for the 1993 year class low of 0.334 yr^{-1}, the overall mean was 0.612 yr^{-1}. Unlike bigeye tuna, correlation to environmental conditions such as the Southern Oscillation Index could not be detected. It appears that yellowfin tuna that normally inhabit waters above the thermocline were less sensitive to these episodic events.

Movement and Distribution of Pelagic Fishes – In cooperation with University of Hawaii-JIMAR researchers and others, scientists at the Honolulu Laboratory have employed "pop-up" satellite archival tags (PSATs) and conventional archival tags in a number of different ways to address several questions relevant to the fishery biology and the ecophysiology of pelagic fishes. These studies include investigation of rates of morbidity and mortality in pelagic fishes (marlin and sharks) following release from longline and recreational fishing gear. In this project, PSATs are attached prior to release while simultaneously extracting blood samples to derive biochemical correlates of delayed mortality. In other words, using a double-blind approach, the project is attempting to determine if biochemical indices of stress and the vertical movement data provided by the PSATs lead to similar conclusions. Another project is developing a Kalman filter to improve estimates of a "most probable" track, geolocation errors, and parameters relevant to models of long-term fish movements from light-based location data. As part of this project, archival tags have been affixed to a stationary mooring line in the central Pacific and PSATs to Global Positioning System (GPS) drifter buoys. Other research involves development of physiological-based models of pelagic fish behavior in order to better predict vertical movements patterns.

The information derived from these projects will improve indices of abundance based on CPUE data by incorporating depth distributions, oceanographic conditions, and specific gear vulnerability. To date, project personnel have deployed PSATs and received data from the following:

Swordfish – Data for 527 days at liberty. In 2001, four of eight tagged fish reported data for 156 days at liberty, and in 2002, five of 17 fish were tracked for 371 days at liberty.

Blue shark – Data for 1,841 days at liberty; In 2001, 10 of 14 tagged fish reported data for 731 days at liberty, and in 2002, six of 17 tagged fish reported data for 1,111 days at liberty.

Oceanic whitetip shark – Data for 183 days at liberty. In 2001, one of one tagged fish reported data for 169 days at liberty, and in 2002, one of two tagged fish reported data for 14 days at liberty.

Bigeye thresher sharks – In 2002, two of six tagged fish reported data for 500 days at liberty.

Yellowfin tuna – In 2001, two of two tagged fish reported data for 64 days at liberty.

Bigeye tuna – In 2002, two of three tagged fish reported data for 56 days at liberty.

Project personnel have also deployed PSATs on an additional eight marlin (six blue marlin, one black marlin, and one striped marlin), three silky sharks, three oceanic white-tip sharks, and three bigeye tuna but are waiting for the tags to reach their scheduled pop-up dates.

Fishery Oceanography – Scientists at the Honolulu Laboratory have been collecting data on the horizontal and vertical movements and habitats of bigeye tuna and opah in the central North Pacific using pop-up archival transmitting tags deployed on fish caught on commercial longliners. As of February 2003, 26 tags had been deployed and more deployments are planned for March and July 2003.

Commercial Longline Logbooks – An ongoing area of research at the Honolulu Laboratory has been determination of the accuracy of the commercial longline logbook data used to monitor the fishery and the related issue of how best to utilize the logbook data in relation to the two data sets available for use as comparison standards – records gathered by the Hawaii longline observer program and sales records from the United Fishing Agency public fish auction in Honolulu. A presentation on the development and application of generalized additive models to correct incidental catch rates for pelagic marine fisheries in the Hawaii-based longline fishery was made at the annual meeting of the American Fisheries Society, Baltimore, Maryland, in 2002. A manuscript on the integrated use of observer and logbook data sets to enhance fisheries monitoring is currently in review.

Survivorship Studies – Researchers at the Honolulu Laboratory, working in collaboration with University of Hawaii personnel, have continued efforts to determine the survivorship, migrations, and diving patterns of sea turtles released from commercial longline fishing gear. The main objective of this project is to provide reliable estimates of delayed mortality and morbidity in sea turtles following interactions with longline fishing gear. To do this, scientists have trained various seagoing personnel to deploy PSATs on incidentally caught turtles. The tags have a fail-safe/mortality sensor, whereby the tag can be set to jettison if the turtle is stationary for extended periods or if it exceeds a specified depth. Rates of post-hooking mortality and morbidity are compared with a standardized set of scored observations, such as hook location, severity of injury, and a general assessment of the turtle's health.

Since January 2002, NMFS and JIMAR personnel have participated in five workshops to train observers in both the Hawaii longline fishery and the California longline fishery in PSAT attachment procedures. To date, approximately 90 observers have been trained. Since March 2001, PSATs have been taken to sea on approximately 270 longline fishing trips, resulting in approximately 3,120 observed longline sets in the Hawaii fishery. Due to current fishing regulations designed specifically to minimize turtle-longline interactions, only two turtles have been caught and tagged during observed trips. One PSAT remained on for 4.5 months and provided excellent data on horizontal and vertical movements. The second PSAT came to the surface and began downloading data only four days after attachment, apparently due to premature tag loss.

