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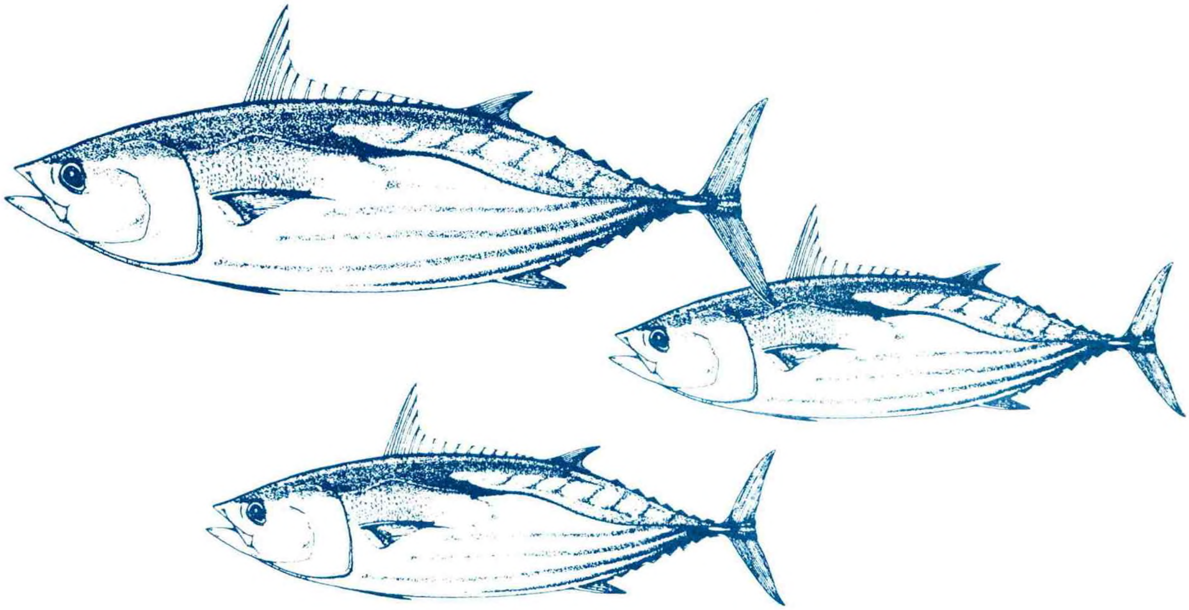

Director's Report to the 43rd Tuna Conference

On Tuna & Tuna-Related Activities at the Southwest Fisheries Science Center for the Period May 1, 1991 to April 30, 1992

ADMINISTRATIVE REPORT LJ-92-10

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I. EXECUTIVE SUMMARY

This report describes tuna-related research at the Southwest Fisheries Science Center (SWFSC) over the past year at the La Jolla Laboratory in La Jolla, California, at the Honolulu Laboratory in Honolulu, Hawaii, and at the Pacific Fisheries Environmental Group in Monterey, California. It is an informal summary rather than a comprehensive account, describing activities and events that have taken place since May 1991. Highlights of the previous year are provided in this executive summary.

Over the past year, the Center continued to provide quality scientific information needed for managing fisheries for tunas and other large pelagic fishes and fishery-associated species of concern, such as marine mammals. The Center focused particularly on meeting the needs of NMFS' Driftnet Research Program, international working groups, regional councils, and NMFS headquarters management. Issues of note concerned high seas driftnetting, new jurisdictional mandates for managing tuna under the 1990 revision of the Magnuson Act (MFCMA), and information needed for the 1992 reauthorization of the Marine Mammal Protection (MMPA) and Endangered Species acts (ESA). The Center also published status of stocks reports on large pelagic fishes and fisheries-associated marine mammals in the regional report "Status of Pacific Oceanic Living Marine Resources of Interest to the USA for 1991" and in NMFS' national report "Our Living Oceans." Excerpts from the regional report are provided in the Appendix.

Although the Pacific Fisheries Management Council (PFMC) has not yet developed a fisheries management plan (FMP) for West Coast oceanic pelagic fisheries, a preliminary FMP does exist to address potential foreign fisheries issues, and the SWFSC is prepared to provide the PFMC with help in developing the Pelagics FMP, especially with regard to coastal sharks. The Center staff also supports the Western Pacific Regional Fisheries Management Council (WPRFMC) and the Joint Institute for Marine and Atmospheric Research in development of a new plan for tuna and billfish research and management. Christofer Boggs, Jerry Wetherall, Samuel Pooley, and Robert Skillman of the Honolulu Laboratory as well as Director Izadore Barrett and Gary Sakagawa of the La Jolla Laboratory participated in the Pacific Pelagic Fisheries Planning Workshop in Honolulu, Hawaii, March 25-27, 1992, to advise a steering committee on the research needs for pelagic fisheries management in the U.S. Exclusive Economic Zones (EEZ) of the central and western Pacific. Norm Bartoo of the La Jolla Laboratory also assisted NMFS headquarters in developing a research plan for highly migratory species within the context of new jurisdictional responsibilities of the 1990 revision of the MFCMA.

The Center staff has been very active in international forums concerning tuna issues over the past year. Last July, the SWFSC was well represented at the North Pacific Albacore Workshop in Shimizu, Japan, at the International North Pacific Fisheries Commission (INPFC) Driftnet Symposium in Tokyo in November, and in December at the U.N. Food and Agriculture Organization (FAO)-sponsored Consultation of Pacific Tuna Fisheries held in Noumea, New Caledonia. The SWFSC has also been organizing the first workshop of the Western Pacific Yellowfin Tuna Research Group to be held in June 1992. Elected chairperson for the group in 1992 is SWFSC Fishery Biologist Dr. Gary Sakagawa, Chief of La Jolla's Pelagic Division. This group of scientists and fishery representatives and spokespersons from 16 countries was created in 1991 to determine a safe level of yield and exploitation for central-western stocks of yellowfin tuna, the degree of interaction among different fisheries, and factors contributing to local depletion. Review papers will be presented on stock structure, age and growth, length-weight, and estimates of natural and fishing mortality for yellowfin tuna. Catch-and-effort data sets will be examined for suitability in computing abundance indices for the stock and its size/age components.

