National Marine Fisheries Service
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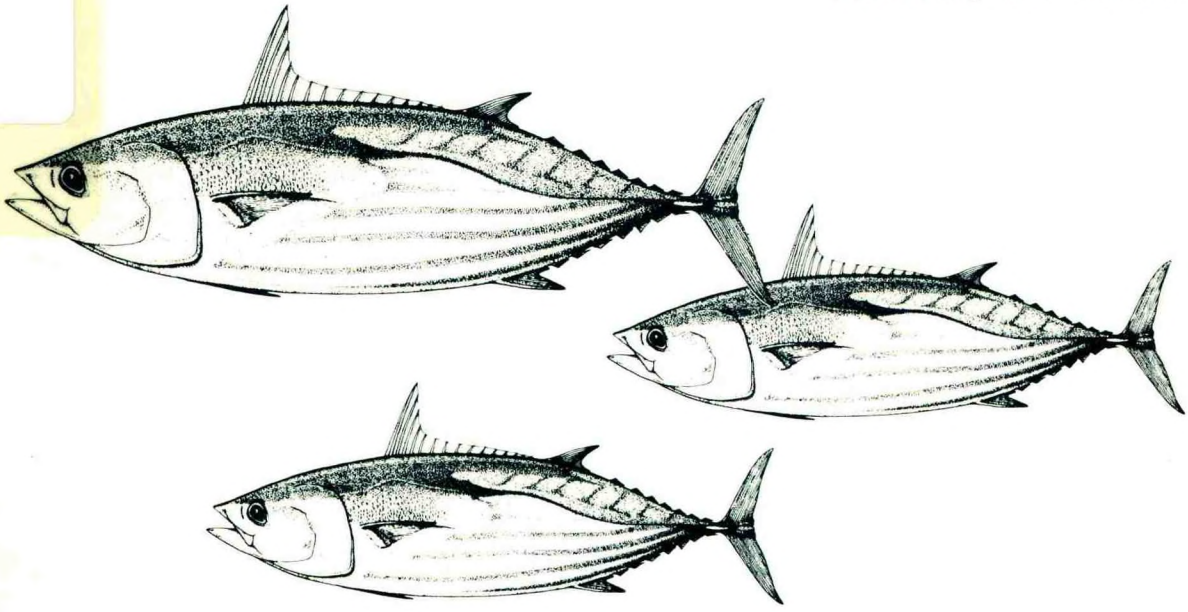

Director's Report to the 44th Tuna Conference

On Tuna & Tuna-Related Activities at the
Southwest Fisheries Science Center
for the Period May 1, 1992
to April 30, 1993

ADMINISTRATIVE REPORT LJ-93-05

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TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

This annual report describes research at the Southwest Fisheries Science Center (SWFSC) relating to tuna and other large pelagic fishes, and to marine mammals that are affected by their fisheries. The work was conducted from May 1992 to April 1993 by the Center's La Jolla Laboratory in La Jolla, California, and by the Honolulu Laboratory in Honolulu, Hawaii. It is not meant to be a comprehensive account, but rather an informal summary of activities and events that have taken place since last year's Tuna Conference in May, emphasizing highlights of the previous year.

During the year, the SWFSC continued to provide scientific information and advice for managing fisheries for tunas and other large pelagic fishes and fishery-associated marine mammals. Since May 1992, much of the Center's fishery research focused on supporting the needs of the Western Pacific Regional Management Council, international working groups and committees, the NMFS Driftnet Research Program, and NMFS Southwest Region and Headquarters. Marine mammal researchers were largely occupied with preparing information for new regulations and reauthorization of the Marine Mammal Protection Act (MMPA) in 1993, conducting the common dolphin survey in the eastern tropical Pacific, launching new dolphin-safe research projects, and producing stock assessments of California cetaceans associated with coastal and high-seas gillnet fisheries. Also, status of stocks reports for Pacific large pelagics and fishery-associated marine mammals were updated for the 1992 edition of NMFS' annual report, "Our Living Oceans," which was released in December 1992.

The following are research highlights by category:

Council-Related Activities

Honolulu Laboratory staff continued to serve on the Pacific Pelagics Plan Monitoring Team and the Scientific and Statistical Committee of the Western Pacific Regional Fisheries Management Council (WPRFMC). During the year, the lab provided scientific and technical input to draft Amendment 7 to the Western Pacific Pelagic Fishery Management Plan. The new amendment will replace Amendment 4, which established a moratorium on the entry of vessels into the Hawaii-based longline fishery. The moratorium will expire in 1994. Amendment 7 will provide information on status of stocks, descriptions of the fishery and markets, and economic and biological analyses of potential management alternatives for the longline fishery.

In May 1992, a report of the Pacific Pelagic Fisheries Planning Workshop was released. The workshop, held in March 1992, was cosponsored by the SWFSC with the WPRFMC, the University of Hawaii-NOAA Joint Institute for Marine and Atmospheric Research (JIMAR) and the University of Hawaii's (UH) School of Ocean and Earth Science and Technology. Its objective was to provide guidance on research priorities to JIMAR and the steering committee that advises JIMAR on pelagic fisheries research. The Director of the Honolulu Laboratory and the Chief of La Jolla's Pelagic Fisheries Resources Division (PFRD) serve on JIMAR's Pacific Pelagics Program Steering Committee. After the workshop report was released in May, research proposals were subsequently solicited by JIMAR. In recent months, a special group of experts from outside and within NMFS reviewed the tuna and billfish pelagic fisheries research proposals assembled by JIMAR. A formal team review was held at the La Jolla Laboratory in February 1993 to discuss reviewers' comments and make final recommendations.

In November, a Council-sponsored workshop was held at the Honolulu Lab on longline permit transferability. The main focus was a simulation model developed by the Honolulu Laboratory which featured a graphical presentation of the current swordfish longline fishery as well as alternative fishing patterns.

Also during the year, the Honolulu Laboratory developed a preliminary strategic plan for future Honolulu Laboratory pelagics research. This plan

will be discussed during the Honolulu Laboratory annual program review scheduled for this summer.

International Tuna-related Activities

The Center staff remains active on international forums concerning tuna and other large pelagic fishes. Two of the staff were theme leaders at the World Fisheries Congress in Athens, Greece, in sessions dealing with International Development and Assessment Methods and Management, respectively. The SWFSC also organized and hosted the second workshop of the Western Pacific Yellowfin Tuna Research Group (WPYRG) in June 1992 in Honolulu, Hawaii. The PFRD Chief, La Jolla, was chairperson for the group, which is composed of scientists, fishery representatives, and spokespersons from 16 countries. It was created in 1991 to develop and examine models of stock production and potential yield, the degree of interaction among different fisheries, and factors contributing to local depletion. At the June meeting, the group assembled fishery data for creating a common, catch-by-size data base and completed a review of information on the population biology of yellowfin tuna. The ultimate objective is to complete a stock assessment in 1993 or 1994.

The Center was also represented at a MEXUS-Pacifico Meeting in Manzanillo, Mexico, in September. Cooperative research interests under this bilateral research agreement have expanded in recent years to include large migratory pelagics such as marlin and sharks. During the year, a second sonic tagging cruise was completed by PFRD's Stock Assessment and Fishery Impact Analysis Program with Mexican colleagues. The purpose was to determine if striped marlin behavior patterns in Mexico waters vary from those in other parts of the species' range. Mexican scientists will also collaborate in the SWFSC's April-May 1993 *David Starr Jordan* cruise off southern California, aimed primarily at indexing catch-per-unit effort, tagging, and collecting biological and catch information on shortfin mako and blue sharks.

At other international tuna-related meetings, the Center was represented at the Southeast Asia Tuna Conference in the Republic of the Philippines in September; the International Commission for Conservation of Atlantic Tunas Advisory Meeting in Silver Springs, Maryland, in October; the First Japan-U.S. Consultative Meeting on Fisheries Matters in Tokyo in November; the Fifth South Pacific Albacore Research Group Meeting in Tahiti March 27-April 2; and the South Pacific Tuna Treaty Consultation Meeting in Fiji in April.

The SWFSC continues to work with the Inter-American Tropical Tuna Commission (IATTC) in processing incidental dolphin mortality data from the ETP purse-seine fishery, and it is currently reviewing new analyses completed by IATTC on spotted dolphin based on last year's redefinition of spotted dolphin stock structure. The Center also conducted two cooperative research planning meetings with the IATTC to discuss plans for 1993 and the future, and it collaborated on research relating to development of dolphin-safe fishing methods.

Albacore and Driftnet-related Work

The SWFSC continues to participate in cooperative assessments of North and South Pacific albacore with international working groups, reporting on northern and southern Pacific albacore standing stocks and recruitment. In 1992-93, work continued on gathering, compiling, and analyzing information on the status of Pacific albacore stocks and associated fishery interactions.

Tuna researchers within the PFRD at the La Jolla Laboratory and the **Pelagic Resources Investigation (PRI)** at the Honolulu Laboratory continue their work in driftnet research. The work is part of the intra-agency NMFS Driftnet Research Program to assemble information about North Pacific high-seas driftnet fisheries. Most of the data were collected under bilateral and multilateral scientific programs as part of agreements between the United States and other countries.

The PRI staff in Honolulu is involved in estimating bycatch levels of the driftnet fishery, analyzing sea surface temperature fields in the North Pacific Transition Zone (NPTZ) driftnet fishing area, and analyzing biological samples. A report is nearing completion on bycatch levels of all

major cephalopod and fish species, including tunas and billfishes, sharks and pomfret. It provides numbers and biomass removal estimates for the driftnet fishery in 1990 and 1991. Another report, focusing on the tuna and billfish bycatch in the driftnet fishery and comparing these removals with those from other fisheries, is also planned for the coming months.

The La Jolla Laboratory staff with PFRD's Stock Assessment and Fishery Impact Analysis Program again monitored the incidence of gillnet scarring of albacore in the U.S. troll catch over a wide fishing area of the North Pacific Ocean. In this project, carried out since 1990, observers collect data on the frequency of gillnet marks on troll-caught albacore. Observers were placed on commercial trollers with the help of the Western Fishboat Owners Association. The study provided valuable information on the interaction between high-seas driftnet fisheries and troll fisheries for albacore.

Certain auxiliary studies were conducted this year relating to driftnet research and albacore biology. Within PRI at Honolulu, the staff compared net-scarred and normal albacore caught in the troll fishery to determine effects on size or condition of netted fish that become entangled but drop out of the nets, which may cause higher "natural" mortality. Also, PRI in Honolulu and PFRD in La Jolla have been collaborating on an albacore age-and-growth verification study.

The Stock Assessment and Fishery Impact Analysis Program (PFRD, La Jolla) prepared and distributed the 1992 Albacore Tuna Forecast to interested subscribers last June, and plans are to distribute the 1993 Forecast for the upcoming season in June 1993.

Also during the year, the Annual Summary of 1991 North Pacific Albacore Fisheries Data was completed by PFRD's Multispecies Data Collection and Evaluation Program staff. The report provides information on catch and effort, fish size, incidence of fish scarring, and fishery-associated oceanographic conditions.

The Center continues to provide statistical and research support to the South Pacific Commission and South Pacific Albacore Research (SPAR) group on South Pacific albacore. The Stock Assessment and Fishery Impact Analysis Program (PFRD, La Jolla) completed a project conducted jointly with the Tuna and Billfish Assessment Program (TBAP) and the South Pacific Commission (SPC) on spawning seasonality of albacore in the South Pacific. Results of this study were presented at the Fifth South Pacific Albacore research meeting in Papeete, Tahiti, in April 1993.

