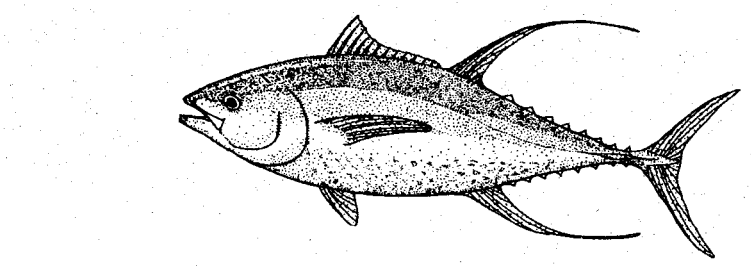
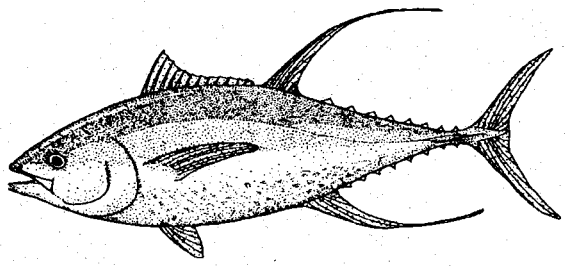
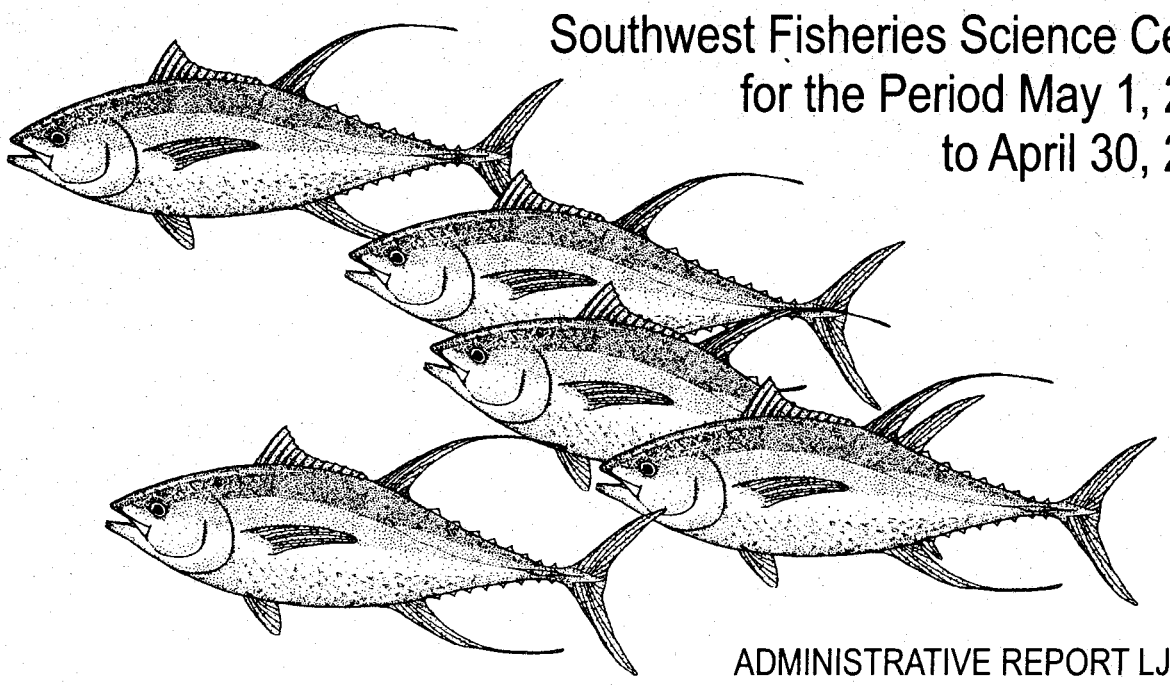
National Marine Fisheries Service
Southwest Fisheries Science Center

Director's Report to the 53rd Tuna Conference





On Tuna and
Tuna-Related Activities at the
Southwest Fisheries Science Center
for the Period May 1, 2001
to April 30, 2002



ADMINISTRATIVE REPORT LJ-02-03

DIRECTOR'S REPORT TO THE 53rd TUNA CONFERENCE ON TUNA AND TUNA-RELATED ACTIVITIES AT THE SOUTHWEST FISHERIES SCIENCE CENTER FOR THE PERIOD MAY 1, 2001–APRIL 30, 2002

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ADMINISTRATIVE REPORT LJ-02-03

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INTRODUCTION

This report describes Southwest Fisheries Science Center research activities relating to tropical tunas, albacore, billfishes, oceanic sharks, and the protected species associated with their fisheries. The work was conducted by the Center's La Jolla and Honolulu Laboratories during May 2001 through April 2002.

The Center's biological, economic, and oceanographic research was focused on supporting the information needs of the 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 was 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, La Jolla and Honolulu Laboratory 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 Multilateral High Level Conference on the Conservation and Management of Highly Migratory Species in the Western and Central Pacific.

The sections that follow provide informal summaries of research activities that took place at the Center since last year's International Tuna Conference.

Michael F. Tillman, Ph.D.

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La Jolla, California

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

U.S. fisheries for pelagic fishes in central and western Pacific 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 Pacific are not overfished, although the aggregate catch from some stocks may be approaching the maximum sustainable yield. Likewise, assessments completed during the past year for North Pacific swordfish and Pacific blue marlin, while preliminary, 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 western and central Pacific.

U.S. Tuna Purse-seine Fishery in 2001 –The National Marine Fisheries Service (NMFS) monitors the U.S. purse-seine fishery for tropical tunas in the central and western Pacific Ocean as part of U.S. obligations under the 1988 South Pacific Regional Tuna Treaty. The NMFS Southwest Region and 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. At the annual meeting of treaty participants in March 2002, the SWFSC presented a working paper 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.

Thirty-five U.S. purse seiners were licensed to fish under the treaty in 2001, but only 30 vessels landed fish. The season was the poorest on record, with a catch of 112,000 metric tons (t), 11% lower than in 2000. Much of the fleet stopped fishing in December 2000 and remained inactive through January 2001 in an effort to decrease supplies of light meat tuna. Cannery prices for small tunas (<7.5 lb) continued at record low levels.

When fishing resumed in February 2001, the U.S. fleet concentrated fishing effort on schools of free-swimming tunas (51%) and spent less fishing effort on schools associated with fish aggregation devices (49%). Free-swimming schools of tuna usually contain larger fish and higher proportions of yellowfin tuna, market categories that typically yield higher prices. However, sets on free-swimming schools are half as successful as sets on fish aggregating devices, and this weakened the fleet's performance. As a result, catch rates decreased to 25 t per day fished in 2001 from 27 t per day fished in 2000, and the average number of sets per trip increased 7% from those reported in 2000. Skipjack tuna dominated the catch (74%), followed by yellowfin tuna (20%) and bigeye tuna (6%). The relatively high catch rate is consistent with stock assessment results indicating healthy tuna stocks in the central-western Pacific Ocean.

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 2001, and length measurements and species composition samples were taken from landings of 46,000 fish.

NMFS researchers also evaluated sampling variability associated with estimates of species composition of the U.S. tuna landings. Scientists indicated a high precision in species-composition statistics for landings from the fishery in 2001 and concluded that current sample sizes are adequate. Although sample estimates were found to be very reliable, researchers recommend that sampling teams distribute the data collection effort throughout the fishing year to ensure collected samples are indeed representative of the total annual tuna landings.

Hawaii Longline Fishery – The Hawaii-based longline fishery is the most productive and wide-ranging commercial fishery based in Hawaii, operating in a large area of the central North Pacific. The fishery is monitored using mandatory Federal logbooks, a mandatory NMFS observer program, and frequent sampling of landings at the United Fishing Agency auction in Honolulu, as well as a mandatory State of Hawaii commercial landings reporting system. Extensive information about the fishery during 2000 and the previous decade is provided in the annual report of the Hawaii-based longline fishery for 2000 (SWFSC Administrative Report H-01-07) issued December 2001.

In 2000, there were 125 Hawaii-based longliners in operation, 57 targeting swordfish and the others fishing for tunas. The fleet deployed 20.3 million hooks (76% in tuna operations), 47% in waters outside the U.S. 200-mile exclusive economic zone (EEZ). Landings of 10,823 t of tunas, billfishes, sharks, and other pelagic fishes valued at $50.2 million ex-vessel were reported in 2000. Major components of the landings were swordfish (2,949 t, $12.7 million), bigeye tuna (2,632 t, $20.8 million), yellowfin tuna (1,141 t, $7.0 million), and albacore (923 t, $3.0 million). Of significant additional economic value to the fishery was the catch of non-target species including mahi mahi (dolphinfish), opah (moonfish), and ono (wahoo) totaling 652 t and valued at $2.9 million.