In order to circumvent the problem of getting too few tags out with the Hawaii longline fishery, at-sea observers have also been trained to deploy PSATs in the California longline fishery and also in Costa Rica, where sea turtle bycatch is high. During fall 2002 and winter 2003, four hard-shelled turtles incidentally caught in longline gear from California vessels were tagged with PSATs, each set to release in October 2003. In Costa Rica,10 sea turtles (nine olive ridleys, one green turtle), seven of which were caught in longline gear and three captured while free swimming, have been tagged with PSATs. These latter individuals served as controls to which the behaviors of longline-captured turtles could be compared. To date, 11 tags have reported data, which range in duration from 6 to 9 weeks, considerably shorter than expected. From the vertical movement data obtained so far, there have been no apparent mortalities.

In association with colleagues on the mainland, a method for attaching PSATs to leatherback turtles released from longline gear was also tested. The method involves a subdermal attachment of the PSAT's tether using a medical-grade titanium bone anchor.

Bait Modification Studies – During 2001 and 2002, Honolulu Laboratory and JIMAR scientists have conducted experiments on captive sea turtles aimed at identifying a potential turtle-repellent bait. Behavioral experiments using subadult green turtles (*Chelonia mydas*) (*n*=23), loggerhead turtles(*Caretta caretta*) (*n*=49), and Kemp's ridley turtles (*Lepidochelys kempii*) (*n*=28). The former have been maintained at the Kewalo Research Facility (NMFS Honolulu Laboratory) and the latter two species at the Sea Turtle Research Facility (NMFS Galveston Laboratory). Studies have found that sea turtles do indeed use vision, specifically color vision, in being attracted to bait. More specifically, turtles' attraction to food is a function of food color, whereby blue is least attractive and red apparently most attractive, and that this color "preference" is conserved in all three species tested. Furthermore, in tests of artificial baits that disguise visual differences between edible items, green turtles did indeed rely on gustatory cues to bite "food."

Baits have been modified with potentially repellent compounds such as garlic, cilantro, habanero chili extract, *Aplysia* ink, squid ink, urea, and quinine hydrochloride. All baits were also fed to captive yellowfin and skipjack tunas. Tunas and sea turtles have willingly eaten all baits tested thus far. Therefore, the search for a repellent bait is still in progress.

Sensory Physiology of Sea Turtles and Pelagic Fishes – During January 2003, the Honolulu Laboratory hosted a sea turtle-pelagic fish sensory biology working group meeting at the laboratory. Scientists, managers, and industry representatives gathered to discuss recent findings on various aspects of research in marine turtle and pelagic fish sensory physiology and behavior, with the ultimate aim of identifying a measure to eliminate or reduce the incidental capture of marine turtles in longline fishing gear. The various research projects, which span the globe from Australia, Sweden, and the United States, have been funded by the NMFS Honolulu Laboratory for the past two years. The goal of the meeting was to synthesize information gained and to identify either a visual, olfactory, or auditory cue that would repel turtles from biting bait. Presentations were made on odor reception and olfaction in sea turtles; visual capabilities in sea turtles and pelagic fishes; auditory capabilities in tunas and sea turtles; and behavioral responses to both light sticks and chemical deterrents. At present, it appears that a visual deterrent could be developed based on differences in the visual responses of targeted fish species and sea turtles.

Hawaii Longline Turtle Bycatch Fishing Experiments – In January 2002, NMFS issued a scientific research permit (#1303), under Section 10 of the Endangered Species Act, authorizing the Honolulu Laboratory to conduct a limited portion of its proposed at-sea research to reduce longline fishery bycatch and mortality of sea turtles. The objective of the proposed work was to develop longline fishing methods to harvest swordfish and tuna, while reducing or eliminating the bycatch of sea turtles. The long-term goal was to implement these "turtle-safe" fishing methods internationally. The research covered by the permit was designed to complement similar research being conducted in the Atlantic Ocean, but was distinctly different because longline fishing strategies and tactics differ in the Pacific from those followed in the Atlantic. In granting the permit, the main portion of the proposed Pacific work was put on hold pending results of the related research in the Atlantic.

The proposed experiments were designed to test various gear modifications over three years using contracted longline fishing vessels. The largest effort was intended to test blue-dyed bait and a rearrangement of branch lines to keep all branch lines at least 40 fathoms away from float lines. These gear alterations were based on analyses of fishery observer records on branch lines that showed which branch lines catch the most turtles and on results from blue-dyed bait experiments with captive sea turtles. Statistical analysis of five years of longline observer data showed that branch lines attached less than 40 fathoms from float lines caught the most turtles.

And although captive green and loggerhead sea turtles were attracted to natural squid bait, when they were presented with a choice between blue-dyed and natural bait, the turtles ignored blue bait for 8 to 10 days in an experimental setting.

The statistical design of the blue bait and rearranged branch line experiment called for 520 sets with modified gear, contrasted with 520 control sets per year for three years. This number of sets was required by a statistical power analysis that demonstrated it would require 12 leatherback captures per year for three years to detect a 50% reduction in leatherback sea turtle bycatch compared to the control. Statistical power to detect success would be much higher for loggerhead turtles since more would be caught (an estimated 65 per year). A small number of green (4) and olive ridley (6) sea turtles would also be captured. Estimated mortality of these captured turtles would include four leatherbacks, 24 loggerheads, one green, and two olive ridleys per year. Estimated mortalities include immediate mortality (dead on retrieval of the longline) plus delayed (post-release) mortality where 0.27 lightly hooked plus 0.42 deeply hooked turtles are assumed to suffer delayed mortality.