Within the **Coastal Fisheries Resources Division** at the La Jolla Laboratory, a manuscript was published on North Pacific albacore ecology and oceanography, one of six papers from the 1988 North Pacific Transition Zone Workshop published in NOAA Technical Report NMFS 105. This report was distributed in late 1992. The paper summarizes a broad range of knowledge of albacore ecology and associated oceanography in the North Pacific that has resulted from almost two decades of studies conducted by the fisheries oceanography group in the Coastal Division.

Research on Marine Mammals Associated with Fisheries for Large Pelagics

Within the **Marine Mammal Division (MMD)** at La Jolla, scientists continue to study the status of dolphins associated with the eastern tropical Pacific (ETP) purse-seine tuna fishery and other marine mammals taken incidentally in domestic and foreign fishing operations.

Important field studies were completed last year within the Division. The first Populations of Delphinus Stocks (PODS) survey to obtain minimum abundance estimates of the central stock of common dolphin in the ETP took place from August to November; the survey was carried out by the MMD's Dolphin Stock Assessment Program. Also completed were the first research cruises relating to dolphin-safe technology, as part of the new Dolphin-Safe Technologies Program. A LIDAR (light detection and ranging) test cruise was conducted in September and October, and an IATTC-NMFS-industry experiment to simulta-

neously track dolphins and tuna was conducted in November. Because of complications with the contractor, results from the LIDAR cruise are still pending; preliminary results of the tuna and dolphin tracking experiments are provided in this report.

Stock assessments for 22 species (37 stocks) of cetaceans were completed during the year--a major accomplishment for MMD and its Coastal Marine Mammal Program. A review of California cetacean stock assessments was held at the La Jolla Laboratory March 31-April 2, 1993.

Genetic and morphological research on cetacean stock definition continues and is being carried out by MMD's Population Identity/Photogrammetry Program and the SWFSC Senior Scientist office. A collaborative genetic study on the common dolphin conducted with Scripps Institution of Oceanography (SIO) and L.A. County Museum researchers was completed during the year. Results of the study indicate that the long-beaked and short-beaked forms of the common dolphin, which are taken incidentally in the ETP purse-seine and high-seas driftnet fisheries, are probably distinct species. Stock structure was also redefined for the eastern spinner dolphin, based on a combination of genetic and morphological evidence, and for the spotted dolphin, based on morphological differences. Excellent progress was also made this year on distinguishing stock structures of the northern right whale dolphin (taken in the high-seas driftnet fishery) and harbor porpoise (taken mainly in the California gillnet fishery for shark and swordfish).

West Coast Shark/Swordfish Gillnet Fishery

In July 1992, a comprehensive report was completed by the California Department of Fish and Game (CDF&G) and La Jolla's PFRD (Stock Assessment and Fishery Impact Analysis Program) on the California drift-gillnet fishery for sharks and swordfish (1981-1991). This report will be published as a CDF&G Fish Bulletin. It includes historical and contemporary data on target fishes as well as incidental species (including marine mammals) and information on areas fished and regulations. Data were summarized from the California logbook system, landing receipts, and market samples. Among some of the findings, the authors found that the average size of thresher shark decreased 30 percent since the 1982-83 season. They also found the incidental catch of marine mammals to be low and not compromising any stock, though the potential remains and continued monitoring is advised.

Billfishes

The former editor of the SWFSC's *Billfish Newsletter*, produced by PFRD's Stock Assessment and Fishery Impact Analysis Program, retired in December 1992 after having worked many years coordinating the Pacific International Billfish Angler Survey and Cooperative Marine Gamefish Tagging programs. This position at the La Jolla Laboratory is still vacant, and although some research has been curtailed, program staff are carrying on most billfish activities. The 1993 "Billfish Newsletter" is scheduled to be released this summer, and PFRD staff taking over the Cooperative Marine Gamefish Tagging Program continues to distribute tags to billfish anglers in Mexico, Hawaii, and elsewhere in the Pacific in cooperation with the International Billfish Association and others. In August 1992, a record number of blue marlin (122) was tagged with NMFS tags and released during the Pro Am and Hawaiian International Billfish tournaments conducted off Kailua-Kona.

In September 1992, a joint billfish tagging cruise was conducted off Cabo San Lucas, Mexico, as mentioned above in discussion of International activities. The purpose of the cruise was to track the horizontal and vertical movements of striped marlin for comparison with results of similar tracking experiments in other parts of this species' range. This work is part of a special cooperative study conducted by the La Jolla Laboratory, the Centro Interdisciplinario de Ciencias Marinas and Centro de Investigaciones Biologicas de Baja California Sur.

During the year, results of a 1991 striped marlin tracking experiment, conducted in Hawaii by fishery biologists within Honolulu's PRI and La

Jolla's Stock Assessment and Fishery Analysis Program (PFRD) and researchers from SIO and Woods Hole Oceanographic Institution, were prepared and accepted for publication. The work involved monitoring fish movements with ultrasonic depth-sensitive transmitters and simultaneously measuring associated temperature and ocean current patterns. Results showed that striped marlin spend much of the time drifting with the currents in the warmest water available, that is, in the upper mixed layer, and that maximum depth of descent appears limited by colder water temperatures relative to the upper mixed layer.

In addition, research within the Honolulu Laboratory's PRI is being conducted on the diet of swordfish to evaluate the ecological relationships of swordfish and seasonally migrating North Pacific Transition Zone (NPTZ) species, such as the flying squid.

Biology of Hawaii Tunas and Other Larger Pelagics

Most biological research on Hawaii tunas and large pelagics is carried out within PRI at the Honolulu Laboratory, where the staff focuses on gathering biological information to improve the scientific basis for effective management of billfish, tuna, oceanic sharks, wahoo, and mahimahi.

In September, PRI staff completed a study of habitat depth, hooking time, and vulnerability to longline gear of blue marlin, yellowfin tuna, and associated species using time-depth recorders. Hook timers indicated that fish survived many hours after being captured, with tuna tending to survive longer than billfish. A subsurface oceanographic feature was found to influence catch rates of bigeye tuna between 16.5° – 18° N latitude.

Work also continued on tuna and billfish physiology and habitat requirements. Over the past year three papers were published on tuna physiology, including two on effects of temperature changes on blood physiology in yellowfin tuna. Research currently focuses on a review of tuna physiology research and its application to fishery oceanography and management, for eventual publication in a fisheries journal.

A faunal atlas of marine resources of the North Pacific Transition Zone, based on existing literature and driftnet observer information, is in preparation. Billfish and tunas will be covered in the atlas as well as other fishes, cephalopods, marine mammals, seabirds, and turtles.

Tuna-related Fishery Data Bases

The SWFSC staff handles extensive and complex fishery data bases from tuna fisheries around the world in support of stock assessment research and fishery evaluation. The Multispecies Data Collection and Evaluation Program within La Jolla's PFRD, continues the important task of processing tuna-dolphin observer data, California coastal gillnet observer data, tropical tuna fisheries data, North and South Pacific albacore data, and other data collected from field experiments, expeditions, port sampling, and logbooks. The staff maintains the Atlantic tropical tuna data base and maintains data bases for Pacific Ocean and Indian Ocean tunas and large pelagics. They also process data and evaluate the sampling regime for collection of South Pacific Regional Tuna Treaty data in cooperation with the Forum Fisheries Agency as required by the treaty. The group also provides annual summaries and analyses of data for U.S. Pacific albacore fisheries for distribution to the U.S. albacore fishing fleet and data collected by tuna-dolphin observers are used in marine mammal stock assessments. The staff works closely with the California Department of Fish and Game in editing and processing drift-gillnet logbook data from coastal California to better describe and assess the effects of this fishery on sharks, billfish, and other target species.

At the Honolulu Laboratory, most data management on tunas and large pelagics is organized under the **Fishery Management and Performance Investigation**, which provides fisheries data to the Council and other domestic and international clients. The data are obtained primarily from Federal logbooks, wholesale market monitoring, and shoreside sampling as well as from at-sea observations and interviews at dockside. This investigation continues to provide annual and quarterly reports on the status of major fisheries, including those for tunas and large pelagics. The

WPACFIN element is the central source of information on most fisheries in Hawaii as well as in American Samoa, the Commonwealth of the Northern Marianas Islands, and Guam. This year the PacFIN and WPACFIN data committees joined forces, holding their first joint meeting in October at the Honolulu Laboratory. The matter at hand was the important task of prioritizing projects and planning allocations for the much-reduced amount of funds available in FY 93 for operating Fishery Information Network data programs in each state and island area.

Also during the year, staff of Honolulu's PRI and CoastWatch program began developing a prototype integrated data analysis and archiving system to process and analyze ecological and fisheries data from the North Pacific Transition Zone Driftnet Program. The system should greatly improve the Center's ability to access and integrate large and complex environmental, biological, and fisheries data sets generated from the driftnet sampling program.

Mathematical Modeling for Stock Assessment

Work continues within PFRD's Pelagic Ecosystem Model Development Program (La Jolla) on evaluating mathematical modeling techniques used in stock assessments. Analysts examine them for accuracy and relevancy for providing advice for management of tuna and tuna-related fisheries. The staff also assists in designing and conducting stock assessments and in planning sampling projects for other programs. The head of the program returned from New Caledonia where he was posted to the South Pacific Commission (SPC) for most of the previous year. The posting was a collaborative arrangement between NMFS and the SPC's Tuna and Billfish Assessment Programme, which has been conducting tuna-tagging operations in the central and western Pacific Ocean. Work focused on using tag-return data to model skipjack tuna fisheries interactions and to examine how skipjack movement is influenced by the presence of Fish Aggregating Devices (FADs).

Industry Economics and Global Trends

At La Jolla, the Multispecies Data Collection and Evaluation Program (PFRD) monitors tropical tuna trade and fishery developments on a global scale to help interpret and evaluate fishery statistics used to analyze stock condition. Data obtained from international sources are summarized in various publications, including the popular "Tuna Newsletter."

Finally, statistics of the U.S. canned tuna industry were compiled for the first three quarters of 1992. Other activities continue, such as monitoring U.S. production of tuna for the fresh fish market and various analyses in support of tropical tuna management.

DR. MICHAEL TILLMAN
Science and Research Director,
Southwest Region

May 1993
La Jolla, California

II. ECONOMIC OVERVIEWS

Statistics of the U.S. Canned Tuna Industry Compiled for the First Three Quarters of 1992

Statistics for the U.S. canned tuna industry for the first three quarters of 1992 were tabulated by Pat Donley of the Southwest Regional (SWR) Office and were summarized by Al Jackson of the Southwest Fisheries Science Center (SWFSC). The reports describing the statistics appear as articles in the August and November 1992, and February 1993, issues of the SWR/SWFSC "Tuna Newsletter."

The total number of vessels in the U.S. tropical tuna purse-seine fleet was down two vessels in the third quarter of 1992 from the same quarter the previous year.

For the first quarter of 1992, receipts of domestic and imported raw tuna by U.S. canners were up 7 percent from the first quarter of 1991, at 110,500 short tons (st) (converted to round weights). Second quarter totals showed a 12-percent decline, with 114,600 st received, but third quarter receipts showed a 1-percent increase over the previous year's receipts, with 118,900 st. Species composition data for all three quarters showed skipjack tuna to be the largest component of the deliveries, comprising 56 percent of the total, followed by 22 percent albacore and 21 percent yellowfin.

As in the first three quarters of 1991, tuna delivered to U.S. canneries for the first three quarters of 1992 originated principally in the western Pacific. Tuna imported by U.S. canners increased from 52 percent of the total receipts in the first quarter to 59 percent of the total receipts in the second quarter of 1992, but the third quarter showed a decline in imports to 44 percent of the total receipts. Domestically caught deliveries to canneries in Puerto Rico for the third quarter of 1992 were up 445 percent from the previous year. This was almost entirely due to increased skipjack deliveries. The domestic component of deliveries to American Samoa/California was down 28 percent.