The last few years have been a period of difficult adjustments for the Hawaii-based longline fleet, as regulations have been imposed on the fishery to reduce the incidental capture of sea turtles. The fishery restrictions have been prompted by a series of decisions by the U.S. District Court in Honolulu in response to a February 1999 lawsuit brought against the NMFS by the Earthjustice Legal Defense Fund on behalf of the Center for Marine Conservation and the Turtle Island Restoration Network. The restrictions have been particularly adverse to Hawaii swordfish vessels because as shown by NMFS observer data, incidental takes of leatherback and loggerhead sea turtles have generally occurred with a higher frequency in shallow-set longline operations targeting swordfish than in operations using deep-set gear to target tunas. In its most recent order, issued March 30, 2001, the court prohibited any vessel registered for use with a Hawaii longline limited access permit from using longline gear to target swordfish north of the equator, among other restrictions. In its ruling, the court adopted turtle take mitigation measures spelled out in the preferred alternative of a final environmental impact statement filed by the NMFS on that date. On June 12, 2001, the NMFS issued regulations implementing those measures, including prohibition of shallow-set longline gear, prohibition of light sticks aboard Hawaii longline vessels, and several other measures.

As a result of the restrictions on swordfish operations, many Hawaii-based swordfish longline vessels have turned to tuna fishing or have sought opportunities in other locations. Several have left Hawaii to join the California longline fleet, which is not currently subject to the same restrictions as the Hawaii-based vessels. In 2000, there were 40 California-based longliners, most targeting swordfish outside the U.S. west coast 200-mile EEZ. Their swordfish landings in 2000 were 1,918 t. Longline vessels landing their catch in California are monitored through compulsory Federal logbooks issued under the High-Seas Compliance Act, California state sales records (pink tickets), and port sampling.

American Samoa Longline Fishery – The longline fishery based in American Samoa has undergone significant growth recently. The fleet has increased from seven small *alia* longline vessels (<12 m) in 1996 to a total of 66 vessels in 2001 setting 5.7 million hooks. Most of the newer longliners are larger vessels ranging up to 30 m in length. The principal target species is albacore, of which 3,800 t were landed in 2001 (preliminary data through September).

Longlining by U.S. Vessels in Other Pacific Island Waters – In addition to the activity of longline fleets based in Hawaii, California, and American Samoa, a few U.S. longline boats have fished in waters of the Marshall Islands, Federated States of Micronesia, Fiji, and Papua New Guinea under arrangements with local fishery authorities. In 2000, three such vessels recorded a catch of 81 t of yellowfin, bigeye, and albacore.

Troll, Handline and Pole-and-Line Fisheries – Fisheries using troll, handline, and pole-and-line gear contribute to pelagic fish landings in Hawaii, American Samoa, Guam, and the Northern Mariana Islands. In Hawaii, a fleet of six live-bait pole-and-line boats targets skipjack tuna for sale on local markets. Landings of 580 t were reported in 1999. More significant are the larger fleets of Hawaiian handline and troll vessels, both commercial and recreational. A number of the tuna handline boats in Hawaii fish over seamounts or around tuna-aggregating weather buoys. In 1999, combined landings of the Hawaii troll and handline fleets consisted of 970 t of yellowfin tuna, 324 t of albacore, 283 t of blue marlin, 252 t of wahoo, and 243 t of mahimahi, among other species. Troll fleets are also important in American Samoa, Guam, and the Northern Mariana Islands. During 1999, their combined landings included 107 t of skipjack, 78 t of mahi mahi, 71 t of yellowfin tuna, 39 t of blue marlin, and 38 t of wahoo.

Pelagic Fishery Data Collection and Database Management – The SWFSC laboratories in La Jolla and Honolulu collect fishery statistics from U.S.-flag vessels fishing for highly migratory species in the Pacific Ocean. Information is derived from several sources. State or territorial sales records provide data on landings (volume and value); vessel logbooks provide data on each vessel's catch and nominal fishing effort on a daily basis; port sampling, creel surveys, and fish auction monitoring provide size composition of landings and other biological data; and observer programs enable collection of data on interactions with protected species, size composition of fish catch, volume of discards, and other biological and operational data. In addition, research projects are conducted to collect various biological, oceanographic, and socioeconomic data. Fishery data are also collected for foreign-flag tuna vessels landing or transhipping their catch in U.S. ports.

Databases of U.S.-collected fishery data are maintained and made available to scientists and the public, subject to confidentiality constraints. Domestically, the SWFSC collaborates with state and territorial fisheries offices on data management via the PACFIN and WPACFIN programs. The Honolulu Laboratory makes summary data from WPACFIN databases available on the Internet (http://wpacfin.nmfs.hawaii.edu) in collaboration with American Samoa, Guam, the State of Hawaii, and the Northern Mariana Islands. U.S.-collected data are also shared with scientists of other countries cooperating on stock assessment of highly migratory species, either on an ad hoc basis or as part of international agreements. In this regard, the La Jolla Laboratory is the official repository of fisheries data used in stock assessment research conducted by the North Pacific Albacore Workshop. The La Jolla and Honolulu Laboratories coordinate annual submissions of U.S. fishery data to the Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific and the Standing Committee on Tuna and Billfish. Most SWFSC data are currently maintained as flat files, with Oracle as the primary data management platform. However, development of relational databases for highly migratory species fishery statistics is an ongoing activity at the SWFSC. Work is also underway to streamline entry of data and access to data. Increasingly, data are being captured directly into central Oracle databases, and procedures are being developed to make data available online via intranets and the Internet. A plan is being developed to coordinate the collection, processing, archiving, and distribution of highly migratory species data throughout the NMFS Southwest Region and Center.

International Activities – SWFSC staff continued to take an active part in international activities related to tunas, billfishes, and other highly migratory species. During May 2001, Honolulu Laboratory and La Jolla Laboratory scientists participated in the annual stock assessment review of the Inter-American Tropical Tuna Commission in La Jolla and the 52nd Tuna Conference at Lake Arrowhead, California. During August, SWFSC staff took part in the fourteenth meeting of the Standing Committee on Tuna and Billfish, held in Noumea, New Caledonia. Center staff contributed papers to, or chaired, the various committee working groups. Immediately following the committee meeting, SWFSC scientists presented papers at the third International Billfish Symposium, convened in Cairns, Australia. Proceedings of the symposium will be published in a special issue of the Australian Journal of Marine and Freshwater Research. During January 2002, a large delegation of SWFSC scientists traveled to

Nagasaki, Japan, to participate in the third meeting of the Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean and associated working group meetings. SWFSC staff contributed 10 documents to the working group and plenary sessions, including papers on swordfish stock assessment, blue marlin stock assessment, swordfish biology and oceanography, status of U.S. fisheries and fishery statistics, and research to reduce longline fishery bycatch of sea turtles.

During February 2002, SWFSC staff participated on the U.S. delegation to the second Preparatory Conference for the Establishment of the Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific, convened in Madang, Papua New Guinea. An international agreement to establish the Commission, subject to ratification, was reached by numerous Pacific island nations and distant-water fishing interests in Honolulu in September 2000. The second Preparatory Conference (a first session was held in Christchurch, New Zealand, April 2001) made progress in developing procedures, mechanisms, and an organizational framework to enable the Commission to operate effectively when the agreement comes into force. Part of the work of the conference is to develop a scientific structure for the Commission and provide interim scientific advice on the status of stocks.

In addition to participation in the Standing Committee on Tuna and Billfish, the Interim Scientific Committee, and other established multinational arrangements for cooperation on highly migratory species, SWFSC staff engage in more informal and ad hoc scientific collaborations with scientists of other countries and institutions. During the past year, several joint research projects on blue shark were completed under a cooperative research agreement between the NMFS Honolulu Laboratory and Japan's National Research Institute of Far Seas Fisheries. The agenda included a "species synopsis" of global information on blue shark life history, biology, and exploitation and a statistical model for stock assessment of the North Pacific blue shark population (this study also involving the Oceanic Fisheries Programme, Secretariat of the Pacific Community). Both projects will lead to peer-reviewed publications.

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. The fishing grounds in the North Pacific range from the U.S. west coast to west of the international date line. The North Pacific fishing season runs from April to November, and the size of the fleet ranges from 500 to more than 1,000 vessels. An estimated 710 U.S. troll vessels participated in the North Pacific albacore fishery in 2000. In the South Pacific, the fishing grounds extend from the east coast of New Zealand to about long. 110°W. The South Pacific fishery begins in November or December and lasts into March or April, with 20 to 60 vessels participating. Thirty-six U.S. troll vessels fished for South Pacific albacore during the 1999-2000 season. The U.S. albacore troll fisheries occasionally catch other fish species, such as skipjack, yellowfin, and bluefin tunas, mahi mahi (dolphinfish), yellowtail, and billfishes.

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 with respect to the 1981 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-01-05) issued May 2001 and is highlighted below. Also, information on

U.S. catches and fishing in the Canadian EEZ was presented at the Canada-U.S. Albacore Tuna Treaty consultations in June 2001 and April 2002.