These estimated mortality figures follow NMFS' official procedure for estimating post-release mortality. However, based on analyses of observer data, the actual number of immediate sea turtle mortalities was anticipated to be small. For example, in the case of leatherback sea turtles, it was anticipated that two animals might suffer immediate mortality over the course of all experiments over three years. Based on captures observed from 1994 to 2001, only three of 54 leatherback turtles were dead when brought alongside the fishing vessel. Academic sea turtle specialists have characterized NMFS procedures for estimating post-release mortality as overly conservative, resulting in overestimates of delayed sea turtle mortalities. NMFS procedures may be questioned for leatherbacks because the mortality rates are based on satellite tagging experiments carried out on loggerheads that for the most part were hooked in the mouth, whereas leatherbacks are most often entangled or externally hooked.

Permit 1303 severely limited the scope of the fishing experiments conducted in the Pacific in 2002. Tests of blue bait and rearranged branch lines were not initiated in the Pacific. Fishing experiments conducted in the Atlantic Ocean in 2002 did test rearranged branch lines and blue-dyed bait. However, because of differences between longline fishing gear configurations used in the two oceans, the branch lines were moved only 20 fathoms away from the float lines in the Atlantic experiments. These gear modifications failed to reduce sea turtle bycatch.

A total of 194 experimental longline sets were conducted under the permit in the Pacific in March-July 2002. A proposed portion of this effort was designed to test deep daytime fishing for swordfish (33 sets) and stealth (camouflaged) fishing for swordfish (33 sets) in comparison with normal swordfish fishing (33 sets). Both methods are expected to greatly reduce sea turtle bycatch, but these tests were too limited in scale to measure bycatch reduction (turtle bycatch is a rare event). The purpose of the tests was to determine the economic viability of these rather drastic modifications to normal swordfish fishing methods. Neither gear modification caught any turtles, whereas control fishing caught one turtle, which was released alive. Swordfish revenue using the stealth gear was reduced by 30%, and the reduction using deep daytime fishing was 85%.

The deep daytime swordfish fishing method resulted in considerably higher rates of fishery interactions with black-footed and Laysan albatrosses. The control fishing, where the gear was set after dark with normal squid bait, reduced interactions with albatrosses by about 83% compared to the experimental deep daytime setting with natural squid bait. Stealth fishing, where the gear is set after dark using blue-dyed squid bait, reduced interactions with albatrosses by about 98%.

Research using electronic hook timers and time-depth recorders to document when and where turtle bycatch occurs in the sequence of longline deployment and retrieval was also

allowed under Permit 1303. This information and understanding is vital to the development of additional methods that may alter the exposure of fishing gear to turtles at critical times during the operational cycle. In addition, a piggyback project was allowed that tested the effectiveness that large (18/0) circle hooks might have in catching target species. Circle hooks have been found to be less injurious to sea turtles. To reduce the impacts of this experiment on sea turtles, circle hook testing was conducted using the same gear set for the hook-timers research, and no additional capture of turtles was required to test the circle hooks.

In 2002, hook timers were used on 95 sets to measure the exact time and circumstances of turtle hooking. Two turtles were caught in the hook-timer research to date (too few for meaningful analysis, but the experiment was designed to continue for several years). All turtles were released alive. A single leatherback turtle captured provided the only hook timer data in 2002. The timer indicated that the turtle was hooked 35 minutes before being sighted on the line and 37 minutes before being brought alongside the vessel. The time of capture was 0738 HST, one hour after local sunrise, at ca. 29°N, 174°W. The leatherback threw the hook by itself and escaped. The results from testing large circle hooks versus J hooks showed typical catch rates for tuna using circle hooks but substantially decreased catch rates for swordfish.

Scientists responsible for designing and analyzing both the Atlantic and Pacific turtle longline bycatch experiments met in Honolulu in September 2002 to review results and make recommendations for future work. These scientists recommended proceeding with the entire suite of experiments originally proposed for Permit 1303, with modifications to the stealth and deep daytime gear to improve catch rates for target species. A final report on the 2002 experiments was submitted to the NMFS Office of Protected Resources in November 2002.

However, on June 27, 2002, the Ocean Conservancy, Turtle Island Restoration Network, and Center for Biological Diversity (plaintiffs) filed a complaint in Federal District Court in Honolulu against NMFS, challenging the permit and the process under which it was issued and seeking an injunction against the experiments. The court denied the injunction due to the critical status of the turtles and the need to perform the experiments without delay. However, the court ordered NMFS to complete an environmental impact statement on the work, which is now in preparation. The plaintiffs subsequently appealed and obtained a temporary restraining order against conducting further experiments until the appeal was concluded.