Staff from both the La Jolla and Honolulu laboratories continued research on the impacts of North Pacific high-seas driftnet fisheries on tuna stocks, as part of the NMFS' Driftnet Research Program. Physiological and behavioral research on tunas and billfish and genetic research on dolphin stock separation continue to proceed at a fast pace and are at the cutting edge in this type of research. Great strides were made just within this past year in developing methods to reliably differentiate, using the latest genetic technology, between major dolphin species and stocks affected by the eastern tropical Pacific (ETP) purse seine fishery. The Center also completed some innovative mathematical work that uses tag-recapture data to describe not only fish movements but also fish mortality rates and changes in catch rates in various segments of a fishery over space and time.

The following is a breakdown of some research highlights by category:

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 1991-92, work focused on gathering, compiling, and analyzing information on the status of Pacific albacore stocks and the effects of drift gillnetting on albacore and associated pelagic species. Tuna researchers with Gary Sakagawa's **Pelagic Fisheries Resources Division** (PFRD) in La Jolla and with Jerry Wetherall's **Pelagic Resources Investigation** (PRI) in Hawaii were occupied with work relating to NMFS' Driftnet Research Program as well as with special directed studies. The driftnet work is part of the intra-agency NMFS Driftnet Research Program conducted in support of NMFS policy and management activities in the Southwest Region and Washington, D.C., and other efforts by parties with concerns about the high-seas fisheries, including the U.S. albacore industry.

Staff from both the La Jolla and Honolulu laboratories attended the 12th North Pacific Albacore Workshop held July 23-25, 1991, at the National Research Institute of Far Seas Fisheries in Shimizu, Japan, where 34 scientists from Japan and the United States met to review recent data and research and to evaluate the condition of the North Pacific albacore stock. The Center staff presented seven working papers, including a stock assessment document on North Pacific albacore by David Au (presented by Norm Bartoo) and a summary of albacore catches and catch rates in Hawaii by Jerry Wetherall and Donald Hawn. The workshop is part of a continuing informal research agreement between the SWFSC, the Nanaimo Laboratory of the Canadian Department of Oceans and Fisheries, the National Research Institute of Far Seas Fisheries of Japan, and, since last September, the Institute of Oceanography of Taiwan. State researchers from Washington, Oregon, and California also attended this year's meeting. The purpose of the agreement is to foster international cooperation and information exchange on North Pacific albacore.

Within Sakagawa's **Pelagic Fisheries Resources Division** in La Jolla, Norm Bartoo, collaborating with Jerry Wetherall's staff in Hawaii, continues to assess the abundance of albacore and measure the impact of high-seas driftnet fishing on the U.S. fishery. Since 1990, the program has conducted an observer program with the help of the Western Fishboat Owners Association to document fishery interaction with gillnet scarring on albacore in the U.S. troll catch over a wide fishing area of the North Pacific Ocean. This is one of the few direct-evidence studies documenting the impact of high-seas driftnetting on albacore. In February 1992, the Center released a report on the driftnet damage rate during the 1991 U.S. troll season, which revealed a decline in driftnet-damaged albacore. Only 3.1% of the troll-caught fish showed gillnet marks, down from 12.1% noted in 1990. These results and other information on the North Pacific albacore stock condition and fishery outlook were presented to U.S. tuna industry representatives in February. The briefing reviewed the likely causes for the fishery decline, especially in relation to driftnetting. In June, the Center will release a report on the results of the 1991 U.S. albacore fishery in the Pacific Ocean, which will point out the build-up of effort in the South Pacific and a record low catch in the North Pacific.

Within Jerry Wetherall's **Pelagic Resources Investigation** at the Honolulu Laboratory, the staff is involved with estimating driftnet bycatch levels, based on data collected by observers deployed on the driftnet fleets and on-effort statistics provided by Japan, Korea, and Taiwan. This includes impacts on albacore, other tunas, billfishes, and other species. Preliminary results were presented at a meeting on driftnet impacts in Sidney, British Columbia, Canada, in June 1991. Final analysis awaits the compilation of data from the 1991 observer programs and delivery of corresponding effort statistics.

In December, at the U.N. Food and Agriculture Organization (FAO)-sponsored Consultation of Pacific Tuna Fisheries held in Noumea, New Caledonia, the SWFSC presented eight papers; one described biology and fisheries for albacore, another described U.S. distant-water and artisanal fisheries for yellowfin tuna in the central and western Pacific, another presented evidence of interaction between high-seas driftnet fisheries and the U.S. troll fishery for albacore, and five dealt with modeling methods for assessing fishery interactions. These papers are now undergoing FAO review.

The Center continues to provide statistical and research support to the South Pacific Commission (SPC) and South Pacific Albacore Research (SPAR) group on South Pacific albacore. Gary Sakagawa attended the SPAR workshop in Taiwan November 4-8, 1991, where he presented information on total albacore catch, sampled catch and logbook effort, and size and age composition of albacore landings from the U.S. troll fishery in the South Pacific during 1986-1991, which had been collected and summarized by Al Coan and Gary Rensink. Sakagawa also reported on a project conducted jointly by the Tuna and Billfish Assessment Program (TBAP), the SPC, and by Darlene Ramon of the La Jolla SWFSC. The project examined the spawning seasonality of albacore in the South Pacific and the relationship of maturity-to-length modes of fish being caught in surface fisheries; it was designed to provide a better understanding of reproductive biology of albacore in the South Pacific. As part of the U.S. commitment to SPAR, this research is being done in collaboration with foreign scientists, and ovaries for the research are provided by various sources. At the Honolulu Laboratory, Jerry Wetherall and Marian Yong continued to provide routine updates of South Pacific albacore longline CPUE indices based on logbook data submitted to NMFS voluntarily by captains of Korean and Taiwanese longliners based in Pago Pago, American Samoa. The indices are used to monitor trends in the spawning stock.