Summary of U.S. North and South Pacific Albacore Troll Fisheries – For 2000, the U.S. catch of North Pacific albacore was 9,300 t, a decrease from 10,200 t caught in 1999. Areas fished by the North Pacific fleet in 2000 were distributed off California and in offshore areas early in the season, off of Washington and Oregon during mid season, and again in offshore areas and off California late in the season. The catch per unit of effort (CPUE), in number of fish per day fished, for the North Pacific increased slightly to 41 fish per day in 2000 from 37 fish per day in 1999. Average size of fish in the North Pacific catch decreased to 69 cm (15 lb or 6.7 kg) in 2000 from 73 cm (18 lb or 8.0 kg) in 1999.

The 1999-2000 U.S. catch of South Pacific albacore was 2,700 t, compared to 1,400 t in 1998-99. Areas fished in the South Pacific were about the same in as in the previous season. The CPUE in the South Pacific decreased slightly to 70 fish per day in the 1999-2000 season from 77 fish per day in 1998-1999. Average size of fish in the South Pacific catch increased to 72 cm (16.9 lb or 7.6 kg) in the 1999-2000 season from 70 cm (16 lb or 7.1 kg) in the previous season.

International Collaboration on North Pacific Albacore Research – La Jolla Laboratory researchers have begun cooperative research with tuna scientists from Japan and Taiwan on a new stock assessment model for North Pacific albacore. The research represents the first attempt to explore length-based modeling for albacore in the North Pacific Ocean. Length-based catch, size-frequency, and fishing effort statistics (1975-2000) have been compiled for international albacore fisheries across the North Pacific Ocean, and a preliminary modeling framework has been established. The first phase implementation of the full model is expected in December 2002.

Cooperative research on alternative stock assessment modeling was an important research recommendation from the seventeenth North Pacific Albacore Workshop (Taiwan, December 2000). The workshop was established in 1974 by informal agreement between the NMFS Southwest Fisheries Science Center and Japan's National Research Institute of Far Seas Fisheries. The workshop was conceived to promote and accelerate joint research on North Pacific albacore, particularly through exchange of data and collaborative research. In 1982, the Pacific Biological Station of the Canada Department of Fisheries and Oceans joined the agreement as a sponsoring member, and in 1991, the Institute of Oceanography, National Taiwan University (Republic of China) became a sponsoring member. Through this agreement, the parties have cooperated and coordinated research on albacore of the North Pacific Ocean. This cooperation includes annual exchange of fishery statistics, exchange of research plans, review of research results, and joint determination of stock condition. A regular scientific workshop is organized to review research findings, assess the conditions of the stock, and coordinate research planning. The next workshop will be held in December 2002 at the SWFSC in La Jolla, California.

American Fishermen's Research Foundation Activities – During the past year, the La Jolla Laboratory started a new research program to collect information on the migratory habits of juvenile albacore throughout the Pacific Ocean. The cooperative research with the U.S. albacore fishing industry and Japanese scientists includes placing archival tags on albacore off California and in the western Pacific Ocean. The sophisticated monitoring devices will be used to record geographical position of the tagged fish, sea temperature and pressure, and internal body temperature on a daily basis. The research is funded by the SWFSC and the American Fishermen's Research Foundation.

The pilot year of this five-year cooperative research project was completed in November 2001. Fifteen tags were deployed on albacore that were released about 60 miles off Point Conception, California. The tagged fish ranged in length from 77 to 93 cm. All were about 4 to 5

years old and were caught in sea surface temperatures ranging from 16.5°C to 16.9°C. Young albacore are believed to travel great distances across the Pacific, and what little is known about their migration routes is based on limited conventional tagging research conducted in the past. Previous tag designs were generally constructed for larger scombrids, billfish, and sharks, but recent advances in technology have produced smaller, more reliable electronic tags that are being used in this new research project. Plans are underway to deploy another 110 archival tags on albacore during fall 2002 and spring 2003.

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

The NMFS Honolulu Laboratory undertakes many scientific activities in support of U.S. domestic and international interests in Pacific highly migratory species. These 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. The Honolulu Laboratory also undertakes 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 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.

Pelagic Stock Assessment – Stock assessments were conducted during the year on North Pacific swordfish and Pacific blue marlin. Both assessments were collaborative efforts. The swordfish assessment involved the NMFS Honolulu Laboratory and the National Research Institute for Far Seas Fisheries in Shimizu, Japan. The blue marlin assessment was a joint effort of the Honolulu Laboratory, the National Research Institute, and the Inter-American Tropical Tuna Commission.

Swordfish – The swordfish assessment used catch, effort, and size composition data for Japanese and Hawaii-based U.S. longline fisheries in the North Pacific. Swordfish data from other longline fleets and other gears in the North Pacific have yet to be assembled. Nevertheless, a preliminary analysis this data set was undertaken with a statistical model, MULTIFAN-CL. A noticeable but mild (less than 30%) depression of swordfish abundance was noted over time due to fishing (Fig. 1). In the late 1950s and early 1960s, a stronger influence of fishing was evident. The findings of the MULTIFAN-CL assessment, presented at the January 2002 meeting of the Interim Scientific Committee Swordfish Working Group, are similar to those of other recent assessments, based on production-type models, suggesting that the likelihood of overexploitation is low at current levels of fishing. Recent independent research on an index of swordfish abundance in the North Pacific, based on historical data from Japanese longline fisheries, is in agreement with swordfish biomass trends predicted by the MULTIFAN-CL model. Considerable additional research is required to improve the swordfish stock assessments; the development of the MULTIFAN-CL model is still in an early stage. In particular, not all capabilities of MULTIFAN-CL could be realized in the recent assessment, probably due in part to complications arising from the strong sexual dimorphism in swordfish growth. Continued assembly of the database is needed to incorporate data from all fleets that catch significant numbers of swordfish in the North Pacific. Further development of the MULTIFAN-CL model is also needed to deal appropriately with catch and size sample data split by sex and other issues.

Blue Marlin – A MULTIFAN-CL model was constructed for Pacific blue marlin incorporating historical catch, effort, and size composition data from the longline fisheries of Japan, the United States, and other fishing nations. Previous blue marlin stock assessments over the past two decades, using different techniques, produced various results, ranging from a stock in decline to a healthy stock sustaining an annual yield at approximately the maximum average level (MSY). Similarly, the MULTIFAN-CL analysis revealed considerable uncertainty in quantifying the current state of the blue marlin stock and assessing the current fishing mortality in relation to the fishing mortality associated with maximum sustainable yield. Nevertheless, the

MULTIFAN-CL analysis showed that it is unlikely that blue marlin are being overexploited at current levels of fishing.

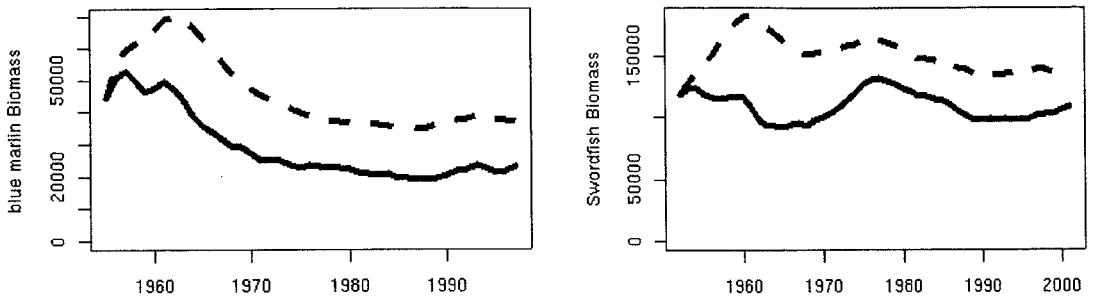

Figure 1. Solid line – estimated biomass of blue marlin in the Pacific and swordfish in the North Pacific. Dashed line – estimated hypothetical biomass in absence of fisheries.

The impacts of fishing are illustrated by comparing the estimated histories of blue marlin and swordfish abundance (biomass) with what those histories might have been in absence of fishing (Fig. 1). A common rule of thumb is that a population exploited at maximum sustainable yield will have its abundance reduced to roughly half of its unexploited state. The results toward the end of the time series in Fig. 1 show that blue marlin are approximately in that state (the solid line is almost half as high as the dashed line) whereas swordfish are more lightly exploited.