Imports in the first quarter of 1992 were mainly from Taiwan, Spain, Japan, France, and Ghana. Taiwan provided 26 percent of U.S. cannery imports. The top five supplying nations provided 69 percent of all imports. In the second quarter, Taiwan, Japan, Ghana, Vanuatu, and Spain contributed 67 percent of the imports. The top five contributors in the third quarter were Taiwan, South Korea, Japan, Ghana, and South Africa. The five countries provided 83 percent of the total U.S. cannery imports. Forty-eight percent of the total was contributed by Taiwan. Imports of canned tuna packed in water through the third quarter in 1992, 133,800 st, were up 4 percent from the third quarter of 1991.

To obtain a more detailed account of tuna statistics, write to: Tuna Newsletter, Southwest Fisheries Science Center, P. O. Box 271, La Jolla, California 92038. (A. Jackson [619] 546-7048)

III. PACIFIC OCEANIC FISHERIES

Pacific Albacore

1991 North Pacific Albacore Summary Completed

Biological Technician Gary Rensink of Southwest Fisheries Science Center's (SWFSC) La Jolla Laboratory and Forrest R. Miller, Inter-American Tropical Tuna Commission (IATTC), co-authored Administrative Report LJ-92-30, "Summary of the 1991 North Pacific albacore fisheries data," which describes the results of the sampling program carried out during the 1991 North Pacific albacore season.

The 1991 U.S. North Pacific albacore fishery started in mid-May and continued through mid-October. Overall sampling coverages for catch-and-effort and length-frequency information were 62 percent and 61 percent, respectively, compared to 57 percent and 56 percent in 1990. The 200+ vessels participating in the fishery expended an estimated 3,866 days fishing (sampled days fishing/coverage rate) compared to 5,523 days in 1990.

The U.S. fleet caught albacore from 33° – 53° N latitude and from 151° E longitude to the U.S. west coast. Catches were highest in August, roughly 900 to 1,300 miles west of southern Oregon and about 50-150 miles south of Cape St. James (Queen Charlotte Islands). Catches from the commercial fishery reflected a new record low of 1,845 metric tons (t) for 1991 compared to 2,818 t in 1990.

The overall catch rate in 1991 of 36 fish/day was the same as in 1990. The highest nominal catch rates in 1991 occurred roughly 1,300 miles west of central Oregon in July (155 to 220 fish/day) and 1,250 miles west of central Oregon in August (205 to 260 fish/day), an area farther offshore than where the highest catch rates were recorded in 1990 (190-225 fish/day).

Over 24,000 albacore were measured for fork length (tip of snout to fork of the tail) from the landings of vessels participating in the 1991 U.S. North Pacific fishery. The average fork length of fish measured decreased considerably from 71.0 cm (weighing 16.4 lb) in 1990 to 65.1 cm (weighing 12.6 lb) in 1991. Fish ranged in size from 41 to 117 cm.

Albacore fishing activity began in July 1991 along the western edge of the sea surface temperature (SST) frontal edge formed by coastal upwelling between Cape Blanco and Monterey Bay, California. In August and September, fishing was concentrated in the offshore SST ridge, where isotherms bulged northward toward Vancouver Island and also in the coastal region from Vancouver Island to northern California, where strong coastal upwelling had formed numerous SST frontal edges.

NMFS observers accompanied four U.S. troll vessels on four trips, starting in early July and finishing in late September 1991. A total of 12,466 albacore were examined and measured. Overall, 3.1 percent of the catch examined showed evidence of net-related damage, compared to 12.4 percent for observed trips in 1990. (G. Rensink [619] 546-7192)

Scientific Observers Document Fishery Interaction in the U.S. North Pacific Albacore Fishery

During the 1992 fishing season, Southwest Fisheries Science Center (SWFSC) in La Jolla, in cooperation with the Western Fishboat Owners' Association, placed scientific observers aboard cooperating U.S. albacore troll vessels to document direct fishery interaction in the U.S. North Pacific albacore fishery as part of an industry-NMFS project begun in 1990.

The observers completed three trips totaling 228 sea days and examined more than 15,000 albacore for evidence of encounters with the large-scale drift-gillnet fishery. As in previous years, marks were most evident on fish captured west of 140° W; these fish averaged nearly 8.5 percent of the catch. East of 140° W, toward the U.S. coast,

the proportion of marked fish declined to 2.4 percent. The overall incidence of marked fish in 1992 was 4.6 percent of the sample as compared to 3.1 percent in 1991 and 12.4 percent in 1990.

Under a United Nations (UN)-sponsored resolution, high-seas, large-scale drift gillnetting terminated at the end of 1992. Scientists expect the presence of net-marked fish to decline markedly in 1993, provided the UN resolution is honored by all participants. (D. Holts [619] 546-7186)

Effects of Entanglement on North Pacific Albacore

As part of the larger effort to determine the impacts of driftnets on the stock of North Pacific albacore, scientists of the Honolulu and La Jolla Laboratories examined net-scarred and normal albacore caught by U.S. trollers during 1990 and 1991 to determine whether the condition of albacore that become entangled and subsequently drop out of the nets is adversely affected, which may cause higher natural mortality. If so, the North Pacific albacore stock could be impacted more seriously by high-seas driftnets than landings indicate. In addition, the scientists are concerned because the North Pacific albacore are heavily overfished and may have experienced recent declines in recruitment.

In this study, length-weight data, otoliths, blood smears, and white muscle samples were collected from net-scarred and normal albacore during 1990 and 1991 by observers placed aboard 10 U.S. trollers by the Honolulu and La Jolla Laboratories in cooperation with the Western Fishboat Owners Association. The trollers operated in North Pacific areas bounded by 52°40' N, 145°52' W and 42°33' N, 129°48' W (within the North Pacific Transition Zone north of Midway Islands as well as offshore and in U.S. coastal fishing grounds).

Only one significant difference was found in the above study between net-scarred and normal fish: normal albacore were larger (mean fork length, body weight, and maximum girth). These data imply that small fish escape from driftnets, survive, and are recaptured by the trollers more frequently than large fish. Although this result appeared to be confirmed by the size-frequency distribution of the sampled fish, the scientists believe it is most likely due to sampling bias of the observers or to time-area variations in fish size composition and the percentage of net-scarred fish. In a separate study, the size-frequency distribution of a larger sample of albacore (12,085 normal and 381 net-scarred individuals) captured in the same areas as the fish sampled for this study, show that normal fish tended to be smaller than net-scarred fish.

The lack of differences between normal and net-scarred albacore caught by the U.S. troll fleet indicates that fish escaping from driftnets and living long enough to resume feeding (and becoming vulnerable to recapture by trollers) probably do not suffer increased natural mortality. The data do not imply, however, that fishing mortality due to high-seas driftnets is limited to actual landings, because a variety of fates may befall albacore that become entangled. The study could only compare animals that had never become entangled with those that were probably not badly injured and had lived long enough to resume feeding. The percentages of albacore dying from falling out or escaping, but so badly injured that they were unable to resume feeding, may well be significant. The results of the study have been accepted for publication in the Fishery Bulletin. (R. Brill [808] 943-1234 and D Holts [619] 546-7186)

Hawaii Fisheries

WPRFMC Activities

Planning Conference Report Released

During the previous reporting period, the Western Pacific Regional Fishery Management Council (WPRFMC), along with NMFS, funded and supported the Pacific Pelagic Fisheries Planning Conference which was held in Honolulu March 25-27, 1992. Organized by the University of Hawaii's School of Ocean and Earth Science technology and NOAA's Joint Institute for Marine and Atmospheric Research (JIMAR), the conference was attended by tuna and billfish scientists from

the United States and the Pacific and was held to chart directions for allocating a special congressional appropriation of $1.7 million annually for 5 years. Experts in fishery oceanography and biology, tuna stock assessment, tuna and billfish interactions, and social science reviewed recent developments in tuna and billfish research; and working groups identified important activities for tuna and billfish research in the western Pacific. Priorities across the disciplines were established.

In May 1992, results of the conference were released in a report, "Pacific Pelagic Fisheries Planning Workshop Report." Proposals for first-year funding were submitted by JIMAR in December 1992 and have been peer reviewed by NMFS. Funding is pending as of March 1993. (S. Pooley [808] 943-1216)

WPRFMC Workshop Held

A workshop on longline permit transferability was held at the Honolulu Laboratory on November 12, 1992. The workshop, sponsored and chaired by the Western Pacific Regional Fishery Management Council (WPRFMC), was in response to requests by some members of the Hawaii longline fishery to allow transferability of limited entry longline permits. The workshop, put together by Laboratory, Council, and NMFS Southwest Region Pacific Office staff combined scientific knowledge of current fishing practices and the potential impact of changes in those practices based on industry knowledge of changes in fishing practices that might occur under various permit transferability plans.

The workshop analyzed the current Council rule that allows only one transfer in a 3-year period (1992-94) along with other alternatives that included (1) selling the permit with the vessel, (2) a one-time sale of permit with a one-time upgrade of vessel harvesting capacity, and (3) unrestricted sale permit and upgrade of vessel harvesting capacity.

The main focus of the workshop was a simulation model, developed by Fishery Biologist Robert A. Skillman and Industry Economist Samuel G. Pooley of the Honolulu Laboratory, which projected the impact of alternative permit transferability rules in the Hawaii-based longline fishery. Skillman and Pooley created a multi-page spreadsheet model, which makes a graphical presentation of the current Hawaii longline fishing situation and alternative fishing patterns. The results of the simulation model, with extensions into risk assessment, will be prepared as a manuscript this year by Skillman and Pooley, and by Dorothy Lowman, staff economist of the WPRFMC. (S. Pooley [808] 943-1216 and R. Skillman [808] 943-1257)

Work Proceeds on Western Pacific Pelagics Amendment 7

Southwest Regional and Center staff have been helping to prepare Draft Amendment 7 to the Fishery Management Plan for Pelagic Fisheries of the Western Pacific Region. The amendment will replace Amendment 4, which was enacted in 1991 and established a 3-year moratorium on the entry of vessels into the Hawaii-based longline fishery because of concern for the resources and impacts on other elements of the pelagic fishery due to the unprecedented growth of and harvest by the fishery. This moratorium will end on April 22, 1994, without results from the Council's proposed assessments since funding has not yet been provided. While preliminary studies have failed to show an impact of the increased longline harvests on catch rates by the surface fishery or on market dynamics within the latter fishery, assertions continue regarding such impacts and the need for continued management of the longline fishery. Longline permit transfer and upgrading of fishing capacity have also become issues because attrition of the longline fleet has occurred under the moratorium due to restrictions in these areas.

Honolulu Laboratory's Samuel G. Pooley, industry economist, and Robert A. Skillman, fishery biologist, have expanded a spreadsheet model of the Hawaii longline fishery to simulate probable changes in catches by species, vessel size classes, and fishing areas due to combinations of four management elements: continuation of existing limited entry (A) permits (no, yes fixed, yes adjustable), permit transfer (yes, no), upgrade (yes, no), and an additional offshore or species-specific (B) permit. Fishery Biologist Christofer H. Boggs

and others at the Honolulu Lab have been writing segments of the draft amendment regarding status of the stocks, descriptions of the fishery and the markets, management alternatives, alternative mechanisms for effort limitation, and biological and economic impacts of alternative management actions. Svein Fougner and Alvin Katekaru of the Southwest Region staff have also been involved in drafting the amendment. (J. Wetherall [808] 943-1258)

WPYRG Meeting Held June 1992

The second meeting of the Western Pacific Yellowfin Tuna Research Group (WPYRG) was held in Honolulu June 17-24 and hosted by NMFS's Southwest Fisheries Science Center. It was attended by 26 participants from Australia, the Federated States of Micronesia, Fiji, French Polynesia, Indonesia, Japan, the Marshall Islands, New Caledonia, New Zealand, Palau, the Philippines, the Solomon Islands, Taiwan, and the United States.