After a planned hiatus in the experiments during the summer of 2002, the experiments were scheduled to resume with the season of swordfish and turtle abundance beginning December 1. The best months for the research are January and February. Initiating the experiments requires several months' notice to contractors, and delays due to the litigation put the earliest estimated start date into March or April 2003. After reviewing the situation NMFS decided that in order to fully utilize information obtained or developed during the preparation of the environmental impact statement, NMFS would withdraw Permit 1303 and conduct no further work without issuing a new permit. However, NMFS remains committed to research into turtle-safe longline fishing gear and fishing techniques and expects to issue a new permit for continued experimentation on longline fishing gear and techniques to the Honolulu Laboratory after completion of the environmental impact statement.

Life and Ecology of Opah and Monchong – Studies on the life history and ecology of opah (*Lampris guttatus*) and monchong (*Taractichthys steindachneri*) in the North Pacific have continued at the Honolulu Laboratory with support from the Pelagic Fisheries Research Program (University of Hawaii). These two pelagic species, incidentally caught by Hawaii-based longliners targeting bigeye tuna, are generally harvested in small but nevertheless significant quantities. Since neither is a targeted species, these fishes have been poorly studied, and as a result available information pertaining to their biology and ecology is virtually nonexistent.

The project activities for both the opah and monchong resources fall under two major categorical subprojects: (1) a comprehensive shore-based biological sampling program designed

to monitor landings and catch composition and to obtain the metrics (length, weight, sex) and samples (ovaries, otoliths, and stomachs) required for a comprehensive biological and ecological assessment, and (2) an analysis of spatial distribution patterns, preferred habitat, faunal associations, and trophic relationships. The latter project involves the analysis and merging of industry, research, and environmental datasets, as well as capture depth information collected from vessels of opportunity.

Among the study highlights, it was discovered early on that opah exhibit sexual dimorphism, thereby enabling the determination of sex without having to cut into the body cavity to access the gonads.

During efforts to estimate age and growth, preliminary examination of hard parts indicated that the second dorsal fin ray for opah and both sagittal otoliths and fin rays for monchong provide the best opportunities for ageing these animals. As suspected, sagittal otoliths in opah are of vaterite form and are not conducive for daily increment enumeration. Assuming that annuli are formed annually, ages of opah taken in the fishery are estimated between 1+ and 6+ years (i.e., 2 to 7 annuli). If microincrements (on postrostrum and/or rostrum of sagittal otolith) are daily, monchong appear to grow rapidly in the first year; ages of 42- to 49-cm fork length fish ranged from ~1 year to 13.5 months.

The project has been especially successful in obtaining capture-depth information for both opah and monchong and in obtaining biological samples on cooperative commercial longline fishing trips. On two trips, 108 monchong and 34 opah were caught on 26 longline sets. Of these, 15 monchong and one opah were caught on the sections of longline instrumented with a series of time-depth-temperature recorders and hook timers. Additionally, another seven opah (four males, three females) were instrumented with PSATs upon capture and released. A work in progress, the opah-monchong project will continue data and sample collection, as well as data analysis, through 2003.

IV. EASTERN TROPICAL PACIFIC TUNA FISHERIES

International Dolphin Conservation Program Act (IDCPA) Research – The IDCPA research activities conducted by the SWFSC during 2002 included the production of a "Report of the Scientific Research Program under the IDCPA," supported by 31 administrative reports. The administrative reports fall under four research categories: (1) abundance estimates for depleted dolphin stocks, (2) ecosystem studies, (3) stress and other possible fishery effects, and (4) quantitative stock assessments of depleted dolphins. All data were collected and analyzed and reports were written with the goal of helping the Secretary of Commerce determine whether chase and encirclement by the tuna purse seine fishery is having a significant adverse impact on one or more depleted dolphin stocks in the eastern tropical Pacific Ocean (ETP). In its entirety, the research conducted by SWFSC under the IDCPA has produced many important, substantial new results: current estimates of abundance for depleted dolphin stocks as well as for other cetaceans in the ETP, with advances in analytic methods for abundance estimation; sharpening the focus on likely mechanisms of stress effects on individual dolphins; and an improved understanding of the likely effects of chase and encirclement on the dolphin cow-calf bond. All reports mentioned above underwent independent peer review in order to evaluate methods, analyses and results of all aspects of the IDCPA research.

Abundance estimates – Research conducted under the IDCPA focused on three stocks of dolphins considered "depleted" under the Marine Mammal Protection Act (MMPA): the northeastern offshore spotted dolphin, the eastern spinner dolphin, and the coastal spotted dolphin. Current abundance estimates were derived from research vessel surveys conducted in the ETP during 1998, 1999, and 2000, using improved analytical methods for abundance estimation. Survey data from nine earlier abundance surveys dating back to 1979 were also re-analyzed using these new methods. The average of the abundance estimates for the years

1998, 1999, and 2000 is 641,153 (CV = 0.169) for northeastern offshore spotted dolphins, 448,608 (CV = 0.229) for eastern spinner dolphins, and 143,725 (CV = 0.357) for coastal spotted dolphins. Although the abundance for the coastal spotted dolphins was estimated based on a single stock, recent genetic analyses indicate multiple coastal stocks, making this single abundance estimate of limited relevance.