Age, Growth, and Stock Structure of Swordfish – A joint calibration test of swordfish ageing methods based on the anal fin ray was conducted by scientists of the Honolulu Laboratory, Mexico's Centro de Investigación Científica y de Educación Superior de Ensenada, Chile's Instituto de Fomento Pesquero, Japan's National Research Institute for Far Seas Fisheries, and National Taiwan University's Institute of Oceanography. Inter-laboratory variability in swordfish age estimates was determined. A sample of 20 fin ray sections was prepared by each of the five Pacific fisheries laboratories. These 100 sections were digitally imaged by the Honolulu Laboratory and distributed to the five laboratories for age estimation, with the identity of images cloaked. An analysis of covariance (ANCOVA) performed on each laboratory's age estimates versus the agreed mode age (age based on a subset of 59 sections where at least three of the five laboratory's age estimates coincided) indicated that four of the five laboratories were ageing the specimens equivalently. The fifth laboratory appears to have generally underestimated fish ages. Age estimates were also analyzed by region to evaluate possible geographic variation in swordfish growth rate. An ANCOVA on length versus agreed median age by region revealed apparent regional differences in length-at-age, with fish from Hawaii and Chile generally aged younger than swordfish of the same length sampled off Japan or Taiwan. These preliminary results are based on small sample sizes; further analysis with larger samples is required for corroboration. Validation of the presumed annual growth bands observed in the fin ray sections remains a critical need for studies of age equivalency and geographical variations in growth rate.

In a second biological study, meristic counts of total dorsal and anal fin ray elements were conducted on two samples of post-larval (n=34) and young-of-year juvenile (n=115) swordfish captured off Hawaii. This study was part of an initial attempt to evaluate the usefulness of meristics as an indicator of stock separation among nursery areas. Swordfish in both samples had similar mean total dorsal (46) and anal (17) fin counts. Dorsal ray counts exhibited greater variation (range of 40-50) than anal rays (16-19). Meristics data from other regions in the Pacific are needed for comparison with the Hawaii data to determine the feasibility of this approach.

Movement and Distribution of Pelagic Fishes – The movement patterns of swordfish, blue shark, tunas, and other highly migratory species are being studied by opportunistic dart tagging of fish caught by U.S. commercial and research longline vessels, application of standard archival tags, and, more recently, by deployment of pop-up satellite archiving tags (PSATs) on longline-caught fish. Dart tags have been applied to tunas, billfishes, and sharks (the latter in collaboration with the National Research Institute for Far Seas Fisheries). Standard archival tags have been placed on several bigeye tuna.

Of particular interest is the research using PSATs, carried out in cooperation with the Joint Institute for Marine and Atmospheric Research (JIMAR), University of Hawaii. During March and April 2001, PSATs were attached to eight swordfish measuring about 140-200 cm (lower jaw-fork length) caught by longline near lat. 28°30'N, long. 160°W. The PSATs were programmed to automatically release from the fish and transmit data if the fish experienced no significant pressure changes during four consecutive days, reached a depth greater than 1,200 m, or was still at large on a predetermined pop-off date. As of December 2001, six of the eight tags had transmitted data; however, all six tags had been shed prior to their anticipated release date. For the three PSATS that transmitted data, tags were attached to the animals for 5, 14, and 33 days. Straight-line distances between tagging locations and the locations of data upload were 17, 88, and 366 nautical miles (nmi), corresponding to maximum movement rates of 3.5, 6, and 11 nmi per day. Swordfish #3, transmitting data after 33 days, was usually in the upper 100 m of the water column during the night and dove to a maximum depth of 700 m during the day. Ambient water temperature ranged from 6°C to 28°C, with the fish mostly occupying a thermal habitat between 8°C and 24°C. Swordfish #3 typically commenced an upward vertical migration approximately one hour before sunset and a downward vertical migration one hour before sunrise. The vertical distribution results from swordfish #1 (transmitting after 5 days) and swordfish #2 (14 days) were not similar. Swordfish #2 remained in the upper 150 m of the water column throughout the 14 days. Swordfish #1 had the most erratic behavior of the three swordfish and spent most of the time shallower than 100 m.

In addition to the swordfish releases, PSATs have been deployed on 14 blue sharks, two yellowfin tuna, and one oceanic whitetip shark in waters of the central Pacific. Research cruises to deploy many more PSATs are planned for 2002. The PSAT studies will help describe horizontal and vertical movements and local distribution (including residence time) of these species. Results will be combined with environmental data to develop models of preferred habitat and catchability for improved stock assessments. The PSAT research may also lead to a better understanding of post-release survivability, help identify seasons and locations of spawning (and shark pupping), and help identify longline deployment methods that will catch target species (e.g., swordfish) while reducing the potential for interactions with sea turtles and other bycatch species.

Physiology and Behavior of Tunas and Billfishes – Various studies on the physiology and behavior of pelagic fishes were conducted with the collaboration or sponsorship of the Honolulu Laboratory, including studies of the auditory and visual capabilities of tunas and billfishes; the principal investigators in these studies are in other laboratories. For example, in recent studies using the NOAA ship *Townsend Cromwell* and the Honolulu Laboratory's Kewalo Research Facility, scientists from Australia and Sweden have found significant differences in visual

capacity between swordfish and bigeye tuna, both well adapted for deep nocturnal feeding, and yellowfin tuna, which forage more actively at shallower depths during daylight.

Fishery Oceanography – An oceanographic study was completed characterizing swordfish longline fishing grounds in the subtropical North Pacific Ocean during spring. The work was carried out by scientists at the Honolulu Laboratory and their collaborators at the University of Hawaii and the University of South Florida. During January-May, surface manifestations of multiple, individual planetary-scale fronts accentuate the central North Pacific Subtropical Frontal Zone (STFZ) system. The most prominent of these fronts are climatologically located at latitudes 32°-34°N and 28°-30°N (herein nominally referred to as the Subtropical Front (STF) and the South Subtropical Front (SSTF), respectively), although considerable interannual variability in both position and intensity is observed. This seasonally dynamic system was in the region typically targeted by the Hawaii-based swordfish longline fishing fleet, where the presence, position, and strength of the convergent fronts are believed to strongly influence the catch and catch rates of swordfish. A recent series of meridional hydrographic surveys and concurrent satellite remote-sensing data elucidate structural patterns and coupling of the physics and biology associated with these fronts. This enables a recharacterization of the winter-spring North Pacific STFZ and offers new insight into seasonal variability of the phytoplankton dynamics in the subtropical North Pacific.

On synoptic time scales, geographic positioning of the fronts may be systematically identified through surface outcropping of diagnostic thermohaline isopleths and is therefore readily discerned from both shipboard surveys and space-borne sensors. The STF during winter-spring can be characterized by the surface expression of the 34.8 isohaline and the 17°C isotherm within the frontal gradient. Biologically, the STF marks the transition between low chloropigment (chlorophyll + phaeopigments), nutrient-depleted surface waters to the south and a more productive regime to the north. To the south, the 20°C and 35.0 surface isotherm and isohaline, respectively, are characteristically embedded in the thermohaline gradients associated with the SSTF. A sharp increase in depth-integrated chloropigment is also observed at the SSTF and is ascribed to an increase in the concentration and thickness of the subsurface chloropigment maximum prompted by the shoaling of the nutricline with the thermocline structure into the euphotic zone.

Other oceanographic studies have focused on the basin-wide Transition Zone Chlorophyl Front (TZCF), located at the boundary between the low chlorophyll subtropical gyres and the high chlorophyll subarctic gyres in the North Pacific. These have led to an increased understanding of the front's importance to several oceanic species. Satellite telemetry data for loggerhead turtles and detailed U.S. troll fishery data for albacore tuna show that both apex predators travel along this convergent front as they migrate and forage across the North Pacific. The TZCF is easily monitored with ocean color satellite remote sensing (TOPEX/Poseidon), allowing studies of the front's movements over different time scales (e.g., between El Niño and La Niña episodes) and associated changes in the distribution of tunas, turtles, and other marine biota. In waters farther south, Honolulu Laboratory scientists have studied the cyclonic eddies that form leeward of the main Hawaiian Islands. The strength and persistence of these eddies, generated by the interaction of northeasterly trade winds and island topography, strongly influence local biological productivity and the availability of large pelagic fish (e.g., blue marlin) to recreational anglers.

Research on the Interaction of Longline Fisheries with Sea Turtles and Albatrosses – A significant program of research is underway by Honolulu Laboratory scientists and various collaborators to address the issue of incidental capture of sea turtles and albatrosses in the Hawaii-based longline fishery. The objectives of the research are to estimate the magnitude of incidental takes, understand the factors contributing to interactions, assess the impacts of associated mortality on affected populations, and develop methods to reduce the likelihood of interactions with longline gear.

Statistical methods have been developed to estimate annual incidental takes of turtles and albatrosses in the fishery using NMFS observer data and logbook statistics reported by Hawaii longline vessels. The take estimation methods employ generalized linear models and generalized additive models. Other statistical models have been developed to predict time-area strata that would satisfy target reductions in sea turtle interaction levels in the Hawaii longline fishery. Simulation models have been developed by the NMFS or under contract to study the dynamics of Mexican leatherback turtles, western Pacific leatherback turtles, Japanese loggerhead turtles, and Hawaiian green turtles, four of the principal sea turtle populations affected by the longline fishery. All models were developed with extensive international collaboration and the guidance of sea turtle experts. The models will be applied as tools to assist in assessing impacts, identifying critical areas for additional research, and evaluating potential recovery strategies.