Objectives of the meeting were to (1) prepare a data base for conducting a comprehensive stock assessment by 1993 or 1994, and (2) outline specifications for conducting that stock assessment.

To meet objective one, the group analyzed compiled data collected by the participants. They agreed, however, to postpone creation of the master data base for 6 months since the volume of data received at the workshop was large, additional data sources were identified, and some data needed to be rechecked against the original records. NMFS was assigned responsibility for coordinating the data base.

Working toward this objective, Biological Technician Laura Halko, Computer Programmer Donna DaRodda, and Task Leader and Mathematician Al Coan of the La Jolla Laboratory have been compiling data for Philippine handline, ringnet, and purse-seine tuna fisheries. Catch data have been summarized and software is being developed to reformat yellowfin tuna length data from LOTUS spread sheets to ASCII files. The Inter-American Tropical Tuna Commission (IATTC) has completed updating data bases containing historical western Pacific U.S. purse-seine data for 1981 to 1985. DaRodda is working on reprocessing these data for WPYRG. WPYRG will use the information to generate length distributions of yellowfin tuna. DaRodda will reprocess 1986-1988 data as soon as these data are completed, and she and Computer Programmer Doug Prescott are completing the U.S. portion of a western Pacific yellowfin tuna data base for purse-seine gear, a data base managed by WPYRG. IATTC recently provided key pieces of 1986 and 1987 U.S. data.

To meet the second objective, the group reviewed available information on the population biology of the western Pacific yellowfin tuna, focusing on parameters necessary for a stock assessment. The group concluded that there is currently insufficient information on the population biology of this species to conduct an assessment with an age-structured model. The group recommended that research be focused on the long-term goal of closing the information gaps identified by the group.

The group developed a work plan for 1992/93 and will meet in 1993 to review results and progress. (G. Sakagawa [619] 546-7177)

WPACFIN Activities

Two fisheries data committees, the west coast Pacific Fishery Information Network (PacFIN) Data Committee, and the Western Pacific Fishery Information Network (WPACFIN) Fisheries Data Coordinating Committee (FDCC), held their first joint meeting on October 20, 1992, in Honolulu, Hawaii. Four PacFIN representatives joined forces with five FDCC representatives to develop recommendations for allocating the FY 93 funds available for operating PacFIN data programs in each state and island area.

The joint committee reviewed and ranked 24 proposals for projects of considerable importance for meeting current or long-term federal fishery management requirements in the Pacific, within the limits of the FY 93 budget. Since the FY 93 funding ($1.8 million) was considerably less than the total budget required to fund all 24 projects,

projects were prioritized and a recommendation was developed for allocating within the limits of the FY 93 budget.

Participants agreed that the meeting accomplished the goal of developing, for the first time, a joint recommendation from the two data committees for allocating funds among the various agencies, and it gave participants an understanding of each of the participating agencies' needs.

The WPACFIN FDCC met again on December 3, 1992, at the NMFS Honolulu Laboratory. Although the principal purpose of the meeting was to develop a recommendation for revised FY 93 WPACFIN project proposals to reflect a budget reduced by nearly 50 percent (to $278,000), the Committee also reviewed two fisheries applications of integrated data systems.

The first system reviewed was the Gulf of Mexico Shrimp Harvest Data Base developed by the Southeast Fisheries Science Center (SEFSC) and the National Ocean Service's (NOS) Office of Oceanography and Marine Assessment using their computer mapping and analysis system technology. The most important feature of the system is the mapping interface that allows the user to quickly display maps of the Gulf of Mexico with user-selected shrimp landings data graphed in statistical areas and depth ranges.

The second system reviewed was the first phase of the Central WPACFIN On-line Query System (CWOQS, verbalized "sea walks"). Still in its early stages of development, CWOQS is a dial-in system running under the dBASE IV environment on a centrally operated IBM-compatible 486 PC. The basic user-interface shell of this menu-driven system allows the user to select various types of data from among the four WPACFIN island areas (American Samoa, Hawaii, Guam, and the Northern Mariana Islands) and produce either standard or user-defined monthly and annual reports. The design of the full system currently contains modules to process data from over thirty data sets covering all aspects of fisheries monitoring in the exclusive economic zones of the western Pacific. At future meetings, the FDCC will be discussing priorities and proposed schedules for developing and implementing other phases of CWOQS to improve fishery monitoring and data accessibility in the western Pacific. (D. Hamm [808] 943-1214)

Tuna Longline Research Cruise Completed

A study of the habitat depth, hooked longevity, and vulnerability to longline fishing gear of blue marlin, yellowfin tuna, and associated species was conducted on the NOAA ship *Townsend Cromwell* in September 1992. This and similar studies are needed to understand variations in catch-per-unit (CPUE) statistics upon which fishery management advice is based.

Time-depth recorders (TDRs) were used to keep track of the depth of longline fishing gear while hook timers were used to measure the time at which fish were caught. Since the depth of longline gear changes during deployment, soaking, and retrieval, hook timers combined with TDRs are necessary to establish capture depth. Changes in fishing depth relative to habitat depth can affect CPUE in ways that may obscure the true status of the resource. This research was an extension of a study published this year in *Fishery Bulletin* (Boggs 1992, "Depth, capture time, and hooked longevity of longline-caught pelagic fish: timing bites of fish with chips").

A total of 25 sets was made, with fishing effort totaling about 13,000 hooks. The catch totaled 384 fish of 21 species, mostly non-target species such as lancetfish, mahimahi, and sharks. Blue marlin were the most common billfish. Due to the lateness of the season, yellowfin tuna were less numerous than bigeye tuna or albacore.

These records provided data on the behavior (with respect to depth) of some fish after they were caught, and the records confirmed (through abrupt changes in depth) some of the capture times indicated by hook timers. Hook timers indicated that fish survived many hours after being captured, with tuna tending to survive longer than billfish. Blue marlin tended to be less hardy (had shorter survival times) than striped marlin, based on striped marlin data from previous cruises.

Most tuna, billfish, and sharks were alive when retrieved and were released. Fifty-one fish were also tagged and released, including 6 yellowfin tuna, 8 bigeye tuna, and 22 blue marlin. Experiments were conducted to see if longline-caught tuna could be tethered until haulback was completed and then recovered in good condition. The objective was to provide live fish that could be fitted with sonic transmitters and tracked by the same vessel that caught the fish. This method would allow tracking to be conducted in the open ocean where the small vessel normally used for tracking cannot operate. Out of seven tuna tethered, five survived in good condition. However, because of problems with the tracking equipment, no fish were tracked.

Ocean thermal structure was monitored with expendable bathythermographs and conductivity-temperature-depth casts with Niskin bottles for dissolved oxygen measurements. A subsurface oceanographic feature was found to have an influence on CPUE for bigeye tuna. This feature was a transition in the depth of the thermocline and oxycline found between latitude 16.5–18° N. The thermocline rose 40 m and the oxycline rose 100 m on the south side of the feature. Bigeye tuna were abundant along the north edge. (C. Boggs [808] 943-1222)

North Pacific High-seas Driftnet Statistics Analyzed

Since the late 1970s, high-seas driftnet fisheries have been the dominant fisheries in the North Pacific Transition Zone (NPTZ). Three species (or groups) have traditionally been targeted in these fisheries: neon flying squid, tunas, and billfish. Vessels from Japan, Taiwan, and the Republic of Korea target neon flying squid (hereafter referred to as the squid driftnet fishery), while other vessels from Japan and Taiwan target tunas and billfish (hereafter referred to the large-mesh driftnet fishery). The rapid expansion of these fisheries in the early 1980s and increasing incidental kill of non-targeted species (including marine mammals, sea birds, turtles, and salmonids) by these nets has become a focus of international attention and concern. Time-area regulatory measures were adopted in 1989 for the squid fishery, the northern boundary changing monthly to minimize the incidental take of salmonids. In 1989, a pilot cooperative scientific observer program was established between Japan, Canada, and the United States. Later, bilateral observer programs were launched by the United States and the Republic of Korea and by the United States and Taiwan. The goal of the scientific observer program was to monitor fishing operations and obtain data on the incidental take of various species of fish, marine mammals, turtles, and birds in an effort to assess impacts. Increased public concern over the potential impact of these fisheries has resulted in a U.N.-mediated ban on large-scale driftnet fishing to take effect on January 1, 1993.

Gerard DiNardo, Research Fishery Biologist, is assessing impacts of the high-seas driftnet fisheries on fish (non-salmonid) and cephalopod resources in the North Pacific and is finalizing total bycatch estimates for the 1990 and 1991 fishing seasons. These estimates represent the first step toward a complete assessment of impacts resulting from the high-seas driftnet fishery.

An initial step toward estimating total bycatch required the assessment of "dropouts" during net retrieval and their incorporation into subsequent bycatch modeling efforts. A retrieval dropout is defined as an animal that emerges from the water entangled in the net, becomes disentangled, and falls out of the net before it reaches the deck, either of its own accord or due to deliberate shaking of the net by the crew (although other dropouts occur during fishing, data were not available to estimate their magnitude). Results from this analysis are used to "scale-up" observed decked bycatch to account for dropouts. A log-linear model is used to study the effects of observer nationality, time of day (diel), sea state, and mesh size on retrieval dropout rate.

Total bycatch levels are calculated using a ratio estimator, with fleet effort being provided by the different countries. Because fishing operations differed based on target species, bycatch estimates are stratified by target species and country. The identification of temporal and spatial strata was determined analytically and by analyzing spatial maps of catch-per-unit effort (CPUE). In all

analyses, a unit of fishing effort is standardized and equal to 50 meters of driftnet. Bootstrap procedures (N = 1000) are being used to develop 95 percent total bycatch confidence intervals.

Species-specific metrics of exploited biomass are estimated by apportioning total bycatch to length categories based on length-frequency data collected by observers and converting length to weight using derived length-weight relationships. These data will be used in the development of ecosystem and fishery interaction models.

Modeling is also under way to identify factors contributing to the observed bycatch. Environmental data collected by observers and physical data pertaining to the NPTZ are being analyzed in an effort to elucidate relationships and foster hypotheses of biological-physical interactions. (G. DiNardo [808] 943-1259)

Tuna and Billfish Studies Under Way as Part of Driftnet Program

As part of the North Pacific driftnet monitoring and assessment research at the Honolulu Laboratory, several ancillary studies related to tuna and billfish resources are under way. Studies estimating the age and growth of North Pacific albacore, *Thunnus alalunga*, are being conducted by Honolulu Laboratory Fishery Biologist Keith Bigelow, with the cooperation of Bob Nishimoto of the La Jolla Laboratory. Bigelow is interpreting increment depositions from transverse slivers of sagittal otoliths using transmitted light microscopy and scanning electron microscopy (SEM). The study, employing alternative methods and technologies to complement prior work in ageing albacore, is based on reading increments on whole mounted saggitae.

Mike Seki, Honolulu Laboratory fishery biologist, is conducting diet studies of the swordfish *Xiphias gladius* to evaluate the ecological relationships of swordfish and seasonally migrating transition zone species (particularly flying squid, *Ommastrephes bartramii*). Preliminary results support the notion that swordfish feed on concentrations of mature, spawning flying squid. (Seki, in press, "Trophic relationships of *Ommastrephes bartramii* during winter migrations to subtropical waters north of the Hawaiian Islands," in Okutani et al. (eds), pp. 521-527, Recent advances in cephalopod fisheries biology, Tokai Univ. Press).