Norm Bartoo and Jerry Wetherall also attended the International North Pacific Fisheries Commission (INPFC) Conference in Tokyo in December 1991, which included a comprehensive 1-day symposium on driftnetting in the North Pacific and results of research. Bartoo presented results on the troll fishery observer program, gillnet drop-out studies, analyses of incidental catches, and troll-gillnet interaction studies. Wetherall presented bycatch information based on observer data from the high-seas driftnet fishery.

Work on impacts of West Coast gillnetting was also conducted during the year. Norm Bartoo and his staff within La Jolla's PFRD gathered, analyzed data, and provided expertise for assessing effects of coastal California gillnetting. A comprehensive report will be released in July 1992 on the California gillnet fisheries--both set net and driftnet. This report will include historical and contemporary data on target fishes as well as incidental species, including marine mammals, and information on areas fished and regulations.

Within John Hunter's **Coastal Fisheries Resources Division** (CFRD) at the La Jolla Laboratory, Oceanographers Mike Laurs and Ron Lynn completed a manuscript on North Pacific albacore ecology and oceanography, which will be published within NOAA's Technical Report series. The report 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. It includes information on the major fisheries for North Pacific albacore, stock structure, migrations, food habits, habitat definition, and relation of migration-and-catch distribution to mesoscale and large-scale oceanographic fronts.

At the **Pacific Fisheries Environmental Group** in Monterey, California, scientists continue work on environmental influences on albacore catches. Computer models at differing spatial resolutions have been developed, and their ability to forecast albacore catch-per-unit-effort is being evaluated. The biological part of the analyses has been completed, and the physical component has been enlarged to include data from the Committee on Earth Observing Systems (CEOS). The completion date has been set for September 1992.

Billfish

Richard Brill (PRI, Honolulu Laboratory) and David Holts (PFRD, La Jolla Laboratory) worked with other researchers in Hawaii this year on a collaborative tagging study using ultrasonic depth-sensitive transmitters to monitor the horizontal and vertical movements of striped marlin, expendable bathythermographs to determine depth-temperature profiles, and an acoustic Doppler current profiler to determine oceanic current patterns. Their data provide the first description of the movements of pelagic fish with simultaneously gathered oceanic current information. Movements of billfishes have been implicitly assumed to be uninfluenced by currents, but their data on striped marlin's horizontal movements and on the ocean currents clearly show that striped marlin movements are strongly influenced by current patterns and that some individuals spend most of their time simply drifting. Furthermore, their vertical movement data show that the depth distribution of striped marlin is limited, not by an absolute temperature, but rather by water that is 8°C colder than the upper mixed layer where these fish spend the majority of their time.

In another joint billfish tagging project, Dave Holts traveled to La Paz, Mexico, in February to collaborate with Mexican researchers in tracking the horizontal and vertical movements of striped marlin. This work is part of a special cooperative study conducted by SWFSC, the Centro Interdisciplinario de Ciencias Marinas and Centro de Investigaciones Biologicas de Baja California Sur. Though they had some technical difficulties, useful data were obtained on one fish, and plans are for Holts and Dr. Arturo Muhlia to conduct another joint tagging study this summer.

This year Christofer Boggs (PRI, Honolulu) published a paper on billfish gear vulnerability, which shows how increased by catches of billfish in Hawaii's domestic longline fishery may have been caused by the transition to new monofilament longline gear and how the new gear can be modified to greatly reduce the by catches of striped marlin, spearfish, and mahimahi while actually increasing fishing efficiency for bigeye tuna, at least in winter.

Within the PFRD at the **La Jolla Laboratory**, Fishery Biologist James L. Squire, Jr., edits the *Billfish Newsletter*, which gives results of the Pacific International Billfish Angler Survey and Cooperative Marine Game Fish Tagging Program. The 1992 Billfish Newsletter will be released in time for this year's Tuna Conference in May. Since 1969, NMFS has conducted an annual postcard survey to assess billfish catch-per-unit-of-effort (CPUE) for the major recreational fishing locations in the Pacific. Results for the 1990 survey showed an increase over the previous year in CPUE for striped marlin in the high catch-rate areas off Baja California, Mexico, and off Ecuador, and that the CPUE for blue marlin off Hawaii remained the same.

Squire also continues to manage the Cooperative Marine Game fish Tagging Program and distributes tags to billfish anglers in Hawaii and elsewhere in the Pacific in cooperation with the Honolulu Laboratory and the International Billfish Association. This year, Squire and biologists from the Honolulu Lab noted long-range movements of blue marlin from Hawaii to the South Pacific and from Mexico to Hawaii--journeys of over 2,500 miles. A blue marlin tagged off Hawaii in August was caught near the Marquesas Islands in November, and in December, a blue marlin tagged the previous year off Baja California was captured off Oahu, Hawaii. Earlier recaptures of two other Pacific blue marlin also indicate long-distance movement across the Equator and from east to west across the Pacific. The pattern of recaptures and seasonality of fishing suggests that many blue marlin leave Hawaii for part of the year and then return, perhaps traveling long distances in the interim.

Tuna-related Fishery Data Bases

The SWFSC staff handles extensive and complex fishery data bases from tuna fisheries around the world. Within La Jolla's PFRD, Al Coan 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, and port sampling. The staff maintains the Atlantic tropical-tuna data base and develops 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. After processing by the SWFSC, the information is submitted to 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 albacore fishing fleet. Data collected by tuna-dolphin observers are used in marine mammal stock assessments. Coan works closely with the California Department of Fish and Game in editing historical drift-gillnet logbook data from coastal California to better describe and assess the effects of this fishery on sharks, billfish, and other target species.

Industry Economics and Global Trends

Gary Sakagawa and his staff at La Jolla also monitor 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*, edited by Al Jackson.