Significant research has been directed at studies of the oceanic habitat of loggerhead and olive ridley sea turtles migrating and foraging in the central North Pacific. Horizontal and vertical movements of turtles released with conventional transmitters linked to Argos satellites have been tracked in relation to remotely sensed sea surface temperature, surface chlorophyll, and currents. Research is also underway using PSATs to study the horizontal and vertical movements of olive ridley sea turtles incidentally caught in tuna longline gear and released near Hawaii and off the Pacific coast of Costa Rica. This research will help determine the effects of capture and handling on turtle morbidity and mortality risks following release. The research involves collaboration with JIMAR and scientists in Costa Rica. PSAT studies of other turtle species are planned.

In early 2001, the Honolulu Laboratory developed and submitted plans for controlled field experiments to find ways to reduce sea turtle bycatch in the Hawaii-based swordfish longline fishery and associated mortality. The rationale for this research lies in the critical need to develop longline gear technologies and fishing strategies that will reduce sea turtle mortality in longline fisheries throughout the Pacific. The plan called for extensive research to be conducted over three years, using chartered Hawaii-based commercial longliners, each carrying a scientific technician and following rigid experimental protocols. In January 2002, the NMFS was issued a permit under Section 10 of the U.S. Endangered Species Act to conduct a limited part of the planned experiments. The main experiment, involving 12 Hawaii-based longline vessels and 1,040 research longline sets, will test two potential take reduction measures: the use of blue-dyed squid bait and increasing the distance between float lines and the attachment of branch lines.

The restricted research plan was launched in March 2001. This involves seven or fewer vessels fishing part time, making a total of about 250 research sets. The experiments will test the use of stealth (camouflaged) longline gear and deep daytime sets targeting swordfish against normal gear deployments (control sets) to determine whether the altered methods of fishing would be economically viable. After the swordfish stealth gear experiment is completed, the same gear will be used in experiments targeting tuna. Research will also be conducted using hook timers and time-depth recorders to document when and where turtles are caught most frequently during the deployment and retrieval of swordfish gear. A piggyback project will test whether larger circle hooks have better catch rates for target fish species than the smaller circle hooks tested by other researchers during 2000-2001. Circle hooks appear to catch as many turtles as standard hooks but with reduced injury to the turtles.

There is a similar effort to find ways to reduce mortality of albatrosses in longline operations. On all experimental longline sets made in waters north of Hawaii, the observers are required to collect detailed data on interactions of the gear with albatrosses. In addition, directed research to reduce longline fishery interactions with albatrosses recently commenced with the testing of an underwater line setting machine. The F/V *Katy Mary* departed February 21 for the first trials with a researcher from Tasmania Parks and Wildlife Service on board as chief scientist. This bird deterrent research is a cooperative project organized by the Audubon

Society, with participation by the Western Pacific Regional Fishery Management Council, NMFS, and U.S. Fish and Wildlife Service. Honolulu Laboratory scientists developed the scientific design for the highly successful experiments aimed at reducing the bycatch of albatrosses in pelagic longline fisheries.

To complement various programs of field work, the Honolulu Laboratory is collaborating in or sponsoring laboratory studies of captive sea turtles and pelagic fishes. Principal investigators in these studies are from JIMAR or other institutions in the United States. Research topics include the efficacy of modifications to longline gear (e.g., hook guards) and baits to reduce the incidence or severity of hooking, the physiology of olfaction in sea turtles, hearing and color perception in sea turtles and pelagic fishes, and behavioral responses of sea turtles to light (e.g., chemical and electronic light sticks), chemical stimuli, and magnetic stimuli. Because sea turtles, which evolved from terrestrial reptiles, are evolutionarily distant from commercially targeted pelagic fishes, they should have different sensory capabilities and defining these should be achievable. Techniques that exploit the differences (i.e., that repel sea turtles or make longline gear less attractive to them without reducing catch rates of tunas and swordfish) may then be developed.

Experiments by JIMAR researchers are underway with captive adult green turtles at the NMFS Honolulu Laboratory's Kewalo Research Facility and juvenile loggerhead turtles at the NMFS Galveston Laboratory facility. These researchers are investigating the importance of visual and olfactory cues in attracting turtles to bait. The studies include the development of artificial baits in which key experimental factors such as shape, color, and chemical composition can be altered.

Economics Research – Economics research on pelagic fisheries continues on a variety of fronts through cooperation between the Honolulu Laboratory and researchers funded under the Pelagic Fisheries Research Program (PFRP) of JIMAR. Ongoing work includes updating the cost-earnings profile of Hawaii-based domestic longline fishing vessels and compiling an initial profile of American Samoa longline fishing vessels. In addition, a PFRP research report was released on charter boat patron motivations (O'Malley, J. M., and E. W. Glazier. 2001. Motivations, satisfaction and expenditures of recreational pelagic charter fishing patrons in Hawaii, SOEST 01-03/JIMAR 01-339). As a follow-up to previous PFRP-sponsored economic research, another paper is forthcoming on inter-industry linkages and economic multipliers in the Hawaii longline fishery (Leung, P. S., and S. Pooley. Regional economic impacts of reductions in fisheries production: a supply-driven approach).

IV. EASTERN TROPICAL PACIFIC TUNA FISHERIES

The tuna industry has used the association between tuna and dolphins in the eastern tropical Pacific Ocean (ETP) to catch large yellowfin tuna for more than 50 years. Stocks of two dolphin species were depleted by high historical levels of mortality in tuna purse-seine nets. Although changes in the fishery during the last three decades have greatly reduced the observed mortality of dolphins, there is concern that the fishing methods used are causing stress to the dolphins involved in the fishery and may affect their population recovery.

In 1997, the U.S. Congress passed the International Dolphin Conservation Program Act, directing the NMFS to determine if chase and encirclement have a significant adverse impact on dolphins involved in the ETP tuna purse-seine fishery. As part of this determination, Congress specified that research cruises be undertaken to generate new estimates of the current size of ETP dolphin stocks targeted in the fishery. These estimates of dolphin abundance will be the main data used to judge whether ETP dolphin populations are recovering at the expected rate.

International Dolphin Conservation Program Act (IDCPA) Research – IDCPA research conducted by the NMFS La Jolla Laboratory during the year focused on dolphin population assessments and stress studies. Research activities included (1) revising estimates of

abundance of dolphin stocks affected by the tuna purse-seine fishery, (2) analyzing ecosystem data to assess dolphin habitat and possible climate-driven regime shifts in the ETP study area, and (3) completing a research study to determine the effects of stress on dolphins caused by chase and encirclement in the ETP tuna purse-seine fishery. Three external peer reviews were held with researchers from the University of Miami's Center for Independent Experts to evaluate analyses of these projects.

Dolphin population size estimates were determined from data collected during a series of ETP research cruise surveys conducted in 1998-2000. These stratified, large-scale surveys aboard oceanographic research vessels were designed to estimate abundance of target dolphin stocks. Abundance estimates were made for eastern spinner dolphins, northeastern offshore spotted dolphins, and the coastal subspecies of spotted dolphins for 1998, 1999, and 2000. Revised estimates of abundance for eastern spinner dolphins and northeastern offshore spotted dolphins were made for nine additional years from data collected on previous surveys (1979-1990). Estimates of abundance for each stock were based on modified line-transect methods, using covariates to model the detection process and group size.

Although the primary focus of the ETP research cruises was to estimate abundances of target dolphin stocks, a study of the ecosystem in which they live also was carried out, using physical and biological oceanographic data collected throughout the surveys. These auxiliary data provide both useful and academic information about dolphin habitat. By monitoring the physical and biological habitat, it is possible to look for ecosystem changes over time that may be affecting recovery of dolphin population levels. Analyses were conducted on data collected during the dolphin abundance survey and during an earlier dolphin monitoring survey (1986 through 1990). The inclusion of both data sets allowed for a more thorough evaluation of habitat and investigation of possible climate-driven regime shifts and interannual and interdecadal variation. The ecosystem studies consisted of seven components, each of which addressed the general question: are there temporal patterns with respect to that component of the ecosystem and if so, how are they best described? The seven components of these studies were: (1) environmental change in the ETP; (2) review of El Niño-Southern Oscillation and decadal variability; (3) estimates of abundance of striped and common dolphins and of pilot, sperm, and Bryde's whales; (4) habitats of target dolphin stocks; (5) distribution, abundance, and habitat relationships within seabird communities; (6) distribution and habitat associations of prey fishes and squids; and (7) analyses of ichthyoplankton collected in manta (surface) net tows.

The chase-encirclement research cruise was conducted from August to October 2001. This research included the repeated chase and capture of dolphin stocks targeted in the ETP tuna purse-seine fishery. The goal of the experiment was to provide scientific data on physiological indicators of stress in chased and captured dolphins, and if possible, to estimate a range of consequences for the individual dolphin's survival and reproduction.