Ecosystem studies – Physical and biological oceanographic data were collected throughout the ETP research surveys in order to assess substantial ecosystem changes since the dolphin stocks were depleted. Research was focused on temporal variation because carrying capacity for long-lived animals such as dolphins is more likely affected by long-term environmental changes (decadal) than by short-term occurrences (seasonal). All investigations indicated that variability associated with El Niño-Southern Oscillation (ENSO) events is the predominant variability throughout the ecosystem. Decadal-scale variability was also evident, but the magnitude was much smaller than that recorded during ENSO cycles. Ecosystem data were collected beginning in 1986 as part of the NMFS dolphin assessment cruises. These cruises were conducted seasonally through 1990 and a second series of cruises was conducted from 1998 through 2000. No dramatic shifts were detected from analyses of these data, but this series of data does not cover the period before the late 1970s shift.

Stress and other possible fishery effects – The IDCPA required that NMFS conduct studies on stress and other fishery effects on ETP dolphins, addressing the question *do chase and encirclement adversely affect dolphins*? Primary focuses of the stress studies included research on potential separation of mothers from their calves, measurement of acute and chronic physiological effects that could result in injury or death, observation of behavioral responses to fishing activities, and estimation of the average number of times a dolphin might be chased and encircled per year per stock. The findings support the possibility that purse seine fishing involving dolphins may have a negative impact on the health of some individuals. Analyses of more than 1,800 purse seine sets from 1973 to 1990 in which all dolphins that died in the net were examined led to the conclusion that there is some separation of calves from their mothers. It was estimated that total mortality was underestimated by 10% to 15% for spotted dolphins and 6% to 10% for spinner dolphins in this sample, based on reasonable assumptions about length of nursing dependency. Several lines of research suggested potential physiological stress effects, but larger sample sizes and baseline data for the affected species are needed to fully interpret findings. Sample sizes for both the necropsy program and the field studies were insufficient to estimate potential population-level impacts or to determine whether population recovery of the depleted stocks may be delayed by these effects. Additionally, estimates were made on the number of interactions dolphins have with the fishery on an individual and population basis. The number of interactions is large relative to population size, with an estimated 2.5 million eastern spinner dolphins chased per year and 280,000 coastal spotted dolphins chased per year.

Stock assessments – The stock assessment modeling was the final component of the IDCPA research, with particular focus on how current dolphin populations compare to their pre-fishery abundances. Under the MMPA, a marine mammal population is considered depleted when its abundance is less than 60% of carrying capacity. Northeastern offshore spotted dolphins are currently estimated to be at 20% of their pre-fishery abundance and eastern spinner dolphins are estimated to be at 35% of their pre-fishery abundance. A significant result from the trend and assessment analyses for both spotted and spinner dolphins is that their population growth rates are very low, ranging from -2% to 2% per year depending on details of the analysis. Incorporating all of the assessment analyses, these results do not indicate that either dolphin population is recovering as would be expected from a depleted state.

The four components of the IDCPA research discussed briefly above result from intensive field and laboratory work conducted by the SWFSC. Overall conclusions of the research were that both northeastern offshore spotted dolphins and eastern spinner dolphins are significantly below their pre-fishery levels and that neither population is recovering as might be expected. The

"Report of the Scientific Research Program under the IDCPA" and the accompanying administrative reports are available on the SWFSC's Web site (swfsc.nmfs.noaa.gov/IDCPA/TunaDol_rep). Information about the Department of Commerce's dolphin-safe determination can be found on the NMFS Web site (www.nmfs.noaa.gov/pr/PR2/Tuna_Dolphin/finalfinding.html).

V. SHARK RESEARCH

Juvenile Shark Abundance Survey – The juvenile shark abundance survey, conducted since 1994, provides fishery-independent CPUE trend analysis and abundance indexing for pelagic sharks off the southern California coast. The California and Oregon driftnet and offshore longline fisheries catch significant numbers of juvenile and mature thresher, mako, and blue sharks. Recent fishery closures north of Point Conception, California, increased fishing effort south of Point Conception to the California–Mexican border. These pelagic stocks are transboundary with northern Mexico, where they have also come under increased commercial fishing pressure. Currently there are no stock assessments for these species, although they will soon be managed under a new west coast fishery management plan. This survey provides data on relative abundance, size of catch, and life history parameters needed to address issues of stock condition.

The 2002 juvenile shark survey was completed in July. Two fishing sets were conducted daily with a total fishing effort of 6,054 hooks at 35 separate sampling stations. Captured sharks were tagged with conventional spaghetti tags, satellite archival tags, and injected with tetracycline. The catch included 119 mako sharks, 73 blue sharks, and two common thresher sharks. Preliminary data indicate that the overall catch rate for mako sharks was 0.53 sharks per 100 hook-hours and 0.33 sharks per 100 hook-hours for blue sharks. The CPUE for mako sharks was less than in 2001 and continues a long-term decline in catch rate. The catch rate for blue sharks was lower than in 2000 and 2001 but does not indicate a change in the long-term trend (**Fig. 3**). Length frequencies for blue sharks and mako sharks increased in 2002 but average size of sharks taken has not changed significantly during the study period (**Fig. 4**). In addition, 163 sharks were tagged with conventional tags for movement analysis, 101 sharks were marked with oxytetracycline for age and growth studies, 93 DNA samples were collected, and 55 blood samples were obtained for condition and post-release survival studies.