Statistics of the U.S. canned tuna industry were tabulated for the first three quarters of 1991 by Pat Donley of the Southwest Regional Office, and they were summarized by Al Jackson and Doug Prescott of the SWFSC, La Jolla. The statistics show the number of U.S. tropical purse-seine vessels were down by seven from the previous year. The reduction in the size of the U.S. fleet in the eastern tropical Pacific (ETP) was mainly the result of the U.S. canners' policy of not purchasing tuna caught in association with dolphins. Receipts of domestic and imported raw tuna by U.S. canners was down 3% in the first quarter and 4% in the second quarter of 1990, but it was up 19% in the third quarter. As in the first three quarters of 1990, tuna delivered to U.S. canneries originated principally in the western Pacific. Tuna imported by U.S. canners increased from 57% of the total receipts in the first quarter to 59% of the total receipts in the second quarter of 1991. The third quarter, however, showed a decline in imports to 55% of total receipts. Imports of canned tuna packed in water in 1991, 155,400 st, were up 22% from 1990. Based on cannery receipts through October, 1991, projected 1991 year-end receipts of domestic and imported tuna should reach approximately 432,000 st, up 5% from 1990. Imported tuna receipts are expected to be 234,000 st, or 54% of this total. 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.

Mathematical Modeling for Stock Assessment

Work continues within PFRD at La Jolla on evaluating mathematical modeling techniques used in stock assessments, examining them for accuracy and relevancy to management of tuna and tuna-related fisheries. The staff also assists in designing and conducting stock assessments and planning sampling projects for other programs. While Pierre Kleiber has been in New Caledonia on loan to the South Pacific Commission for most of the year, Carlos Salvadó has been working at the La Jolla Laboratory completing a general theoretical model for analyzing movement of tunas and for estimating population dynamics by means of tag recapture data. Salvadó is currently working on the next phase of the study which involves a series of simulations to determine the sensitivity of parameter estimates to errors in input values and data.

Research on Marine Mammals Associated with Fisheries for Large Pelagics

Within the **Marine Mammal Division** at La Jolla, led by Doug DeMaster, scientists study the status of dolphins associated with the eastern tropical Pacific (ETP) yellowfin-tuna purse-seine fishery and other marine mammals taken incidentally in domestic and foreign fishing operations. Research-vessel surveys of ETP dolphin stocks are carried out to monitor stock abundance as mandated by the Marine Mammal Protection Act. The standard Monitoring of Porpoise Stocks (MOPS) research-vessel surveys, which up until 1990 had been conducted annually since 1986, will henceforth be conducted triannually. These two-vessel surveys will now alternate with California Marine Mammals Surveys (CAMMS) cruises, and the more stock-specific Populations of *Delphinus* Stocks (PODS) surveys of the ETP.

Last July, Jay Barlow's **Coastal Marine Mammal Program** began the first CAMMS research cruise, a comprehensive census of cetacean stocks and oceanographic features along the entire length of the California coast out to about 300 nautical miles. The survey counts will be used to make minimum population size estimates of the stocks to provide to managers this year. In the long term, counts will serve as a benchmark against which to compare data from future cruises and to track population trends. The information will be used as a baseline against which to measure the effects of marine mammal-fishery interactions and other man-induced sources of cetacean mortality. The California driftnet fishery, which targets on pelagic species such as swordfish and thresher, Pacific angel, soupfin, and shortfin mako sharks, is an example of a fishery that interacts with marine mammals.

Stock assessments of California coastal marine mammals were completed this year for California sea lions, harbor seals, northern elephant seals, and harbor porpoise and were presented at the April 27-30, 1992, Status of West Coast Pinniped Stocks Workshop. A review of West Coast cetacean stocks by the Coastal Marine Mammal group is tentatively scheduled for August or September 1992. Minimum abundance estimates were calculated for dolphins that interact with California gillnet fisheries based on the 1991 spring aerial survey. This information will be combined with results of the 1991 fall survey results and presented at the fall 1992 review of cetacean stocks.

This year, stock assessment work on fishery-associated dolphins in the ETP culminated in the completion of the 5-year status and trends study. In November, a series of three workshops was held to review status and trends in abundance of ETP dolphins and selected California marine mammals. Results were also presented for review at the 3rd Annual International Tuna-porpoise meeting in November. A summary report was completed in March 1992, and finalized documents on the status of ETP dolphins and California coastal marine mammals were provided to the Southwest Regional office and NMFS headquarters in April for deliberations of Congress as it moves to reauthorize the Marine Mammal Protection Act in 1992. This summer the first PODS survey, which will concentrate on obtaining minimum-abundance estimates of the central stock of common dolphin in the ETP, will be launched.

In March 1992, the Center developed and presented for review a comprehensive Dolphin-Safe Research Program for investigating alternative tuna fishing methods and gear which do not affect dolphins. A proposal for consideration of funding in FY-1992 was assembled by Doug DeMaster and Elizabeth Edwards. Recommended studies include work on sonic tracking of pure schools of tuna, radio tracking dolphins, and examining food habits of tuna and dolphins. Edwards continues to analyze dolphin abundance trends and skipper performance and has begun to evaluate the statistical effects of small fleet size on dolphin mortality rate.

Steve Reilly continues to examine ETP dolphin encounter rates in relation to environmental features that may affect dolphin distributions, and he has completed two manuscripts on methods to incorporate habitat data into analyses of research vessel dolphin surveys and tuna vessel observer data.

Andrew Dizon continues to study genetics of ETP dolphins by extracting DNA from dolphin tissue samples collected from live animals during research cruises using special crossbow-fired collecting darts. The goal is to genetically differentiate the major species and stocks of dolphins affected by the ETP tuna purse-seine fishery. Work continues on temporal patterns in life-history parameters and the correlation between stress in dolphins and patterns of calcification in their teeth. A report on trends in life history parameters of ETP dolphins was completed in February.