The two-month cruise was divided into two legs and required the use of two vessels, the NOAA ship *McArthur* and a chartered tuna purse-seine vessel to repeatedly capture and release individual dolphins and collect biological samples for evaluating stress. During the entire study, 28 sets were made on dolphin schools during 40 days within a 120 nmi radius of the center of operations. Approximately 1,500 dolphins were captured and 283 of those dolphins were marked. A total of ten dolphins were outfitted with radio-saddle packages and of these, seven were successfully tracked and recaptured. Other tags also were deployed during sets, including four time-depth recorders, four time-depth-velocity recorders, two thermal tags, eight bullet tags, 213 roto tags, and six satellite tags. In total, blood for at least some analyses was obtained from 61 different dolphins, 53 of which were presumed to have been captured for the first time during the course of the study. Skin samples for genetic studies and histopathological analyses were obtained on 283 occasions, including 14 samples from individuals known to have been previously captured. Thermal photography provided 623 images of dolphins swimming in the net, of which 343 images were of sufficient quality to be analyzed. Body core temperatures were obtained on 55 occasions from 48 different individuals, and 95 hours of heat flux data

were recorded for the two thermal-tagged dolphins. Two of the four time-depth recorder tags were recovered, yielding tracks of two and six days, respectively, and two of the four deployed time-depth-velocity recorders were recovered, each providing a one-day track.

Preliminary analyses conducted on the data collected during the chase-encirclement research cruise were presented at an external review by the Center for Independent Experts in February 2002. Presentations included an overview of the chase-encirclement research cruise; radio and satellite tagging and tracking of dolphins; behavior of dolphins during sets; single and repeat blood samples; immunological studies; thermal studies to investigate heat stress; stress response protein levels in skin samples to determine the existence and levels of chronic stress; necropsy results; necropsy immunology; and a synthesis of research cruise results. Additional presentations that provided background and supplemented the chase-encirclement studies included cow/calf behavior, energetics model from the tuna fishery chase, reaction of dolphins to the research vessel, and reproductive and demographic parameters of ETP dolphins.

The three activities briefly discussed above (dolphin abundance estimates, ecosystem studies, and the chase-encirclement research cruise) along with the habitat modeling are all works in progress. All components of the IDCPA research will be reevaluated after careful consideration of comments from Center for Independent Experts reviewers. The research results then will be integrated into a final science report addressing the question of whether intentional encirclement of dolphins with purse-seine nets has significant adverse impact on depleted Pacific dolphin stocks.

IDCPA Research Results Presented at International Marine Mammal Conference – Researchers from the La Jolla Laboratory made presentations on IDCPA scientific research at the fourteenth Biennial Conference on the Biology of Marine Mammals in Vancouver, BC, Canada (November 2001). Their presentation topics included the potential effects of the separation of dolphin cows and calves resulting from the tuna purse-seine fishery chase and an overview of the chase-encirclement stress studies conducted on dolphins involved in the ETP tuna purse-seine fishery. Posters also were presented on a new methodology for monitoring environmental stress impacts on cetaceans, including molecular analysis of stress activated proteins and computer-assisted image analyses to quantify stress.

V. SHARK RESEARCH

Juvenile Shark Survey – The La Jolla Laboratory started a survey in 1994 to track changes in relative abundance of juvenile sharks within the Southern California Bight. Survey methodology was based on historical records of the longline shark fishery (1988 to 1991). Fishing logbook data provided average densities; spatial distributions and variations in catch were used to develop the sampling design. A minimum of seven standard stations are sampled four times during each survey. The surveys are conducted on the laboratory's research vessel, NOAA ship *David Starr Jordan*. Sampling gear consists of a two-mile longline constructed of stainless steel on which 175 leaders and hooks baited with mackerel are attached.

In the most recent survey, researchers conducted 49 longline sampling stations off southern California during June–July 2001. Seventeen stations were designed to sample common thresher shark and 32 stations were designed to sample shortfin mako and blue sharks. In total, 198 mako sharks, 6 thresher sharks, and 260 blue sharks were captured and sampled in 2001. The catch and CPUE for shortfin mako shark declined from 1.59 sharks per 100 hook-hours in 1994 to 0.27 sharks per 100 hook-hours in 2000, but CPUE increased to 0.92 sharks per 100 hook-hours in 2001 (Fig. 2). For blue shark, the catch and CPUE increased from 0.60 sharks per 100 hook-hours in 1994 to 7.38 sharks per 100 hook-hours in 2000 and declined to 0.50 sharks per 100 hook-hours in 2001 (Fig. 2). The survey was not conducted in 1998 and 1999 in order to conduct alternative shark-related studies.

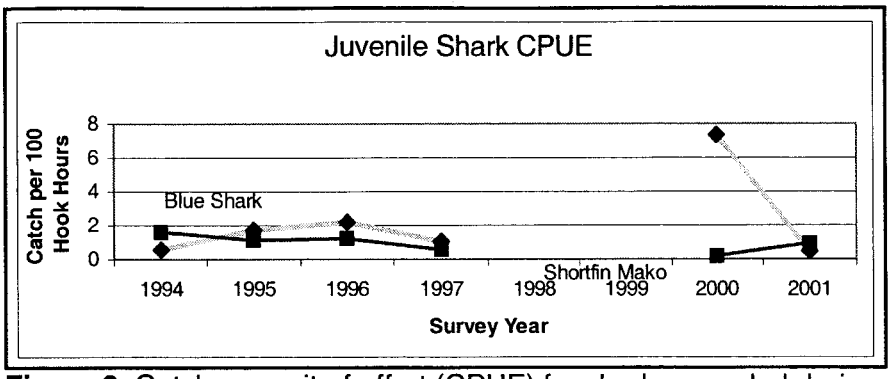

Figure 2. Catch per unit of effort (CPUE) for sharks sampled during juvenile shark abundance surveys.

The mean total length for juvenile sharks taken was documented for the entire time series of the surveys (Fig. 3). Captured mako shark lengths changed little over the eight years that the survey has been conducted, although considerable variance occurred between years. The mean total length of blue sharks taken decreased somewhat over the sampling period. The absence of any significant trend in CPUE or length-frequency for mako and blue sharks may indicate that regulatory actions taken in the late 1980s have allowed the juvenile shark populations to stabilize in the Southern California Bight.

Several ancillary research projects are conducted during the juvenile shark surveys. All sharks are released alive and most are tagged with conventional spaghetti tags to help determine migration patterns, stock boundaries, and age and growth. In 2001, 185 mako sharks and six thresher sharks were tagged and injected with oxytetracycline for ongoing age and growth studies. This brings the total number of sharks tagged with oxytetracycline since 1995 to 259 mako sharks and 102 thresher sharks. The total recapture rate to date is 3.8%. Blood was drawn from an additional 50 mako sharks and five thresher sharks for studies of condition at capture and post-release survival. Preliminary assay of blood chemistry indicates extremely high catecholanse and lactate levels at capture and release when compared to resting, captive sharks. Mako shark seem to have the highest levels. The recapture rate of nearly 4% indicates these sharks can tolerate these elevated levels.

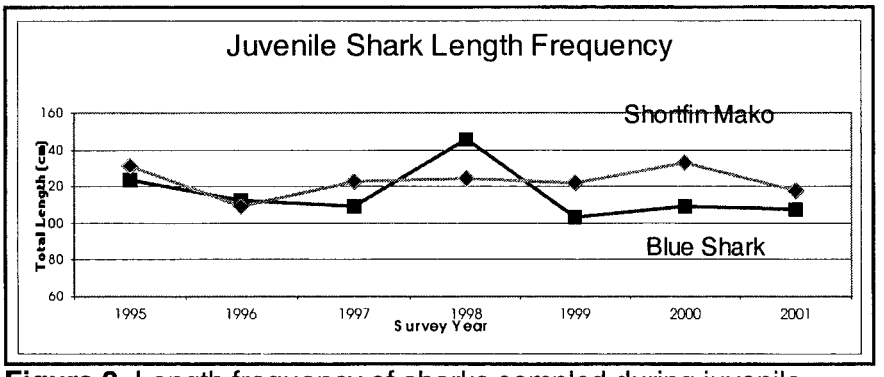

Figure 3. Length frequency of sharks sampled during juvenile shark abundance surveys.

Age-validated Leopard Shark Recaptured after 20 Years – Researchers at the La Jolla Laboratory completed age validation for a tagged leopard shark that was recaptured after being

at liberty for 20 years, longer than any other age-validated shark. The scientists also validated growth for another leopard shark at liberty 21.8 years. Both sharks had been injected with oxytetracycline and tagged and released in San Francisco Bay in a 1979 tagging experiment. This research represents the first full-life-span age validation for any elasmobranch species. It also provides new information on oxytetracycline deposition and sensitivity to light, interannual variability in observed vertebral growth, and information on peripheral band deposition in this species, which should prove useful to other researchers conducting fish age, growth, and validation studies.