In addition, Seki is preparing profiles of tunas and billfishes taken in high-seas driftnet fisheries as part of a comprehensive faunal atlas of marine resources in the North Pacific Transition Zone, where the driftnet fisheries operated. The tunas and billfishes were taken as part of the Foreign High Seas Driftnet Observer Program in 1990 through 1991. The atlas will cover other fishes and cephalopods as well as marine mammals, seabirds, and turtles. Profiles will summarize life history and ecological information available for the pertinent species through an extensive review of existing literature and from information collected by observers aboard commercial foreign squid and large- mesh driftnet fishing vessels.

Don Hawn, Honolulu Laboratory biological technician, has compiled and analyzed information on the disposition and shipboard processing of tuna and billfish that were landed from 1990 to 1991 by foreign high-seas driftnet fisheries (squid and large-mesh). He is preparing a paper on the results for publication.

Hawn is also investigating the occurrence of elliptical scars, located antero-laterally of the anal fin, that he has found on 100 percent of the longline-caught albacore that were landed in Hawaii from 1991 through 1993. He has identified the most probable source of the scars as the ectoparasitic copepod, *Caligus* spp. Numerous specimens of the parasite have been found attached to albacore landed on longline gear as well as to larger troll-caught fish. Hawn is preparing a paper describing the findings and their significance. (D. Hawn, D. Bigelow, and M. Seki [808] 943-1219)

Tuna Physiology Research Review Under Way

Based on detailed data on the physiological abilities and habitat requirements of some tuna species acquired by Laboratory and field studies, Honolulu scientists state that, contrary to earlier

hypotheses, tunas have rapid and extensive control of the efficacy of their vascular counter-current heat exchangers (they are not strictly prisoners of their own thermoconserving mechanisms). This means tunas are not forced out of formerly suitable habitats as they grow because of potential overheating. Furthermore, tunas can exploit food resources below the thermocline because rates of heat loss can be minimized when diving into colder waters and rates of heat gain can be maximized when returning to the upper mixed layer. Work on low ambient oxygen tolerance shows that widely cited estimates of limiting oxygen levels, based solely on calculated metabolic rates at minimum hydrostatic equilibrium swimming speeds, are not accurate. Tunas have high oxygen demands even at very slow speeds because of their large thin gills (which permit high rates of oxygen and carbon dioxide exchange), which also apparently allow high rates of passive salt and water movements. The result is a high energy cost for maintaining salt and water balance and, therefore, a high metabolic rate even at slow swimming speeds. Recent laboratory research and modeling efforts also indicate that the ability of the tuna's cardiorespiratory system to deliver oxygen at extraordinarily high rates most likely evolved to permit rapid recovery from strenuous exercise, rather than to permit high sustained cruising speeds. The rate at which reduced ambient oxygen prolongs the time required to recover from strenuous exercise appears to serve as a good index of habitat suitability. The manuscript covering this research will be submitted for publication to the journal *Fisheries Oceanography*. (R. Brill [808] 943-1234)

Studies Completed on the Influence of Hematocrit, Temperature, and Shear Rate on the Blood Viscosity in Yellowfin Tuna

The high cardiac output, arterial blood pressure, and cardiac energy demand of tunas make it likely that blood viscosity is an important influence on the cardiovascular function in tunas. Furthermore, tunas regularly subject themselves to ambient temperature changes of 10°C or more during their daily vertical migrations, maintain muscle temperatures several degrees above ambient, and reach maximum muscle temperatures of 15°C above ambient. The blood of tunas is, therefore, subjected to more frequent and rapid temperature changes than occur in other teleosts. Nothing is known, however, about the effects of temperature, shear rate, or hematocrit on the viscosity of tuna blood.

Fishery Biologist Richard Brill, of the Honolulu Laboratory, and David Jones, of the University of British Columbia, measured the viscosity of yellowfin tuna blood (hematocrits of 0-55 percent) at 15 °C, 25 °C and 35 °C, and at shear rates of 45, 90, 225, and 450 s^{-1} using a cone-plate viscometer. As found for the blood of other vertebrates, viscosity increased with increasing hematocrit. Viscosity also increased nonlinearly with decreasing shear rate until a shear rate of 90 s^{-1} was reached. There was no significant increase in viscosity when shear rate was decreased further, to 45 s^{-1}. Because of the relatively flat hematocrit-viscosity curves, predicted optimal hematocrit curves were nearly flat above a hematocrit of approximately 30 percent. Results of this study have been accepted for publication by the *Journal of Experimental Biology*. (R. Brill [808] 943-1234)

Striped Marlin Tracked near the Hawaiian Islands

Scientists recently conducted a study of the horizontal and vertical movements of striped marlin, *Tetrapturus audax*, while simultaneously gathering water temperature and oceanic current information near the Hawaiian Islands. (The scientific group included Fishery Biologists Richard Brill and Randy Chang of the Honolulu Laboratory; Fishery Biologist Dave Holts of the La Jolla Laboratory; Scott Sullivan of the NOAA Corps; Heidi Dewar of the Scripps Institution of Oceanography; and Frank Carey of the Woods Hole Oceanographic Institute.) Fish movements were monitored using ultrasonic depth-sensitive transmitters; depth temperature profiles were measured using an expendable bathythermograph system, and oceanic current patterns were measured using an acoustic Doppler current profiler. The NOAA ship *Townsend Cromwell* and the small 33-ft research vessel *Kaahele 'ale* were used as the tracking vessels. Results showed that horizontal

movements of striped marlin can be strongly influenced by currents; some individual marlin spent most of the time drifting. Striped marlin near Hawaii, like Indo-Pacific blue marlin, *Makaira mazara*, spend over 85 percent of their time in the upper mixed layer (above 90 m). By comparing the data in this study to similar data collected on striped marlin near the California coast by Holts and California Department of Fish and Game's Dennis Bedford, it was found that striped marlin do not have an absolute temperature preference, but rather spend the majority of their time in the warmest water available (the upper mixed layer). The data also show that the maximum depth to which striped marlin descend appears to be limited, not by an absolute temperature, but rather by water temperatures 8 °C colder than the upper mixed layer. A manuscript describing the results of this study has been accepted for publication by *Marine Biology*. (R. Brill [808] 943-1234)

Scientists Study Tuna in a Swim Tunnel

Scientists are using a swim tunnel to study tuna in captivity at the Honolulu Laboratory's Kewalo Research Facility. The swim tunnel allows scientists to monitor the performance of individual tuna during experiments lasting more than 35 hours. Previously, tuna could be monitored for only a few hours before they died.

The swim tunnel, a 1.2-m-long (4-ft long) sealed box, was designed and built by Jeff Graham, director of the Marine Biology Research Division at Scripps Institution of Oceanography (SIO) in La Jolla, California. In the tunnel, fish can swim freely while being studied. Seawater is recirculated through the box through large plastic pipes extending from either end.

The tunnel is similar to a treadmill: the tuna remains in one location while swimming against the flowing current within the sealed box. This "tuna treadmill" enables scientists to measure how well tuna perform at different swimming speeds, temperatures, and oxygen levels.

Graham brought his swim tunnel to Hawaii because Honolulu Laboratory scientists had developed the techniques for maintaining and studying tuna in captivity. Nowhere else in the world is this type of research being successfully done. Special handling techniques were perfected by Honolulu Laboratory Fishery Biologists Richard Brill and Randy Chang. Laboratory Director George Boehlert also assisted Graham with the project.

The present studies by Graham and Scripps Institution of Oceanography graduate students Torre Knower and Keith Korsmeyer are examining how the skin, muscles, and heart of yellowfin tuna affect performance. Tuna are high-performance animals with correspondingly high metabolic demands, a large heart, and high oxygen demands. Tuna are always being pushed to the limit: their barren environment has limited food and large predators; they are exposed to different levels of temperature, oxygen, and light at differing depths as they move through the ocean hunting for prey and escaping from predators.

Graham believes it is important to understand how the performance of tuna relates to their natural history—their vertical movements in response to changes in environment, temperature, food, and salinity. Understanding the physiology of tunas can reveal the type of environment where tuna will be found.

Data Analysis and Archival System Prototype Developed

The ability to access and integrate environmental, biological, and fisheries data is central to dealing with critical natural resource management problems such as overfishing or multispecies interactions and is important in testing scientific hypotheses. This is particularly true when the knowledge base consists of large heterogeneous data sets collected at varying scales, which is so often the case. Yet, procedures to support the integration and analysis of these data are lacking. Given the already enormous and continually growing knowledge base, a more efficient way of organizing, processing, and analyzing ecological and fisheries data is required rather than a reduction of data.

Honolulu's Fishery Biologist Gerard DiNardo and Coast Watch Node Manager Craig Motell are developing a prototype integrated system to process and analyze ecological and fisheries data to be applied to the North Pacific Transition Zone (NPTZ) Driftnet Program. The Data Analysis and Archival System (DAAS) is modular in design and intended for use in storing, interpreting, and diagnosing physical and biological data collected in the NPTZ. System modules include data base, satellite image processing, mapping, data manipulation and analysis, graphics, and report writing. The integration of analytical tools with data base management provides users with an interactive system for efficient data management, browsing, and analysis. DAAS will be UNIX-based and networked to a Sun workstation which acts as a file server.

Current prototype development is limited to the data base and mapping modules. Instead of developing the prototype system from scratch, existing systems and software were identified and evaluated based on desired attributes of the system. By using existing systems, development time and cost is minimized.

For the mapping module, the software package Generic Mapping Tools (GMT) is being explored. GMT is a free public domain software package that can be used to manipulate columns of tabular data, time-series, and gridded data sets and display these data in a variety of forms ranging from simple x-y plots to maps and color, perspective, and shaded-relief illustrations. The Naval Environmental Operational Nowcasting System (NEONS) is being evaluated for use with a relational data base in the data base module. NEONS was developed by the Navy and is used in many interactive information and processing systems for meteorology, oceanography, and hydrology. NEONS is a software package that provides a set of tools to access, create, and manage environmental data that are stored in a NEONS schema within a relational data base. The Navy's NEONS Data Browser is being examined as an interface between NEONS and the relational data base. The NEONS Data Browser allows users to select, locate, and access needed data sets through a series of temporal and spatial queries. The accessed data set can then be exported to another file or application for data analysis or visualization. At the present time, NEONS manages environmental data using the relational data base EMPRESS as the relational data base management system. However, NEONS supports SQL protocol and should allow conversion to any relational data base supporting ANSI SQL, including ORACLE version 7 (ORACLE version 7 is needed to be compatible with NEONS since it supports a binary data type such as that used by satellite imagery). The conversion of EMPRESS to ORACLE is being evaluated as well as the expansion of permissible data types to include fisheries data. (C. Motell [808] 943-1226 and G. DiNardo [808] 943-1259)

South Pacific Tuna Fisheries

Tag Data Shows Effect of FADs on Tuna Movement

Fishery Biologist Pierre Kleiber returned in 1992 to Southwest Fisheries Science Center in La Jolla from a one-year posting to the South Pacific Commission (SPC) in Noumea, New Caledonia. The posting, a collaborative arrangement between NMFS and the SPC's Tuna and Billfish Assessment Programme, was based on mutual interest in monitoring the status of tuna stocks in the central and western Pacific Ocean. The Tuna and Billfish Assessment Programme has been conducting tuna-tagging operations throughout that region, and Kleiber's principal objective during his stay was to use a subset of the tag-return data to develop a skipjack population dynamics-and-movement model for the Solomon Islands, for use in addressing concerns about fishery development and fishery interaction in the region. In particular, there are questions about the effectiveness of deploying more floating aggregation devices (FADs) in the Solomon Islands to further develop a local purse-seine fleet and there are concerns about the possible effects such development has had, and will have, on a previously established pole-and-line fleet.