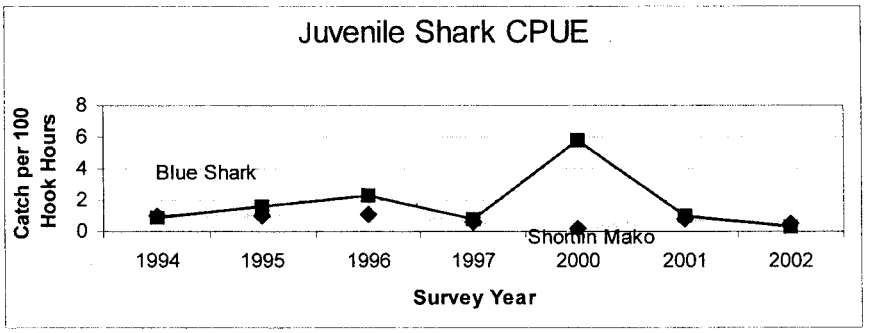

Figure 3. Catch per unit effort (CPUE) for sharks sampled during juvenile shark abundance surveys.

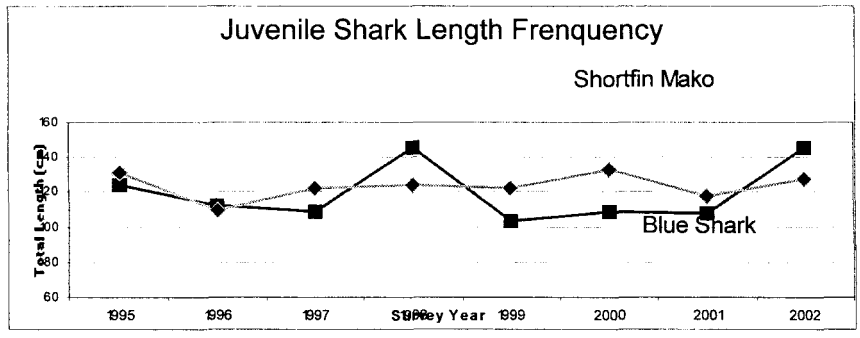

Figure 4. Length frequency of sharks sampled during juvenile shark abundance surveys.

Acoustic and Satellite Archival Tag Studies – During the 2002 juvenile shark abundance survey, several studies were conducted using acoustic and satellite archival tags to examine mako and blue shark habitat use and factors affecting post-release survival. In a pilot study to examine mako shark swimming and feeding behavior, one shortfin mako shark was tracked with an ultrasonic transmitter for a period of 12 hours. The 145-cm mako was caught during the juvenile shark survey and was tracked from an inflatable skiff for the first seven hours and then with a VR-28 tracking system aboard the NOAA ship *David Starr Jordan*. During the track, the shark traveled a total distance of 15 nmi in an area east of San Clemente Island. The tracking team was able to gather location information, swimming speeds, and depths of vertical excursions. Tracking was most effective with the skiff but less effective with the ship due to its large size. This pilot study proved also to be a successful training experience, resulting in seven additional mako shark tracks totaling more than 170 hr of tracking during the following months.

Eight mako sharks were tagged with satellite archival pop-up tags to examine movement patterns in relation to their physical environment and to help determine post-release survival. All eight satellite tags recorded and transmitted archived data on water temperature, swimming depth, and day light intensity as programmed. Four of the tags were programmed to detach from the host shark after 60 days and the other four were programmed to detach after 120 days. Results showed all eight sharks survived the stress of capture and release for periods of at least 60 to 120 days. Five of the mako sharks remained in the Southern California Bight during the experiment, while the other three moved south and east into Mexican waters. Preliminary environmental data indicate mako sharks remain in water temperatures of 16° to 22°C and above a depth of 50 m, although they occasionally descend to depths greater than 500 m, where the water temperature ranged from 8° to 10°C.

In a cooperative project with the Census of Marine Life program and the Tagging of Pacific Pelagics Project, five blue sharks were each equipped with a pop-up archival tag and a satellite positioning tag. The pop-up tags record and archive light intensity data, water temperature, and depth information, while the positioning tags report an accurate location each time the shark comes to the surface. This experiment was designed to calibrate the geolocation data (and software algorithm) collected by the pop-up archival tags with actual GPS reported positions from the satellite positioning tags. Preliminary results indicate that there is great need to improve accuracy of the pop-up geolocation algorithms. The transmitted data for the five blue sharks showed the sharks survived the tagging event and surfaced often enough to allow for satellite transmitters to report on a daily basis.