Tagging and recapture of fish whose calcified structures have been marked with the bone-labeling fluorophor oxytetracycline offers a simple and conclusive method for establishing the timing of growth zone formation in these structures. With sharks, tetracycline marking is especially preferred over alternate methods of age validation because of their slow and highly variable growth patterns, and because calcified bands in their aging structures (e.g., vertebral centra) are often very difficult to interpret. Additionally, unlike teleosts, periodicity of band deposition in aging structures has been validated for only a few shark species, and few fish in general have had ages validated over the full range of age classes.

Mako and Thresher Shark Sustainable Catch Estimates – Catch and catch rate data for shortfin mako shark and common thresher shark caught in the California driftnet fishery were examined by La Jolla Laboratory researchers. The work was done to determine levels of sustainable catch from the available population for these species, which will be managed under the Pacific Fishery Management Council's fishery management plan for west coast highly migratory species.

For mako shark, California Department of Fish and Game statistical squares from the Southern California Bight for 1981-99 were used to determine trends in CPUE in the driftnet fishery. No trends were found that were consistent with how catches and fishing effort changed during the period. The conclusion was that changes in the catches of predominantly juvenile mako sharks taken incidentally in fishing for swordfish do not reflect the status of the stock, which is wide-ranging and extends far beyond the Southern California Bight. The present low level of commercial catch taken by U.S. fishers (63 t in 1999) is not likely due to overfishing; the stock apparently is protected by the unavailability of the adult reproducing segment of the population. The analysis resulted in a maximum sustainable yield proxy estimate of 200 t for mako shark, the average catch for the species during 1981-99.

The California population of common thresher was overfished in the early 1980s, but season and area restrictions have since resulted in its slow recovery. The population had not previously been assessed for yield potential. Levels of sustainable catch were estimated from a logistic production model, using parameters for maximum population size and intrinsic rate of increase. Maximum population size was estimated using catch rate information from California Department of Fish and Game statistical squares for 1981-99 catches, with assumptions on how population recovery is related to CPUE, intrinsic rate, and the production function. The intrinsic rate was estimated independently from demographic parameters. This resulted in an estimated maximum sustainable yield of about 450 t for common thresher shark taken in the California driftnet fishery.

Age-growth Study of Thresher Shark – During the year, Fisheries Resources Division scientists at the La Jolla Laboratory conducted a study of age, growth, and sexual maturity of common thresher shark, using observer data and fish sampled from the California and Oregon driftnet fishery (1990-99). This type of basic biological information is essential to understanding of the biology and population dynamics of this species. Common thresher shark is the most commercially important shark in California, and the species is now slowly rebounding after being overfished in the 1980s. Previous work on age, growth, and maturity of this species was hampered by sample sizes too small to analyze growth rate differences by sex, and by errors made because of imprecise alternate length to total length conversions. Data on size at first

sexual maturity for males and females of this species also were lacking, especially upper range estimates of female first maturity and of size at male maturity.

The vertebral centra of 107 female and 68 male common thresher sharks were aged using x-radiography and combined with data points from the previous study (total *N*=317). In constructing the growth curve, researchers also applied a more precise alternate length to total length conversion. For estimating maturity, researchers took the mean of the first quartile of 19 driftnet-caught females with fetuses or egg capsules present in their uteri, and they noted the rate of increase in clasper size and calcification and presence of seminal fluid in males (*N*=769). Females were estimated to reach maturity at 303 cm tail length and 5.5 yr old, and males were estimated to reach maturity at about the same size (4.8 yr; 293-311 cm tail length, mean=303 cm).

These improved estimates should make demographic and population analyses for common thresher shark more reliable. The study also corrects a length conversion problem that had made former age-at-size estimates inaccurate.

VI. BILLFISH RESEARCH PROGRAM

The SWFSC's billfish research program provides information for the conservation and management of Pacific billfish resources. Many of the program's investigations rely on cooperation from billfish anglers, sportfishing clubs, commercial fishers, and agencies affiliated with the SWFSC. Program activities include the Billfish Newsletter, an annual report on the key activities of the SWFSC billfish program; the Billfish Angler Survey, which provides angler catch and fishing effort information at major fishing centers throughout the Pacific; and the angler-based Billfish Tagging Program, which provides data on the biology, distribution, and migration patterns of Pacific billfish.

The International Billfish Survey – The International Billfish Angler Survey provides a long time series of recreational catch and fishing effort for billfish in many key Pacific locations. Information from this survey is used to measure trends in angler catch rates. Angler catch per unit of effort (CPUE) is measured in catch of billfish per angler fishing day. This measure of angler success can indicate changes in stock size, changes in environmental conditions, or local depletion by a fishery. CPUE is an important part of stock assessment models used in determining fishery allocations.

In 2001, 487 billfish anglers responding to the survey reported catching 2,822 billfish during 6,399 fishing days. The annual mean catch per effort (measured in catch per day fishing) for all billfish was 0.44 billfish per day in 2001, down from 0.61 billfish per day in 2000. The current overall mean catch rate of 0.44 billfish per day is below the prior five-year average catch rate of 0.50 billfish per day (1996 to 2000). The all-time high mean catch rate of 0.57 billfish per day occurred during the first years of this survey (1969 to 1971). The lowest catch rates averaged 0.33 billfish per day during the mid-1970s.

Reported catches of blue marlin off Hawaii in 2001 totaled 591 blue marlin in 3,126 days of fishing, for a catch rate of 0.19 blue marlin per day. The catch rate was a little better than the prior three years but fairly constant within a 20-year range. Blue marlin are tropical and subtropical in habitat and rarely extend north of Magdalena Bay in Baja California, Mexico. The catch off Baja California totaled 96 blue marlin in 1,150 days fishing (catch rate of 0.08), which is consistent with prior years. The catch rate in Tahiti (0.56) was higher than normal, influenced by a few days of very good catches. No blue marlin catches were reported from Costa Rica, Mauritius, or Fiji.

For striped marlin, angler catch rates reported off southern California (0.10) and Hawaii (0.10) improved slightly in 2001 but have remained fairly consistent since the mid-1980s. Around the southern tip of the Baja California peninsula, anglers reported catching 490 striped

marlin in 1,225 days of fishing. This catch rate of 0.40 striped marlin per angler day was slightly more than the catch rate for all of Mexico (0.37). The area of Mexico around the tip of Baja California, Guaymas, and south to Mazatlan has always provided good catch rates for striped marlin, which are less abundant south of Mazatlan.

Catch rates of sailfish throughout Mexico (0.20) did not reflect the greater angler success off the central coast of Mexico from Manzanillo to Zihuatanejo and Acapulco (1.48), where sailfish are more abundant. Guatemala reported the highest catch rate for sailfish (4.81) with 130 sailfish reported in just 27 fishing days, and Costa Rica continues to see improved catches from the mid-1990s.

Black marlin are common in tropical waters and occasionally frequent temperate areas. The reported catch rate of black marlin in Australia (0.67) during 2001 improved over prior years, although the catch rate off Panama (0.17) remained below levels seen the early 1990s. Black marlin are often reported around the tip to Baja California and rarely occur off southern California.

Shortbill spearfish continued a strong run off Hawaii, where anglers reported catching 340 spearfish in 3,126 fishing days for a catch rate of 0.11.

The Billfish Tagging Program – Release and recapture data from tagged billfish are used to determine movement patterns, geographic distribution, and growth patterns of billfish. Since the program's inception in 1963, more than 49,579 fish of 75 different species have been tagged and released. The Billfish Tagging Report cards received for 2001 indicate a total of 1,735 billfish were tagged and released by 1,055 anglers and 193 fishing captains. This is more than twice the number of billfish tagged in 2000. Thirty-eight striped marlin were tagged off southern California in 2001. In Hawaii, 632 blue marlin and 292 striped marlin were reported tagged and released. It also was another good year for tagging shortbill spearfish in Hawaii, where 256 of the fish were tagged. Tagging off Mexico remained similar to past years with 112 billfish tagged from Magdalena Bay south to La Paz and 129 more billfish tagged between Mazatlan, Zihuatanejo, and Acapulco. Two swordfish also were tagged off Mexico in 2001.

Tag Recoveries in 2001 – Ten billfish were reported recaptured in 2001, including five blue marlin, four striped marlin and one sailfish. All of the blue marlin and three of the striped marlin were tagged off Kailua-Kona and Lanai, Hawaii. Three of the blue marlin were recaptured by sportfishers while the other two blue marlin were captured by commercial longline fishers. Time at liberty for the blue marlin ranged from 2 to 28 days and distance traveled ranged from 5 to 209 nmi. The striped marlin were at liberty from 13 to 68 days and ranged from 294 to 410 nmi. The striped marlin tagged off Magdalena Bay was recaptured 162 nmi south at Cabo San Lucas, Mexico, more than a year later (410 days at liberty). The sailfish was tagged and recaptured near Zihuatanejo, Mexico, after 23 days at liberty.