Working in collaboration with SPC Fishery Scientist John Hampton, Kleiber developed a model which incorporates natural mortality and fishing mortality by purse-seine and pole-and-line fleets.

In addition, it deals with skipjack movement, which is affected by the presence of FADs and also by the presence of islands.

In fitting the model to the tag data, it appeared that some signal from the FADs is inherent in the tag data and that the model is sensitive to it and captures at least some of that signal. Although modification of individual tuna movement behavior by FADs has been observed with sonic tracking, this is the first time it has been documented with ordinary tag release and recovery data.

As a follow up to that work, Kleiber has been refitting the model under different conditions to help confirm first examination conclusions that the data indicate movements associated with the presence of FADs around the Solomon Islands.

During his stay at SPC, Kleiber also established a computer connection between SPC and the La Jolla laboratory using the Pacific-wide Peacesat system which makes use of National Oceanic and Atmospheric Administration's GOES 3 satellite. This linkage should be helpful in further collaboration between National Marine Fisheries Service and the Tuna and Billfish Assessment Programme, both for continued development of the above model and for other projects of mutual interest. (P. Kleiber [619] 546-7076)

Pacific Billfish Programs

1991 Billfish Angler Survey Results

During 1992, the Southwest Fisheries Science Center (SWFSC) conducted the annual Billfish Angler Survey for 1991. The objective of the year-long survey program, now in its 23rd year of operation, is to collect angler catch-and-effort data to determine the trend of fishing in terms of catch rates for the recreational segment of a Pacific-wide resource. The survey analysis is under way, and the results will be reported in the 1993 "Billfish Newsletter," which will be out in the summer of 1993.

Preliminary figures available from tag cards returned to the SWFSC by fishermen show that anglers tagged and released 164 striped marlin off southern California in 1992, a dramatic increase from the 60 billfish tagged in 1991. Pacific wide, 789 billfish were reported tagged and released in 1992, compared to 999 the year before. (N. Bartoo [619] 546-7073)

Pro-Am and Hawaiian International Billfish Tournaments Held

A record number of blue marlin were tagged and released during the Pro Am and Hawaiian International Billfish tournaments conducted off Kailua-Kona, Hawaii, in early August 1992. Seventy-six fishing teams from throughout the world tagged and released 128 billfish using NMFS tags. Blue marlin accounted for 122 of the billfish. Five striped marlin and two shortbilled spearfish were tagged. Additional blue marlin were tagged by anglers using Australian tags (five) and Billfish Foundation tags (two). A total of 135 billfish was tagged.

Estimated fish weights on the tag cards were totaled, indicating that over 9.7 tons of billfish had been tagged and released during the two tournaments. Blue marlin comprised 9.6 tons of the 9.7 tons tagged and released.

Three days after a blue marlin had been tagged off Kailua-Kona by a Hawaiian International Billfish Tournament contestant from Tahiti, the tagged blue marlin was recovered off Keauhou Bay, a few miles south of Kailua-Kona, Hawaii. (N. Bartoo [619] 546-7073)

Hawaii Longliners Tag and Release Billfish

Since the start of 1991, as part of the Cooperative Marine Gamefish Tagging Program (CMGTP), Hawaii's commercial longline fishermen have tagged and released 119 swordfish, 7 other species of billfish, and 13 bigeye tuna. The Hawaii longline vessels involved in tagging generally target swordfish and tag small (10-40 lb) fish with little market value. They may also tag a few tuna near the beginning of long trips since tuna do not keep as well as swordfish. Due to the northward expansion of the Hawaii swordfish fishery, bluefin tuna are caught by this fishery.

Tags are provided by the CMGTP at NMFS' La Jolla Laboratory and distributed to Hawaii longline fishermen by Biological Technician Robert Dollar of NMFS' Honolulu Laboratory. Those fishermen recovering tags are rewarded with baseball-type caps which carry the CMGTP logo. The Honolulu Laboratory has also been tagging and releasing longline-caught fish on research cruises since 1989, using either CMGTP tags or special tags marked "$REWARD FOR FISH HEAD" to tag billfish that have been injected with oxytetracycline for growth studies. Recovery of these special tags is rewarded by cash payment up to $100. A total of 102 fish has been tagged with the special cash-reward tags.

The number of fish tagged and released from longline gear in Hawaii (commercial and research cruises combined) totals 339, including 142 swordfish, 41 striped marlin, 27 blue marlin, 16 spearfish, 56 bigeye tuna, and 16 yellowfin tuna. Six opahs (moonfish) were the most unusual fish tagged so far.

To date, of 339 fish tagged and released from longline gear in Hawaii, two bigeye tuna and a striped marlin have been recovered. The low overall recovery rate may imply a high rate of tagging mortality, problems with the reporting of tag recaptures, or a high fish turnover rate in the Hawaii area. These fish were released during research cruises in 1989 and 1990—research suggests that bigeye tuna and striped marlin are most likely to survive being caught and released. But there is evidence of underreporting of tag recaptures. Several tags that escaped the attention of fishermen were recovered by Honolulu Lab staff at the United Fishing Agency fish auction in Honolulu. Some species such as swordfish are sold mainly through market channels other than the Honolulu auction. This fact, and reduced auction sampling by the Honolulu Lab staff, may lead to fewer tag recoveries.

Commercial longline fishermen have been helpful in recovering fish tagged by troll fishermen. Hawaii longline fishery recaptures accounted for 50 percent of the striped marlin tag recoveries reported to the Southwest Fisheries Science Center in 1991. Eight striped marlin and one blue marlin were recovered by the Hawaii longline fishery in 1990-92. Two of the recoveries were striped marlin tagged off southern California, and the rest were marlin tagged off Hawaii. Another long-distance recovery was a skipjack tuna tagged and released over 2,000 miles away in the Solomon Sea and recovered southwest of Hawaii 16 months later by a Hawaii longline vessel.

Troll fishermen in Hawaii have also been increasingly active in the tagging program. The Hawaii troll fishery accounted for 33 percent of the striped marlin and 81 percent of the blue marlin reported tagged in the Pacific by the CMGTP in 1991. Together, Hawaii's trollers and longliners accounted for 10 of the 15 CMGTP Pacific billfish recaptures reported in 1991. Hawaii trollers have tagged over 1,000 blue marlin since 1980, including about 400 in 1991-92. (C. Boggs [808] 943-1222)

Striped Marlin Tracked in Cabo San Lucas, Mexico

Fishery Biologist Dave Holts traveled to La Paz, Mexico, in September, 1992, to conduct cooperative U.S.-Mexican research, tagging striped marlin with sonic transmitters to track their horizontal and vertical movements. Mexican colleagues included Arturo Muhlia of Centro de Investigaciones Biologias (CIB) and several scientists from Centro Interdisciplinario de Ciencias Marinas (CICIMAR), La Paz, Mexico, who participated in the planning and operation of the study. The objective was to document striped marlin movements, sea temperature preferences, and daily cycles in an area of relatively high abundance. This information can provide insights into the marlin's vulnerability to various types of commercial and recreational fisheries since, from previous tracking studies, it is known that the striped marlin's behavior patterns vary in different areas of their range.

CIB's 9-m work boat *Barko CIB* was converted into a tracking vessel with hydrophones, acoustic receivers, data recorders, GPS navigation system, bathythermograph recording equipment, and a modest amount of sport fishing gear by which to capture marlin. The first three days were spent

fishing for striped marlin with no success except for a few dorado and sailfish not suitable for tracking.

On the fourth day of fishing, an 80-kg striped marlin was caught, tagged, and released. The scientists monitored the activity of this marlin for approximately 20 nm for the next 24 hours.

In both experiments, striped marlin for the most part stayed above the thermocline as they moved in a general direction away from land and into the open ocean environment. The investigators felt the experiments were a success because several associate researchers gained experience in the tracking technique and data collection procedures. Problems with the vessel's equipment and tracking equipment encountered on a previous March 1992 cruise were easily resolved on the September experiment, and many new techniques were refined, including fish-handling methods and procedures for attaching transmitters to large, active fish. (D. Holts [619] 546-7186)

IV. EASTERN TROPICAL PACIFIC TUNA-DOLPHIN RESEARCH

Strategic Plan Prepared to Develop and Evaluate "Dolphin-safe" Methods

The 1988 Amendments to the Marine Mammal Protection Act (MMPA) stipulated identification of appropriate research into promising new methods of locating and catching yellowfin tuna without endangering dolphins. To meet the amendment requirements, "dolphin-safe" research proposals were compiled by Southwest Fisheries Science Center (SWFSC) scientists Douglas DeMaster, former chief of the Marine Mammal Division, and Elizabeth Edwards, program leader of the Dolphin-safe Technologies Program, and John Young, of the Southwest Regional Office in May 1992.

The comprehensive strategic plan, developed for 1992 and beyond, was based on the advice and comments of a panel of experts that met March 5-6, 1992, at the SWFSC to review the earlier proposals. The final plan stressed the necessity for research to improve understanding of the behavioral association between dolphins and yellowfin tuna in the eastern tropical Pacific (ETP) and to develop new methods for locating and catching yellowfin tuna without the incidental taking of dolphins (detailed in SWFSC Administrative Report LJ-92-16).

In summary, NMFS proposed four specific studies, which were initiated in 1992: an investigation of the feasibility of locating tuna not visibly associated with dolphins or other surface cues utilizing an airborne light detecting and ranging device (LIDAR), and three joint studies with the Inter-American Tropical Tuna Commission (IATTC): a simultaneous tracking study of dolphin and tuna; an evaluation of the potential for using environmental predictors of yellowfin tuna abundance, catchability, and distribution; and a study of food habits of tunas and dolphins. The feasibility and the simultaneous tracking studies were carried out in 1992. Reports will be available in 1993. The evaluation of the use of environmental predictors and the study of food habits are ongoing, and reports are expected to be completed in 1994. It should be emphasized that most of the proposed research is directed at developing alternative methods of fishing rather than improving existing methods of fishing.

The NMFS and the IATTC will continue the following dolphin-safe joint research projects in 1993: (1) a new technological innovations workshop sponsored by IATTC and NMFS; (2) development and, if possible, deployment during 1993 of a cooperative research project between NMFS and IATTC to investigate improvements in FAD technology; (3) further testing of LIDAR technology; (4) support of FAD projects proposed by U.S. tuna skippers; and (5) evaluation of innovative planning procedures specifically applicable to problems in conservation of noncommercial populations interacting with commercial exploitation of related populations. 1993 projects were developed by Edwards, Research Analyst Chuck Oliver, and Fisheries Biologist Wes Armstrong. (L. Edwards [619] 546-7099)

Dolphin-safe Program Research Project Completed

On December 5, 1992, field work for the first joint NMFS/IATTC Dolphin-safe Research Project in the eastern tropical Pacific (ETP) Ocean was completed. NOAA research vessel *McArthur* and the commercial tuna purse-seiner *Nicole K.* returned from a combined research effort directed toward developing a better understanding of the tuna-dolphin associations characteristic of this area. The primary goal of the research program was to collect information that will aid in developing methods of catching large yellowfin tuna in the ETP without endangering the dolphins that often occur in association with these fish. Michael Scott of the Inter-American Tropical Tuna Commission (IATTC) served as scientific director and chief

scientist for the cruise conducted by the Southwest Fisheries Science Center (SWFSC) and IATTC.

Because the nature of the tuna-dolphin bond is still unclear despite the many years of research devoted to both tunas and dolphins in the ETP, the IATTC, in cooperation with the SWFSC and the University of Hawaii, conducted the field research to study the tuna-dolphin relationship by attempting to simultaneously radio track spotted dolphins and sonic track yellowfin tuna from the same aggregation. Study of tuna and dolphin movements and interaction, in conjunction with food-habit studies conducted by the IATTC and NMFS, were proposed to help establish the longevity and dynamics of the tuna-dolphin bond and the degree that it is food-based. They hoped to learn whether the bond loosens or breaks at particular times or under certain conditions and whether the tuna would be vulnerable to fishing at such times.