Mako Shark Ageing – Work continues on ageing shortfin mako shark sampled by Japanese longline from widely distributed localities in the Pacific. The purpose is to help clarify age-differentiated movements as well as 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 the Far Seas Fisheries Laboratory at Shimizu, Japan, and the NMFS La

Jolla Laboratory to independently age a sample of about 250 mako individuals, mainly subadults and adults, sampled by longline from Japanese research ships in the western and central North Pacific. The data include size and sex. Preliminary aging has been completed in Shimizu. At La Jolla, about 80 specimens have been processed by X-ray and acid etching techniques, of which 53 have been age-read. Results from the latter work, combined with size-at-maturity stage data from the literature, indicate subadult makos of both sexes move offshore in their fourth year when about 185 cm in fork length and males become mature. The females appear to reach maturity in their tenth year at about 250 cm in fork length. This is faster growth than determined by the Japanese workers. None of this aging is yet validated. However, tetracycline marking of juveniles in the Southern California Bight has begun as a time calibration (age "validation") experiment.

Thresher Shark Stock Assessment Work – Analyses of catches and catch rates of the common thresher shark off the U.S. west coast, which were presented in the September 2002 draft fishery management plan for highly migratory species, have indicated that maximum sustainable yield production is about 450 metric tons (t) round weight. This refers only to the portion of the stock presently accessed by U.S. California, Oregon, and Washington fishers. This result was obtained from examining both catch and effort data and the species' intrinsic rate of increase derived from life history parameters. Thus the present Pacific States Marine Fisheries Commission's harvest guideline of 578 t may be optimistic, and a new harvest guideline of 340 t is being considered by the Pacific Fishery Management Council.

Thresher Shark Food Habits--El Niño Versus La Niña – Contract work was completed on a new study of the food habits of the common thresher shark during a cool water California Current period (1999-2000), for comparison with a previous warm water transitional period (1998-99). Stomach samples were collected by NMFS observers from the California and Oregon driftnet fishery. Of the 87 stomachs examined from the cold water period, 67 stomachs contained food, comprised of only eight prey taxa, revealing a narrower trophic spectrum than found during the previous warm water transition year, when 20 prey taxa were identified. As in the warmer period, northern anchovy (*Engraulis mordax*) was the most important overall prey category but was considerably more dominant than in the previous year. Additionally, market squid (*Loligo opalescens*) was second in importance and dramatically more prevalent in the cold water versus warm transitional year. Other important diet items in the cold water period, in descending order of importance, were "unidentified teleost," Pacific sardine (*Sardinops sagax*), Pacific hake (*Merluccius productus*), and Pacific or chub mackerel (*Scomber japonicus*), which were also among the top six items in the previous warm transition period. As expected, pelagic red crab (*Pleuroncodes planipes*), relatively common in the diet during the warm transition period, was absent from the diet during the cold water period. Results suggest that during cool water periods the species subsists on a narrow range of favored food items (e.g., anchovy, squid) but during less productive warm water El Niño periods is forced to diversify its diet.

Upcoming Pilot Survey of Thresher Shark Pupping Grounds – Planning sessions were conducted during the year to begin sampling in summer 2003 to define core pupping and nursery areas off California for the common thresher shark. Preliminary longline sampling of 0- and 1-yr-old common thresher sharks will be conducted during the months of June-September 2003 between Point Conception and the California–Mexico border to determine presence/absence and catch rate variance of juvenile thresher sharks. Sampling will be conducted in four depth strata along a transect line in four areas where pups are known to occur – off Coronado near San Diego, San Pedro Bay, Santa Monica Bay, and the area between Santa Barbara and Ventura. The purpose is to develop a final sampling regime to (1) delineate core inshore nursery grounds of year-0 pups; (2) determine growth rates during the first year and second of life; (3) determine physical and biological characteristics associated with thresher shark core nursery grounds; and (4) determine interannual relative abundance. The inshore and along shore boundaries of this nursery area (or areas) are as yet undefined because existing data are based primarily on catches of stationary nets set nonsystematically along the coast and targeting other species. The SWFSC wants to define this habitat, fishing in inshore waters and sampling and tagging neonate

thresher sharks. This inshore coastal area will be sampled with small, lightweight pelagic longlines and possibly setnets to catch neonates, using other sampling devices to record various physical and biological characteristics associated with this habitat. Once distributional patterns are defined, sampling of young juveniles may also prove an efficient way to proactively monitor relative abundance in this species in the future, as adult stock and pup recruitment are so closely tied in sharks.

Participation in Shark Symposium – SWFSC biologists helped organize and presented papers at a symposium on the biology, ecology, and management of sharks of the Pacific coast of Mexico and the United States. The April 2003 symposium was sponsored by the American Fisheries Society's Western Division and held in San Diego, California, during the society's annual meeting. Fourteen papers were presented on pelagic shark biology, ecology, stock assessments, essential fish habitat, and fisheries. The symposium ended with a two-hour panel and audience discussion of management concerns of transboundary species shared by U.S. and Mexican researchers.

VI. BILLFISH RESEARCH PROGRAM

The SWFSC's billfish research provides information for the conservation and management of billfish resources in the Pacific. The primary objectives of this research include monitoring recreational and commercial fisheries, conducting research into the biology and ecology of specific billfish species, conducting stock assessments, and determining the economic importance of billfish resources. The International Billfish Angling Survey and the Billfish Tagging Program produce essential information pertaining to the recreational billfish angling community for exploring 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 patterns of these far-ranging species. Both investigations rely on continued cooperation from billfish anglers, sportfishing clubs, commercial fishers, and agencies affiliated with the SWFSC.