Senior Scientist William Perrin, though intensely involved with the International Whaling Commission and scientific advisory work for the Marine Mammal Commission, continues his research on population biology and stock structure of cetaceans, especially on dolphins associated with the ETP purse-seine fishery. In September 1991, Perrin attended a USSR/US Marine Mammal Project meeting in Vladivostok, where it was agreed to carry out joint research on molecular genetic approaches to delineating stocks of cetaceans involved in gillnet fisheries in the North Pacific.

Hawaii Tunas and Other Larger Pelagics

At the SWFSC Honolulu Laboratory, most research and data management on tunas and large pelagics is now organized under two investigations--Jerry Wetherall's **Pelagic Resources Investigation** and Sam Pooley's **Fishery Management and Performance Investigation**.

Within the **Pelagic Resources Investigation**, Richard Brill, in conjunction with Peter Bushnell (Department of Zoology, University of British Columbia), has recently summarized research on effects of temperature/oxygen conditions on tuna behavior. Brill also collaborated with La Jolla driftnet impact researchers on assessing the physiological impacts of injuries sustained by tunas after entanglement and release from driftnets. In addition, he is supervising Sea Grant research on "burnt" tuna. Research within Robert Skillman's program focuses on gathering information on basic biological parameters--age and growth, size/cohort composition, mortality rates, and reproductive biology and recruitment--to improve the scientific basis for effective management of billfishes, wahoo, mahimahi, and oceanic sharks. The data are collected from fisheries, biological experiments, and ship surveys. Skillman, Christofer Boggs, and Sam Pooley recently completed a manuscript on fishery interactions among segments of the Hawaii pelagic fishery. Also, Skillman and Gary Kamer completed a manuscript on Hawaii's pelagic fish catch and catch-rate statistics of the domestic and foreign fisheries.

The **Fishery Management and Performance Investigation** provides fisheries data for biological and economic research to the Western Pacific Regional Fishery Management Council and other domestic and international clients on federally-managed central and western Pacific fisheries. The primary sources are Federal logbooks, wholesale market monitoring, shoreside sampling as well as 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 Western Pacific Fishery Information Network (WPACFIN) element of this investigation, managed by David Hamm, is the central source of information on most fisheries in Hawaii as well as in American Samoa, the Commonwealth of the Northern Mariana Islands, and Guam.

Finally, this year the SWFSC hosts the 43rd Tuna Conference under the able co-chairmanship of Al Coan and Al Jackson. The theme of the conference deals with the multispecies aspects of tuna fisheries and is entitled "Tuna Fisheries and Ecological Interactions."

Dr. Izadore Barrett, Ph.D.
Science and Research Director
Southwest Region

May 1992
La Jolla, California

II. ECONOMIC OVERVIEWS

Statistics of the U.S. Canned Tuna Industry Compiled for the First Three Quarters of 1991

Statistics for the U.S. canned tuna industry for the first three quarters of 1991 were tabulated by Pat Donley of the Southwest Regional Office (SWR) and were summarized by Al Jackson and Doug Prescott of the Southwest Fisheries Science Center (SWFSC). The reports describing the statistics appear as articles in the August and November 1991, and February 1992, issues of the SWR/SWFSC Tuna Newsletter.

The total number of vessels in the U.S. tropical purse-seine fleet was down seven vessels from the same time last year, and for the first quarter of 1991, receipts of domestic and imported raw tuna by U.S. canners were down 3% from the first quarter of 1990, at 103,300 st (converted to round weights). Second quarter totals also showed a 4% decline, with 130,500 st received, but third quarter receipts showed a 19% increase over the previous year's receipts, with 117,700 st. Species composition data for all three quarters showed skipjack tuna to be the largest component of the deliveries, comprising 57% of the total, followed by 25% yellowfin and 18% albacore.

As in the first three quarters of 1990, tuna delivered to U.S. canneries for the first three quarters of 1991 originated principally in the western Pacific. Tuna imported by U.S. canners increased from 57% of the total receipts in the first quarter to 59% of the total receipts in the second quarter of 1991, but the third quarter showed a decline in imports to 55% of the total receipts. Domestically caught deliveries to canneries in Puerto Rico for the third quarter of 1991 were down 66% from the previous year, while the domestic component of deliveries to American Samoa/California was up 72%. This is largely the result of a reduction in size and partial relocation of the U.S. tropical tuna purse-seine fleet from the eastern tropical Pacific (ETP) to the western Pacific. The reduction in the size of the U.S. fleet in the ETP in 1991 was mainly the result of the U.S. canners' policy of not purchasing tuna caught in association with dolphins.

Imports in the first quarter of 1991 were mainly from Ghana, France, South Korea, Spain, and Taiwan. Taiwan provided 19% of U.S. cannery imports. The top seven supplying nations provided 81% of all imports. In the second quarter, Taiwan, South Korea, and Spain contributed 60% of the imports. The top three contributors in the third quarter were Taiwan, Japan, and Spain, with a combined 57% of the total U.S. cannery imports.

Imports of canned tuna packed in water in 1991, 155,400 st, were up 22% from 1990, and based on U.S. cannery receipts through October 1991, projected 1991 year-end receipts of domestic and imported tuna should reach approximately 432,000 st, up 5% from 1990. Imported tuna receipts are expected to be 234,000 st, or 54% of this total.

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.

III. INDIAN OCEAN FISHERIES

Update on the Seychelles Purse Seine Fishery

Seychelles Fishing Authority data for the first-through-third quarters of 1991 have been updated and summarized in LOTUS spreadsheets by Biological Technicians Gary Rensink, Laura Halko, and Cheryl Brown of the Southwest Fisheries Science Center (SWFSC).

The number of vessels actively participating in the purse-seine fishery in the western

Indian Ocean in the first quarter of 1991 was 43; in the second quarter, there were 41; and in the third quarter, 45 vessels (17 French, 19 Spanish, 3 Mauritian, 1 Panamanian, 4 Japanese, and 1 Seychellois) participated.