Four shortfin mako sharks tagged during the La Jolla Laboratory's juvenile shark abundance survey in 2001 were recaptured after 7 to 83 days and had moved from 8 to 314 nmi. The sharks had all been measured and tagged with tetracycline for age and growth studies. These specially tagged mako and thresher sharks have a white roto tag with a three-digit number attached to their dorsal fins indicating researchers need the vertebrae and tag. A $25 reward is offered for return of a tag with a section of vertebrae from the tagged shark. One additional sandbar shark was tagged and recaptured off Hawaii after 184 days at liberty.

Striped Marlin Archival Satellite Tagging Research – A satellite tagging experiment was conducted during the year to track the seasonal migratory pattern and post-release survival of striped marlin. Fishery data indicate striped marlin migrate into southern California from the central Pacific and the offshore waters of Mexico during the early summer and remain until fall. Their abundance is influenced by seasonally warm water intrusion into the Southern California

Bight and the availability of quantities of small pelagic prey. Striped marlin occasionally move north of Point Conception, California, during periods of unusually warm water.

In cooperation with the Marlin Club of San Diego, SWFSC La Jolla Laboratory staff and members of the Marlin Club deployed five satellite archival pop-off tags on striped marlin during the second annual Offshore Invitational Tag and Release Tournament (September 2001). Four of the satellite tags were programmed to detach from their host fish after 90 days and one was programmed to detach after 180 days. By October 12, 2001, the four 90-day tags had detached and transmitted archived temperature, depth, and light level data. The fifth tag detached and reported data on March 1, 2002, as scheduled.

Two of the satellite transmitters indicated the host fish had died shortly after being released. The three surviving marlin all moved south into Mexican waters off Baja California. The first tag detached prematurely from the host on October 12 for unknown reasons. The striped marlin had moved a net distance of 715 nmi in 35 days, averaging 20.4 nmi per day. The second marlin also moved south into Mexico's coastal waters. Its tag also detached inexplicably on September 23 after 16 days and a net movement of 559 nmi (average 34.9 nmi per day). The third marlin traveled 1,400 nmi southwest in 180 days (7.6 nmi per day). Recorded ambient water temperature ranges indicated the marlin remained in 18°C to 20°C water during the first several days after their release before moving into progressively warmer waters as they moved south into Mexican waters.

The two 90-day tags contained depth sensors to record daily swimming depths and maximum depths attained while attached to the host marlin. The first marlin spent 74% of its time within 10 m of the surface, nearly 12.5% of its time at depths between 10 and 50 m, and only 1% of its time at depths below 50 m but venturing below 100 m. The second marlin spent 89% of its time from the surface to 10 m and 10% of its time at depths from 11 to 50 m. Its maximum depth of 75 m occurred September 15.

These results support the theory that striped marlin, after moving into southern California waters, return to the warmer waters of Mexico and the central Pacific by moving south and west. They prefer the warm surface water above 10 m but will occasionally descend to at least 100 m. Recorded light intensity levels, indicating day length, were used to calculate longitude and confirmed an eastward movement as the fish moved south into warmer water off Mexico. Ambient temperature and longitude data taken together allow for a fairly accurate estimate of the track taken by each of the three marlin.

Overview of Five Major Billfish Tagging Programs – A review of the combined data from five major constituent-based tagging programs for billfish was presented at the Third International Billfish Symposium in Cairns, Australia, last year. The data from the SWFSC's Billfish Tagging Program was combined with that of the Cooperative Tagging Center in Miami, the Australian Cooperative Tagging Program, the New Zealand Cooperative Game Fish Tagging Program, and the Billfish Foundation. That effort summarized results of the five programs on a worldwide basis. All together, more than 317,000 billfish have been tagged and released through these programs, with 4,122 recaptured since 1954. The overall recapture rate is 1.30%. White marlin and sailfish had the highest recapture rate while black marlin had the lowest. Maximum straight-line distances traveled were highest for blue and black marlin followed by striped marlin and sailfish. A blue marlin had the longest movement (14,893 km) as it traveled from the western Atlantic (U.S. east coast) to Mauritius in the Indian Ocean. The longest movement by a black marlin (14,556 km) was transpacific and transequatorial, as it traveled from Cairns to the eastern Pacific Ocean off Costa Rica. The longest distances moved for striped marlin and white marlin were 6,713 km and 6,517 km, respectively. The longest movement for striped marlin was a transequatorial movement, while white marlin demonstrated a transatlantic movement. Sailfish exhibited the shortest maximum distance movement (3,861 km) of the major billfish.

Table 1. Numbers of billfish tagged, released, and recaptured, with maximum number of days distance traveled in kilometers.

Species	Tagged	Recaptured	Percent Recaptured	Maximum Days Free	Maximum Distance (km)
Black marlin	41,919	286	0.68	2,044	14,556
Blue marlin	53,514	648	1.21	4,024	14,893
Longbill	1,181	3	0.25	1,945	1,924
Sailfish	126,71	1,923	1.52	6,568	3,861
Shortbill	1,122	1	0.00	34	293
Striped marlin	45,536	422	0.93	987	6,713
White marlin	42,379	836	1.97	5,488	6,517
Total	312,36	4,119	1.32		

VII. OTHER ACTIVITIES

West Coast Highly Migratory Species Management Plan – A new fishery management plan (FMP) is being developed by the Pacific Fishery Management Council to help the NMFS manage west coast-based fisheries for highly migratory species. In March 2002, the council delayed final adoption of the FMP until November and modified portions of the plan concerning a proposed drift gillnet closure off Washington and Oregon and use of pelagic longline gear within the U.S. EEZ. Fish stocks to be managed under the FMP include albacore, yellowfin, skipjack, bigeye, and bluefin tunas, striped marlin, Pacific swordfish, mako, blue, and thresher sharks, and dorado (dolphinfish). The draft plan includes life history and essential fish habitat information on these species, as well as information about landings by species and fishing gears. Information about the FMP can be found on the Council's Web site at http://www.pcouncil.org.

Community Impacts Analysis – Fishery management measures also must take into account the social and economic importance of fishery resources to fishing communities, providing for sustained participation of the fishing communities and minimizing adverse economic impacts to the communities. To help satisfy this requirement, NMFS La Jolla Laboratory economists analyzed the operation and performance of highly migratory species fisheries and the associated purchasing and processing activities in west coast communities. The analysis gives an extensive socioeconomic baseline from which to gauge the potential impacts of future conservation and management actions for these species. It also provides a good template for monitoring the operations and performance of highly migratory species fisheries that can be used in the Pacific Fishery Management Council's stock assessment and fishery evaluation document.

The community impacts analysis characterizes commercial and recreational fisheries in terms of the highly migratory species targeted, gears used, vessel type, areas and seasons of operation, and related activities beyond the ex-vessel level. Quantities of fish landed and corresponding ex-vessel revenues by species, gear type, and location are provided for commercial highly migratory species fisheries. Catches and areas and seasons fished are presented for charter/party boats and private boats that comprise the recreational fishery for these species. Communities are identified according to their share of total annual west coast landings of highly migratory species. Each community is profiled in terms of its demographics, regional and seasonal commercial and recreational fishing activities, commercial harvesters (gears used), fish buying and processing, and recreational fishing. The community profiles and draft FMP can be found on the Web at http://www.pcouncil.org/hms/draftfmp.html.

Essential Fish Habitat Analysis – A provision of the Magnuson-Stevens Act mandates that essential fish habitat be identified and described in fishery management plans. Designation of essential fish habitat requires a thorough review and analysis of data on the current and historic stock size, geographic range, distribution, and density of each managed species, habitat requirements of each life stage, and information on growth, mortality and production within all habitat areas a species occupies or formerly occupied. Essential fish habitat work for the U.S. west coast highly migratory species FMP was completed by a team of state and federal scientists, including staff from the NMFS La Jolla Laboratory. The project entailed an extensive data and literature review for all FMP species (274 references and data sources) plus selected new analyses. These included analyses of commercial passenger fishing vessel logbook data, driftnet fishery observer data, and commercial fishing vessel logbook data. Where feasible, analyses were conducted of distributional data to determine area occupied by 95% of observed catches by area and bottom topography. Distribution by sex and life stage and size was also analyzed for species for which data were available. Sea temperature structure in the Southern California Bight was examined in relation to distribution of the most tropical species within the southern U.S. EEZ. Thirty maps were created with catch distributions and designated habitat plotted. Life history sections were completed for each FMP species, with subsections on general distribution, growth and development, trophic interactions, migrations, movement and stock structure, reproduction, vital rates and statistics, fishery utilization, and essential fish habitat for three life stages. The project also included revised life history sections for tunas, billfishes, and dolphinfish as well as sharks.

VIII. SWFSC PUBLICATIONS ON TUNA AND TUNA-RELATED SUBJECTS

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