During this preliminary study, between November 6 and December 5, 1992, the scientists attempted to capture spotted dolphins and tunas from the same aggregation, attach transmitters to as many individuals of each species as practical, release them, and monitor their movements. Two types of transmitters were used: one type provided location information while the other transmitted the ambient pressure to monitor the animal's swimming depth in addition to location. Time-depth recorders (TDRs) were attached to some of the dolphin transmitter packages. These devices recorded the depth of the package every 10 seconds, which could then be compared with the vertical movements of tuna tagged with depth-sensitive transmitters. Two areas were targeted where the seas were likely to be the calmest during November: the area within 250 miles of the coast of Costa Rica and Panama and the area between 90–100° W and 10–12° N.

Eleven sets were made on spotted dolphins. Dolphins were tagged during five sets, and tuna were tagged during two sets. Six dolphins were tracked during the study. The radio-tracking system worked well, with reception ranging in distances up to 13 miles from *McArthur* and *Nicole K.* and greater than 5 miles from the launches.

None of the tagged tuna was tracked, generally due to difficulties in releasing the tuna from the net, but the tracking of dolphins was successful and it provided data on the movements and diving times of six spotted dolphins. The capability for making repetitive sets on the same dolphins and observing them from the helicopter provided data on the recruitment of tuna to the dolphins, and it allowed the scientists to monitor changes in herd size and composition of the dolphins.

Tracking the dolphins also provided an opportunity to recover TDRs, which provided a preserved history of the dolphin's diving behavior. The data can be interpreted to determine the times and depths that dolphins feed and their preferred swimming depths, particularly in relation to the thermocline. It can also be potentially useful for calibrating herd size and abundance estimates by calculating the percentage of time that a dolphin would be visible at or near the surface.

A SEACAT mini-CTD (for measuring depth, temperature, and salinity) or an expendable bathymetric thermometer was deployed from *McArthur* approximately every 4 hours. Observations of bird flocking behavior were also made from *McArthur* to study the association of seabirds with dolphins and tunas and to study daily variation in flock size.

During this study, the scientists discovered that they could capture, tag, and track dolphins effectively; the tracking launches could closely approach the dolphins without disrupting their behavior; and they could recapture individual dolphins to recover TDRs. They found that the tuna could be tagged by swimmers in the backdown channel, and if sufficient numbers of tuna were present, they could be backed out of the net with the dolphins.

In future studies, the scientists will refine their methods for tagging the tuna and releasing them from the net nearly simultaneously with the dolphins, thus allowing them to successfully track both species. They found that at least 10-15 tons of tuna should be in the net to successfully tag and release tuna. Larger schools came closer to the surface, particularly as the net constricted, making

it easier to tag the tuna. Larger schools were also easier to back out of the net. (L. Edwards [619] 546-7099; M. Scott, IATTC, [619] 546-7045)

Dolphin Mortality in U.S. Tuna Fishery Continues to Decline in 1991 and 1992

In 1991, for the third consecutive year, there was 100 percent observer coverage on all eastern tropical Pacific (ETP) U.S. tuna purse-seine vessels with fishing permits. The following represents the observed incidental kill of small cetaceans on 40 U.S. tuna purse-seine vessel trips.

The species most frequently killed as a result of tuna purse-seine fishing operations were the pantropical spotted dolphin, spinner dolphin, and common dolphin. The estimated number of dolphins killed in the U.S. eastern tropical Pacific tuna purse-seine fishery in 1991 was 1,004, down 80 percent from the estimated 1990 kill of 5,083, according to data collected by on-board observers from the National Marine Fisheries Service. The 1991 dolphin kill was well below the annual quota of 20,500 and was the lowest on record for the U.S. fleet.

The major reasons for the marked decrease in dolphin kill in 1991 were the continued reduction in the size of the U.S. fleet in the eastern Pacific, reduced fishing on dolphin-associated schools, and improved performance. The first two are consequences of the U.S. tuna canners' decision in April 1990 to purchase only dolphin-safe tuna.

In 1990 there were 28 U.S. purse seiners active in the eastern tropical Pacific, of which 26 made sets on dolphins. In 1991 the active fleet declined to 13 vessels, of which only 9 made sets on dolphins. In both years, 1990 and 1991, the observer coverage rates were virtually 100 percent. Ninety-two fishing trips and 1,845 dolphin sets were observed in 1990. In 1991, 47 trips and 430 dolphin sets were observed. The dolphin kill-per-set rate in 1991 was 2.3, down 18 percent from the 1990 rate of 2.8. It was the lowest annual rate ever achieved by the U.S. fleet.

Based on preliminary data covering the first eight months of 1992, the dolphin kill and kill-per-set rates continued to fall: 281 dolphins killed in 432 sets for a kill-per-set rate of 0.7. Of the seven U.S. purse seiners that were active in the eastern tropical Pacific and permitted to set on dolphins, only five actually made dolphin sets during this period. (J. Barlow [619] 546-7178 and A. Jackson [619] 546-4078)

Estimates Made of ETP Dolphin Abundance from 1986-1990 Surveys

Large-scale research vessel surveys were conducted annually from 1986 through 1990 by the U.S. NMFS to monitor the abundance of dolphin populations in the eastern tropical Pacific Ocean (ETP).

The work relates to information needed on certain dolphin stocks that are killed during tuna purse-seining operations in the ETP. The major populations affected by the fishery are the offshore stock of spotted dolphins and the eastern stock of spinner dolphins. Scientists utilized two research vessels annually from 1986 to 1990 for 120 days each, traversing randomly placed predetermined tracklines in the ETP, for a total of five surveys. A stratified analysis incorporating line-transect methods was used. Sightings of all cetaceans were recorded, leading to the identification of 30 species. Data from all five surveys were pooled to give single estimates of abundance in the ETP for 25 stocks of cetaceans representing 19 species or genera.

When a school was initially detected, the observers estimated the angle and radial distance to the school. When possible, schools were approached to confirm species identification and to make estimates of school size. Abundance estimates of ETP cetaceans based on identified sightings of the stock (in rounded numbers) totaled 9,080. For a complete breakdown, see Southwest Fisheries Science Center's *Report of Activities* dated May-June 1992. (T. Gerrodette [619] 546-7131 and P. Wade [619] 546-4097)

Table 1. Abundance estimates (in thousands) for eastern tropical Pacific cetaceans. N_j is the estimate based only on identified sightings of the stock. N_j*(int) represents intermediate prorated abundance estimates from three categories of sightings not identified as to stock level involving six stocks. N_j* represents final abundance estimates, some of which were prorated from unidentified categories. (Note that the abundance estimates for species in the Globicephalinae and *Kogia simus* did not involve any prorating). CV represents the coefficient of variation for N_j*. N_j*$_U$ and N_j*$_L$ represent, respectively, the upper and lower 95 percent bootstrap confidence limits calculated using the percentile method. (Numbers have been rounded up to one decimal place.)

	N_j	N_j*(int)	N_j*	CV	N_j*$_U$	N_j*$_L$
Delphininae						
Stenella attenuata						
Northeastern spotted	668.9	674.4	738.1	0.2	989.6	574.8
West/south spotted	1258.9	-	1299.3	0.2	2121.4	910.1
Coastal spotted	25.6	27.2	29.9	0.6	87.0	16.2
Stenella coeruleoalba						
Northern striped	118.3	-	128.1	0.3	224.5	82.6
Southern striped	1612.5	-	1694.3	0.1	2129.6	1325.0
Stenella longirostris						
Eastern spinner	568.1	583.5	632.7	0.2	778.9	403.2
Whitebelly spinner	988.8	992.4	1020.1	0.2	1411.5	701.7
Delphinus delphis						
Northern common	433.6	-	477.0	0.5	903.7	106.7
Central common	379.2	-	415.6	0.5	840.7	170.0
Southern common	2127.7	-	2211.5	0.3	4310.4	1001.6
Lagenodelphis hosei	281.5	-	289.5	0.4	581.5	141.3
Tursiops truncatus	226.2	-	243.8	0.3	479.6	205.6
Grampus griseus	179.3	-	192.4	0.3	324.9	95.8
Steninae						
Steno bredanensis	141.4	-	151.1	0.3	256.6	103.6
Globicephalinae						
Globicephala spp.	-	-	160.2	0.2	207.2	106.2
Peponocephala electra	-	-	45.4	0.7	160.5	30.5
Feresa attenuata	-	-	38.9	0.3	67.8	20.4
Pseudorca crassidens	-	-	39.8	1.3	188.5	10.0
Orcinus orca	-	-	8.5	0.3	15.3	5.6
Ziphiidae						
Ziphius cavirostris	16.1	-	19.9	0.2	13.6	28.3
Mesoplodon spp.	20.3	-	25.3	0.3	13.9	42.7
Physeteridea						
Physeter macrocephalus	22.0	-	23.2	0.3	15.6	37.2
Kogia simus	-	-	11.2	0.3	19.8	8.1
Balaenopteridae						
Balaenoptera musculus	1.1	1.4	1.5	0.3	1.0	2.8
Balaenoptera edeni	9.6	11.8	12.8	0.3	9.1	25.3

1992 Common Dolphin Survey Completed

On November 2, 1992, two NOAA research vessels, *David Starr Jordan* and *McArthur*, completed a 3-month survey of the area inhabited by the central stock of common dolphin. During this year's Population of *Delphinus* Stocks (PODS) survey, Southwest Fisheries Science Center (SWFSC) scientists collected information on the density, size, and species composition of marine mammal schools encountered in the eastern tropical Pacific (ETP) Ocean. The primary purpose of the cruise was to collect data to estimate the population size of the central stock of common dolphins. Data from observers on tuna vessels have indicated that this stock of dolphins may have been reduced as a result of incidental mortality in tuna purse seines. Marine mammal surveys conducted in past years have permitted only imprecise estimates of population size for this stock.

The ships covered approximately a 650,000-nm^2 study area off Central America where common dolphins have been seen in the past. The primary grid of northeast/southwest transects was completed, and the secondary grid of northwest/southeast transects was nearly completed. A total of 11,023 nm of trackline was covered with full survey effort in the study area.

Overall, there were 1,326 sightings of cetaceans among 37 different species or species groups. Of these, a total of 945 dolphin schools was seen, including 46 long-beaked and 101 short-beaked common dolphin schools. The data will be analyzed by line-transect methods to produce estimates of abundance for common dolphins and other species.

SWFSC scientists collected data, including photographs, that will aid in defining marine mammal stock boundaries. The photographs will contribute to a growing catalog of individually known blue and humpback whales along the Pacific coast. Resightings of known animals can produce the same kinds of information on movement, mortality rates, birth rates, and population size that resightings of numbered tags do. (T. Gerrodette [619] 546-7131)

Data were also collected on dolphin habitat in the ETP study area and on associated pelagic species such as birds, turtles, and fish eggs and larvae. Oceanographic data collected (surface temperature and salinity, water samples) will be used in an analysis of habitat variability to help interpret the dolphin abundance estimates and to describe spatial patterns of oceanographic processes in an undersampled region of the ETP.