Average catch rates for the first three quarters were up from the same periods in 1990. The first quarter averaged 22.5 metric tons (t) per day compared to 15.3 t/day in 1990, the second quarter averaged 16 t/day compared to 14 t/day in 1990, and the third quarter averaged 19.2 t/day compared to 18.7 t/day recorded for the same period in 1990.

Total catch of yellowfin and skipjack tuna for the first quarter of 1991 was 37,684 t, 35% lower than the 58,127 t in the same period of 1990; the second quarter averaged 32,690 t, down 23% from that of 1990, and in the third quarter, the total was 51,260 t, down 8% from the third quarter in 1990.

A species breakdown of catches for the first three quarters of 1991 showed yellowfin tuna to be up 28% in the first quarter, down 8% in the second quarter, and up 9% in the third quarter over the same periods in 1990. On the other hand, skipjack tuna catches were down 28% in the first quarter, up 9% in the second, and down again 7% in the third quarter.

IV. PACIFIC OCEAN FISHERIES

Pacific Albacore

1989-90 U.S. South Pacific Albacore Fisheries Data Summarized

A summary of U.S. South Pacific albacore fisheries data collected during the 1989-90 season has been completed by Biological Technician Gary Rensink. The report, entitled "Summary of the 1989-90 U.S. South Pacific albacore fisheries data," covers the period mid-November 1989 through mid-April 1990.

Thirty-eight U.S. jigboats participated in the fishery, the same number as in the 1988-89 season. Samplers collected catch-and-fishing-effort statistics from vessel logbooks and measured fork lengths of individual fish from landed catches. Catch-and-effort sampling coverage increased from 43 percent for the 1988-89 season to 86 percent for the 1989-90 season. Length-frequency coverage increased from 68 percent in 1988-89 to 80 percent in 1989-90.

High catches were centered roughly 1,200 miles east of New Zealand in January 1990 and roughly 2,100 miles east of New Zealand in March 1990. The total catch for the 1989-90 season continued an upward trend for the U.S. fishery, reaching 3,882 metric tons (t), a five-percent increase from the 1988-89 total catch of 3,700 t. The catch-per-day fished (CPUE) for the U.S. South Pacific albacore fleet increased 17 percent, from 236 fish/day in 1988-89 to 275 fish/day in 1989-90. The highest CPUE, an average of 291 fish/day, occurred in March approximately 2,100 miles east of New Zealand.

Over 67,000 albacore were measured for fork length (tip of snout to fork of the tail) from U.S. landings in American Samoa and from catches on board New Zealand jigboats during the 1989-90 season. Overall, the average size of albacore decreased for the third straight season, from 68.9 cm (15.0 lbs) in 1988-89 to 67.4 cm (14.0 lbs) in 1989-90. Fish sizes ranged from 41 to 108 cm fork length and showed a tri-modal distribution.

Data Collected on U.S. South Pacific Purse Seiners

Data on U.S. purse seiners fishing under the South Pacific Regional Tuna Treaty have been collected by Southwest Regional (SWR) personnel in American Samoa, under a contract with the government of Guam. The data have been submitted bimonthly to the Forum Fisheries Agency as a requirement of the treaty. The data include logbooks, landings, and size and species composition. The size and species composition data have been added to SWFSC data bases and are being used to monitor the sizes of tuna caught in the area.

Historical Data for Billfish and Sharks from the California Drift- and Set-gillnet Fisheries to be Compiled

Major efforts are under way to compile historical data for billfish and sharks from the California drift- and set-gillnet fisheries. Logbook and market sample data were keypunched, edited, and placed on data bases. Efforts are continuing to document these data and data bases and to recover other gillnet data and California harpoon fishery data. SWFSC's efforts in this data recovery are being supported by NMFS Data Rescue (ESDIM) Funding that is provided by Washington, D.C. Data recovered under this project will prepare NMFS for research on shark populations, where some concern over the stock's capability to cope with current fishery pressures has been expressed.

First FAO Expert Consultation on Interactions of Pacific Tuna Fisheries

The FAO-sponsored Expert Consultation of Pacific Tuna Fisheries was held in Noumea, New Caledonia, December 3-11, 1991. The Southwest Fisheries Science Center (SWFSC) participated in organizing this meeting, and Norm Bartoo and Pierre Kleiber, of the La Jolla SWFSC, serve on the steering committee for international membership. Honolulu Director George Boehlert of SWFSC acted as rapporteur of the December 3-11 general sessions. Fishery Biologist Christofer Boggs was rapporteur of the session on methods of studying pelagic-fishery interactions. Attending from SWFSC in La Jolla were Fishery Biologist Norman Bartoo, Mathematician Al Coan, and Operations Research Analyst Carlos Salvadó. The Consultation involved presentations and discussions on methods for identifying interactions between Pacific tuna fisheries and reviews of various tuna fisheries of concern, namely Pacific skipjack, eastern and western Pacific yellowfin, North and South Pacific albacore, Pacific bigeye, northern and southern bluefin tuna, and Pacific small tunas. Boggs contributed a paper entitled "Methods for analyzing interaction of limited-range pelagic fisheries: the example of Hawaii's pelagic fisheries." Norm Bartoo presented a paper on which he collaborated with Dave Holts and Cheryl Brown: "Evidence of interactions between high-seas driftnet fisheries and the North American troll fishery for albacore." He also presented "The synopsis of the biology and fisheries for North Pacific albacore," a paper co-authored with Terry Forman of the IATTC. Carlos Salvadó presented a paper entitled "Discrete population field theory for tag analysis and fishery modelling," and Al Coan made a presentation on his paper "U. S. distant-water and artisanal fisheries for yellowfin tuna in the central and western Pacific." Participants concluded that potentials for interactions between fisheries were fairly easy to identify but that hard evidence for interactions was lacking in many cases; for example, in the distant-water purse-seine fishery's interaction in the western Pacific with the domestic commercial and artisanal fisheries of islanders. These fisheries operate in the same areas and during the same seasons. However, comparisons of catch rates do not demonstrate a conclusive interaction, and because tagging of yellowfin in the area is fairly new, tagging data are not available. Fisheries for which there is extensive evidence of interactions are northern and southern bluefin tunas, skipjack, and albacore; the evidence comes from extensive tagging experiments on these species or, in the case of albacore, thorough net-marking of fish that escape from gillnets and are later caught by troll gear.