The International Billfish Angler Survey – The Angler Survey began in 1969 and now provides a 34-year time series of recreational catch and fishing effort for billfish in many key Pacific locations. The information developed from this survey is used to indicate trends in angler catch rates in specific areas in the Pacific and Indian Oceans. CPUE is measured in catch of billfish per angler fishing day. This survey provides the only measure of billfish angler success in the Pacific.

In 2002, 477 billfish anglers reported catching 3,038 billfish during 4,824 fishing days. The annual mean CPUE for all billfish was 0.63 billfish per day in 2002, up from 0.44 billfish per day in 2001 and 0.61 in 2000. The current overall mean catch rate of 0.63 billfish per day is above the four-year average of 0.53 (1999 to 2002). The years 2000 and 2002 had the highest overall billfish CPUE recorded since the survey began. The all-time mean high catch rate of 0.57 occurred during the first years of this survey (1969 to 1971). The lowest catch rates averaged 0.33 during the mid-1970s.

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 utilized to determine movement, distribution, and growth patterns of billfish. This constituent-based tagging program depends on the participation and cooperation of recreational anglers, sportfishing organizations, and commercial fishers. Since its inception more than 50,000 fish of 75 different species have been tagged and released. The Billfish Tagging Report cards received for 2002 indicate a total of 799 billfish were tagged and released by 187 anglers and 78 fishing captains. In all, 262 blue marlin, 204 striped marlin, 194 sailfish, 65 spearfish, two black marlin, and two swordfish were reported tagged and released.

Tag Recoveries in 2002 – Six billfish were reported recaptured in 2002, including two blue marlin, two striped marlin, and two sailfish. Release information has not been received for one of the blue marlin and one sailfish. The blue and striped marlins were tagged off Kailua-Kona and Lanai, Hawaii. One of the blue marlin was recaptured by a sport fisher and the other marlin was captured by commercial longline fishers. Time at liberty ranged from 31 to 260 days and distance traveled ranged from 292 to 864 nmi. The sailfish was tagged off Panama and recaptured off Costa Rica after 83 days liberty. Two bluefin tuna were also recaptured in 2002. Both were tagged near Cedros Island, Baja California, Mexico. One was recaptured off Japan, a distance of 4,154 nmi, after three years at liberty. The other bluefin tuna was recaptured north of Hawaii, 1,059 nmi away, also after three years at liberty.

Adopt-A-Billfish – The Adopt-A-Billfish tagging program is coordinated by a team of experienced scientists who work with the NMFS Southeast and Southwest Fisheries Science Centers, the University of Miami's Center for Sustainable Fisheries, The Billfish Foundation, and the Bermuda Division of Fisheries. Tagging operations are currently underway in the Atlantic and Pacific Oceans. In the Pacific, the researchers are collaborating with those affiliated with the Presidential Challenge tournament series off the coast of Central America. In 2002, Adopt-A-Billfish collaborators traveled to Panama, where they tagged three billfish with satellite data archiving tags. This Adopt-A-Billfish-supported study seeks to determine the survival rate of large billfish caught and released during international tournament conditions. In Panama, a 350-lb black marlin, 500-lb blue marlin, and 85-lb sailfish were tagged with satellite archive tags. The black marlin moved west to 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 sailfish remained in the area tagged during the 28 days at liberty and stayed in a temperature range of 24° to 30°C. This sailfish tended to have greater vertical depth excursions and spend more time at depths greater than 50 m than the black marlin. The blue marlin was fought for more than 90 minutes before it was tagged and was exhausted when released. In spite of being resuscitated (walked) for several minutes, the blue marlin died the following day. This program is continuing and plans are set to tag additional billfish in Costa Rica and Guatemala in 2003.

VII. OTHER ACTIVITIES

Highly Migratory Species Fishery Management Plan – During the year, a fishery management plan for U.S. west coast highly migratory species was approved by the Pacific Fishery Management Council, although at the time of this writing the final submission to the NMFS and the Secretary of Commerce was delayed pending examination of new data concerning one management option. SWFSC biologists and economists have contributed substantially to the plan, including preparation of the stock assessment, fisheries description, essential fish habitat, regulatory analyses, and socio-economic impact sections.

Last year the draft plan underwent major revisions after a public comment period, and it was necessary for the plan development team to complete additional sections and analyses requested by the NMFS, U.S. Fish and Wildlife Service, Environmental Protection Agency, and others. Many of the comments dealt with legal requirements. A revised partial draft was prepared August 2002 and sent out for general review, and the revised version was presented to the Council in the fall. The plan was subsequently approved but with some additional changes, including a change in the Council's preferred high-seas longline option, which had formerly proposed to prohibit the targeting of swordfish north of the equator, as in the Hawaii-based fishery. At its October-November 2002 meeting, the Council reconsidered and proposed to permit targeting of swordfish east of 150°W until sufficient data existed to indicate risk to protected species. These and other revisions were completed by the plan team in January 2003. In February 2003, NMFS asked that the Council delay official submission of the plan to NMFS to consider statistical analysis of new observer data from the California high-seas fishery and before final decision on its high-seas longline option. The Council agreed to postpone submission and may reconsider the high-seas longline option at its June 2003 meeting.

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