Eighty turtles were captured, measured, and returned to the ocean. Blood samples were obtained from 55 of these turtles, and 77 were tagged. The Inter-American Tropical Tuna Commission conducted larval tuna sampling in the Panama Bight. Nighttime dipnet stations for surface nekton and Manta tows for fish eggs and larvae were conducted; the flying fish taxonomy of the tropical Pacific is under revision as a result of this continuing effort. The SWFSC also has a unique set of surface samples covering an immense area in the ETP. Seabirds were also observed. (P. Fiedler [619] 546-7016)

SWFSC scientists on the PODs cruise collected skin biopsy samples from 111 dolphins to aid in defining stock structure and boundaries. The tissues will be analyzed for genetic differences using the polymerase chain reaction procedure, in which the DNA segment desired for analysis is isolated and amplified to high concentrations. The amplified segment is analyzed to determine the sequence of nucleotide bases that constitutes the genetic signature of the particular animal. The animals' sequences are then analyzed using computer programs that determine the degree of relatedness between individuals. Besides revealing existence of reproductively isolated populations (stocks) and evolutionary lineages, recently developed methodologies allow estimation of gene flow between lineages and average dispersal distances per generation. (A. Dizon [619] 546-7089)

Aerial photogrammetry was conducted using a new set of reconnaissance cameras that are much more reliable and that provide exceptionally high resolution. The aerial photographs allow estimates of school size made by observers aboard both vessels to be calibrated against counts from aerial photographs. This allows correction for ten-

dencies to over- or underestimate school size, thus providing more accurate estimates of dolphin population size. Lengths of dolphins and whales can also be accurately determined because photographs are taken vertically and with such high resolution. Measurements from the aerial photographs will be used to identify possible differences in average body size among this year's focused stock, the common dolphin. In a cooperative study with Mexican scientists, aerial photographs were taken of California sea lion rookeries along the Pacific coast of Baja California, Mexico. Pupping locations, number of pups, and population size can be determined from these photographs.

Shipboard photographs were also taken to document dolphin body morphology and color patterns, which are known to vary from on- to offshore. (W. Perryman [619] 5456-7014)

V. CALIFORNIA LARGE PELAGICS AND RELATED MARINE MAMMAL RESEARCH

California Drift-gillnet Fishery

California's drift-gillnet fishery developed rapidly in the late 1970s off southern California. The fishery originally targeted thresher sharks (common, bigeye, and pelagic) and the short-finned mako shark. Almost immediately, however, swordfish became an important component of the catch. Albacore and, to a lesser extent, skipjack and yellowfin tuna are a bycatch of the fishery.

Data on California Drift-gillnet Fishery for Sharks and Swordfish Summarized for 1981-82 Through 1990-91

Fishery Biologist Dave Holts and Mathematician Al Coan of the Southwest Fisheries Science Center's La Jolla Laboratory, together with Doyle Hanan of the California Department of Fish and Game, examined and summarized data obtained from the California logbook system, landing receipts, and market samples taken from the California drift-gillnet fishery over the 10 fishing seasons from 1981-82 through 1990-91. During this period, the fishery evolved from a small nearshore experiment to a major California fishery. Major changes in nearly every aspect of the fishery occurred, including boats and gear, techniques and regulations, fishing areas and seasons, and targeted species. These data form a baseline from which changes in the fishery and harvested stocks can be compared in the future.

The drift-gillnet fishery operates primarily in the area between San Diego and Cape Mendocino and concentrates much of its effort on swordfish in the southern California Bight from May to December. Since the 1981-82 fishing season, fishing effort decreased 50 to 60 percent, from highs of 9,000 to 11,000 sets in the 1982-83 to 1986-87 fishing seasons to a low of 4,000 sets in the 1990-91 season. This decrease in effort corresponded to a decrease in total landings of approximately the same proportions. Decreases in landings of thresher sharks led at over 80 percent, while swordfish and mako shark landings decreased 60 percent and 40 percent, respectively. Average sizes of swordfish showed no increasing or decreasing trend during the 1981-82 to 1990-91 fishing seasons. Average sizes of mako sharks showed a decrease of approximately 40 percent from the 1982-83 through the 1985-86 fishing season but rebounded during the 1989-90 season to less than 15 percent of the 1982-83 season. Average sizes of thresher sharks, however, decreased 30 percent from the 1982-83 season and have remained low.

A number of problems and conflicts occurred during the first 10 years of the fishery (for example, sea lion, gray whale, and marlin bycatch) that were resolved, for the most part, through the cooperative efforts of the commercial industry, the sport industry, environmental groups, and the state and federal government. The incidental catch of marine mammals is apparently low and not compromising any stocks although the potential remains; therefore, monitoring is prudent. Bycatch of other fish does not appear to be a problem except for the catch of blue sharks, which has an unknown affect on local populations. (D. Holts [619] 546-7186)

Large Pelagics Tagged

During the first week of September 1992, Laura Halko, biological technician, and Dave Holts, fishery biologist, of the Southwest Fisheries Science Center in La Jolla, participated in a 3-day cooperative tagging cruise aboard the research vessel *Point Sur*, offshore San Francisco, south of the Farallon Islands. The joint cruise was conducted by the Monterey Bay Aquarium Research Institute (MBARI), using newly acquired longline gear, to capture selected pelagic fish for aquatic exhibits.

One goal of the cruise was the sharing of ideas concerning the configuration and deployment of the gear, including the retrieval of healthy specimens. The second goal was to tag and release the expected by-catch of swordfish and a variety of sharks if retrieved alive and to do biological work-ups if not alive.

Two longline sets were conducted. The first set was impaired when several floats malfunctioned allowing the longline to sink well below the desired fishing depth. These floats were replaced with bumper buoys for the second set and the longline fishery gear worked as planned. In all, 12 blue sharks were tagged and released and 6 others were measured and weighed. One grenadier and one "king of the salmon" were collected by MBARI. Additionally, aquarium staff conducted six mid-water and two shallow-water trawls, which yielded copious amounts of vertebrates and invertebrates for their ongoing research as well as for display. (D. Holts [619] 546-7186)

Pinniped and Cetacean Mortality in California Gillnet Fisheries

The number of marine mammals killed in California gillnet fisheries in the eastern tropical Pacific was estimated for the period January-December 1991, based on 10-percent coverage by observers placed aboard commercial fishing vessels. Nontarget species observed as being killed by the gillnets include cetaceans (common, northern right whale, Pacific white-sided, and Risso's dolphins; porpoise; and one unidentified cetacean), pinnipeds (California sea lions, harbor seals, and elephant seals), sea otters, and several species of seabirds and turtles.

Mortality in California Gillnet Fisheries Modeled and Estimated for 1991

A log-linear model, developed by Coastal Marine Mammal Program Leader Jay Barlow, was used to explore factors that may be correlated with entanglement, and it attempted to identify any potentially useful predictors of mortality. The model indicated that entanglement rates are expected to be higher during times of pinniped migration to and from breeding grounds and that, of the two target species considered, pinnipeds may actually be attracted to the gillnets to forage on entangled California halibut. Geographic area, season, and selected fish catches are significantly associated with mortality of California sea lions and harbor seals in the halibut and angel shark setnet fisheries. The type of observation (randomly selected versus systematically selected) may also affect apparent mortality rates. Water depth is significant for sea lions only. For the shark and swordfish driftnet fishery, only fish catch is significantly associated with marine mammal mortality. The estimated mortality (and standard errors in parentheses) for the setnet fisheries is 1,858 (346) California sea lions, 559 (126) harbor seals, 26 (15.2) northern elephant seals, and 38 (18.3) harbor porpoise.

The estimated mortality (and standard errors in parentheses) for the driftnet fishery is 34 (22.3) California sea lions, 110 (31.7) northern elephant seals, 373 (88.0) common dolphins, 59 (27.5) northern right whale dolphins, 42 (30.2) Pacific white-sided dolphins, 42 (24.0) Risso's dolphins, and 17 (12.8) Dall's porpoise. Standard errors for the above mortality estimates are estimated based on the assumption that fishing effort is known without error. Comparisons of different measures of fishing efforts are made for the purpose of estimating total mortality. (J. Barlow [619] 546-7178)

Report Completed on Mexican Sportfish Economic Survey

Cynthia Thomson, industry economist at Southwest Fisheries Science Center's (SWFSC) La Jolla Laboratory, and Santiago Gomez of the Mexican Department of Fisheries have completed a 278-page report entitled "Results of the Mexican Sportfish Economic Survey" (NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-173). The report describes results of the first comprehensive survey of U.S. anglers who fished in Mexican territorial waters in the Pacific Ocean and Gulf of California (Sea of Cortez) during 1991. The purpose of the survey was to obtain baseline information on boat-based fishing activity, harvest by species, fishing expenditures, angler demograph-

ics, and fishing patterns of angling households. The survey was conducted by the Government of Mexico, Department of Fisheries, San Diego, California, with technical assistance from the SWFSC, La Jolla, California.

The survey showed that 44,673 U.S. anglers fished from boats in Mexican waters during 1991 and made over 146,577 angler trips. About 820,912 fish were caught in Mexican waters in 1991 by boat-based U.S. anglers. Cabrilla, rockfish, yellowfin and other tunas, bonita/barracuda/bass, dorado, and yellowtail together accounted for over 80 percent of total harvest. Marlin and sailfish comprised only one percent of the total harvest in number from all boat modes in Mexican waters. About 35 percent of all fish caught were released. Fishing trip expenditures totaled $79 million. (C. Thomson [619] 546-7116)

VI. INDIAN OCEAN FISHERIES

Data for the Seychelles Purse-seine Fishery Updated

The number of vessels participating in the western Indian Ocean purse-seine fishery in the first quarter of 1992 averaged 53 (17 French, 17 Spanish, 3 Mauritian, 1 Panamanian, 3 Russian, 9 Japanese, 1 Iranian, and 2 Seychelles), a significant increase when compared to the average of 41 vessels recorded for the same period the previous year.

First quarter 1992 catch rates averaged 14 metric tons (t)/day, significantly lower than the 22 t/day recorded for the same period in 1991. Catch rates for the first quarter of 1992 were down 65 percent for yellowfin (6 t/day) and up 40 percent for skipjack (7 t/day) from those of the same period in 1991.

Total catch of yellowfin and skipjack tuna for the first quarter of 1992 was 40,834 t, 32 percent lower than for the same period in 1991, primarily due to the lower catch rates and the large number of trips for which logbooks had not yet been collected.

A species breakdown for the first quarter of 1992 showed 47 percent yellowfin, 52 percent skipjack, and 1 percent other tuna, compared to 78 percent yellowfin, 21 percent skipjack, and 1 percent other tuna during the same period in 1991. The change was due to the effect of a strong El Niño-like condition in the Indian Ocean and the increased tendency of the Seychelles fleet to concentrate fishing effort around floating aggregation devices.

Seychelles Fishing Authority data for the first quarter of 1992 have been updated and summarized in LOTUS spreadsheets by Biological Technician Gary Rensink of the Southwest Fisheries Science Center. (G. Rensink [619] 546-7192)

VII. OTHER TUNA-RELATED RESEARCH AT SWFSC

Computer Simulations of Fish Populations

One of the important activities of the Pelagic Ecosystem Model Development Program at Southwest Fisheries Science Center's La Jolla Laboratory is to develop computer simulations of tuna populations based on mathematical models that can include mortality, drift velocity, and diffusivity. The problem is that the more realistic the model becomes, the harder it is to simulate it. Operations Research Analyst Carlos A. M. Salvadó, however, has developed a numerical technique that simplifies simulations of populations in complex environments (for example, the skipjack tuna fishery in the eastern tropical Atlantic).

The approach taken by Salvadó employs the method of Green functions, which provides a measure of the probability of tuna movement from one location to another. In a further development using this method, Salvadó has developed a technique that allows the simulation of realistic models of the dynamics of populations that move, including the presence of complex geographic boundaries. In addition, he has derived an expression in closed form for the transition probability densities of the exchange of tuna between the discrete zones of the population domain. Simulations are therefore considerably simplified. (C. Salvadó [619] 7052)

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