Representatives attending also concluded that quantifying the extent of confirmed interactions is difficult for most fisheries. Untested models have been developed, but they are either specific to a particular fishery or have not yet been applied.

Recommendations were made by the participants which called for improved fishery and tagging statistics and development of tag analysis models. A report with results of the consultation, including a list of recommendations, is in preparation for release by June 1992.

SPAR Workshop Held

Several Southwest Fisheries Science Center (SWFSC) scientists from La Jolla contributed papers for the fourth South Pacific

Albacore Research (SPAR) Workshop held November 4-8 in Taiwan, which was attended by Gary Sakagawa of the La Jolla Laboratory.

Sakagawa presented a report by Fishery Biologist Darlene Ramon which gave the results of a project conducted jointly by the Tuna and Billfish Assessment Program (TBAP), the South Pacific Commission (SPC), and SWFSC that examined the spawning seasonality of albacore in the South Pacific and the relationship of maturity-to-length modes of fish being caught in the surface fishery. The project was designed to provide a better understanding of the reproductive biology of albacore in the South Pacific.

Samples from 101 frozen albacore were analyzed for reproductive status based upon gross morphology and microscopic examination. Maturity stages of the ovaries were examined as were the spawning seasons. For this project, oocyte diameters were used as an indicator of the maturity stage of the ovary, but no ripe or advanced-staged ovaries were found in the samples. The average ovary weight was low during the austral winter months, but the weight increased through the southern spring and summer when spawning takes place. The main spawning season in the South Pacific is from September through March, with peaks between November and February. Since albacore have a protracted spawning season, the biologists found that it is difficult to determine the length of the spawning season or the number of spawnings per season.

Data suggest that albacore in the South Pacific spawn during the austral summer months. However, indications of albacore spawning throughout the year in the northern and southern hemispheres have been reported. The presence of albacore larvae as far north as 20°N during the months of November and April and as far south as 20°S during the months of May through October indicates that spawning occurs throughout the year. The scientists believe spawning during the winter months may be on a reduced basis and increase during the summer or when albacore cross the Equator.

Samples for this project were from Tonga and New Caledonia, the southern albacore spawning region. Consequently, the biologists state that the samples may not be representative of the albacore spawning condition in the rest of the South Pacific Ocean. SPAR Workshop participants agreed that further research on the spawning seasonality of albacore and its relationship to the periodicity of length modes in the surface fishery was a priority. To accomplish this, they believe that samples are needed from a greater number of times and areas, especially samples taken near islands since tuna larvae are more abundant in near-reef waters.

Data collected from U.S. jigboats fishing in the South Pacific during the 1990-91 season were summarized by Al Coan, mathematical statistician, and Gary Rensink, biological technician, and submitted to the SPAR Workshop. According to the data, approximately 58 U.S. jigboats participated in the fishery, catching an estimated 5,500 t of albacore. The fishery concentrated in areas between 35°S to 45°S latitude and 140°W to 165°W longitude. The average catch rate was 197 fish per day of fishing, 29% lower than during the 1989-90 fishing season. Over 10,000 fish were sampled for length in American Samoa and Tahiti, where the majority of the catch was landed. Albacore ranged in size from 38 to 109 cm in fork length. The majority of fish landed was between 61 and 76 cm, with an average size of 71.3 cm. A greater proportion of large fish (>71 cm) was landed during the 1990-91 season than during the 1989-90 season, when the overall average size was 67.4 cm.

Sakagawa also presented Al Coan and Gary Rensink's summary of total catch, sampled catch and logbook effort, and size and estimated age composition of albacore landings from the U.S. troll fishery in the South Pacific during the period 1986-1991. Their report indicates the U.S. South Pacific troll fishery has grown from two vessels landing 89 metric tons (t) in 1986 to 58 vessels landing 5,494 t in 1991. The U.S. troll catch represented approximately 10 percent of the total South Pacific albacore catch in 1990. The fishing season usually runs November through April.

Overall, approximately 50 percent of the trips made by U.S. troll vessels have been covered by the voluntary logbook program (more than 65 percent in recent years). The

U.S. troll fishery concentrated its effort south of French Polynesia between 35°S and 45°S latitude and 135°W and 165°W longitude.

The above index area and the index season (January through March) were selected to calculate catch-per-effort (CPE) in metric tons per day fished. Approximately 85 percent of the catch occurred in the index area/season. CPE in the index area/season reached a high of 2.6 t per day in 1987, declined to 1.8 t per day by 1991, and was always higher than CPE for all areas. CPE in the index area was usually highest in January or February, averaging roughly 2.0 t per day.

Approximately 50 albacore were measured for fork length (tip of snout to fork of tail) from each sampled landing. The majority of the samples were collected in Pago Pago, American Samoa. Overall, more than 70 percent of the U.S. troll landings have been sampled for size composition (length-frequency). During the 1989 and 1990 seasons, New Zealand placed observers on some U.S. vessels and sampled the catch.

The sizes of albacore caught during the 1986-to-1991 seasons generally fell into three modes, representing 2-, 3-, and 4-year-old fish. Age-3 fish were dominant with 36 percent to 62 percent of the catch, age-2 fish made up 16 percent to 41 percent, and age-4 fish made up 8 percent to 25 percent of the catch. Age groups were easily seen in the size frequencies until 1990 and 1991 when the age groups seemed to merge into one mode (53-93 cm), possibly due to the phasing out of gillnet fishing in the area, thus making more fish throughout the size range available to the troll fishery.

North Pacific Albacore Ecology and Associated Oceanography

"North Pacific Albacore Ecology and Oceanography," a manuscript by Oceanographers R. Michael Laurs and Ronald J. Lynn, has been submitted and accepted for publication in the National Oceanic and Atmospheric Administration (NOAA) Technical Report series. The report summarizes a broad range of knowledge of albacore ecology and associated oceanography in the North Pacific that has resulted from almost 2 decades of studies conducted by the fisheries oceanography group at the Southwest Fisheries Science Center (SWFSC) at La Jolla. It briefly reviews the characteristics of the major North Pacific fisheries for albacore, including catch distribution and recent redistribution of effort; stock structure, including the concept of two subgroups; migration based largely upon an extensive tagging program; physiological ecology and habitat definition which cover results of clinical studies, acoustic tracking, and satellite remote-sensing studies; food habits; and the relation of migration-and-catch distribution to mesoscale and large-scale oceanographic fronts.

The manuscript explains that the majority of albacore caught by the U.S. jig and baitboat fishery and the Japanese longline and baitboat fisheries are where surface temperature is within the range of 16° to 18°C despite the fact that albacore spend most of their time within the cooler waters of the thermocline beneath the surface layer. The longline fishery, centered about the subtropical front, is conducted during winter and is the most southerly of the fisheries. As spring warming progresses and a more shallow surface layer forms, the Japanese baitboat fishery develops about the Kuroshio Extension front, and there is a northward and eastward progression of catches. The U.S. jig and baitboat fishery develops last, in the mid Pacific, and moves eastward and northward with the warming. In summer, in the eastern North Pacific, the catches of this latter fishery develop north and east of the subarctic front and often concentrate close to the coastal upwelling fronts.

Shimizu, Japan, Site of 12th North Pacific Albacore Workshop

Southwest Fisheries Science Center (SWFSC) co-hosted the 12th North Pacific Albacore Workshop, the most recent of a series which began in 1975, with the National Research Institute of Far Seas Fisheries (NRIFSF) in Shimizu, Japan, July 23-25, 1991. Thirty-four scientists from Japan and the United States met to review recent data and research and to evaluate the condition of the North Pacific albacore stock. Participants and members included the NRIFSF; SWFSC, La Jolla, California and Honolulu, Hawaii; Pacific Biological Station, Nanaimo, British Columbia; and the Institute of Oceanography, National Taiwan University, Taipei, Taiwan.

Workshop statistics showed that North Pacific albacore are caught in several fisheries, including the Japanese pole-and-line and longline and driftnet fisheries; the United States and Canadian troll fisheries; and the Taiwanese and Korean longline and driftnet fisheries. Annual catches of North Pacific albacore peaked in the early 1970s in excess of 100,000 metric tons (t). Since then, total annual catches have continued to decline to around 40,000 t in recent years. The declines in catches have been predominantly in the Japanese pole-and-line and the U.S. troll fisheries. Over the same period, however, the Japanese and Taiwanese longline catches have remained relatively constant. Increases in catch have been recorded for the driftnet fleets of Korea, Taiwan, and Japan. Catches by the Japanese purse seine fleet have also shown modest increases.

The Workshop examined catch per fishing effort series as indicators of the abundance of various segments of the population. The trend in young fish abundance was best reflected by the surface fisheries, and the trend in adult abundance was best represented by the longline fisheries. Catch per fishing effort in both the U.S. troll fishery and the Japanese pole-and-line fishery are currently stable and about 30% lower than before 1977. Catch per fishing effort in the Japanese longline fishery is relatively flat, declining slowly in recent years.

Jerry Wetherall and Donald Hawn of SWFSC's Honolulu Laboratory summarized available historical data on albacore catches and catch rates in the Hawaii longline fishery and presented the material in a working paper. Data heretofore unavailable to workshop participants will now be incorporated into the North Pacific albacore data base on a routine basis. Almost all albacore taken by the Hawaii longline fishery are mature fish. In this connection, Hawn continues to routinely collect gonads from albacore landed at the Honolulu fish auction for analysis by La Jolla scientists, who are conducting a comprehensive study of Pacific albacore reproductive biology.

The workshop produced a series of recommendations for research and analysis to determine more clearly the status of the albacore stock and the effects of the various fisheries on the stock. A written report detailing the Workshop's discussions and conclusions will be made available to the public.

Results of the workshop showed that the U.S. fishery is "downstream" from the other surface fisheries in the North Pacific, so it is more severely affected by interception of albacore migrating toward the U.S. fishery. Because of the substantial catch taken by the driftnet fleets, they are probably a major factor responsible for the lower recent catches by the U.S. fishery as well as other traditional albacore fisheries in the North Pacific.

1991 North Pacific Albacore Fishery

In 1990 and 1991, Southwest Fisheries Science Center (SWFSC), in cooperation with the Western Fishboat Owners Association, conducted a high-seas impact assessment program to determine the effects of North Pacific driftnet fisheries on albacore. Albacore that encounter driftnets and then escape often bear identifiable external net marks which provide evidence of interaction between albacore and the net fishery.

The assessment showed that in the North Pacific, the small-mesh net fishery of about 600 vessels from Japan, Taiwan, and the Republic of Korea, concentrate on catching the flying squid, but this fishery also incidentally catches albacore. The large-mesh fleet of about 160 vessels from Japan and Taiwan targets its effort on catching albacore. In addition, Japan and Korea have a longline fleet catching albacore in the North Pacific.

Catches and catch-per-effort of the U.S. albacore troll and Japanese pole and line fisheries for albacore have declined continuously since the 1970s. To better determine the effects of the more recent driftnet fisheries on the albacore resource, the SWFSC continued a catch-sampling program at sea in 1991.

NMFS biological technicians made 4 trips on different U.S. albacore trollers in the North Pacific. Time at sea totaled 154 days, and in this time, 12,466 albacore, 2-, 3-, and 4-year olds which are typical of the U.S. troll albacore fishing, were examined for net damage. In 1991, 96.9% of albacore examined showed no visible indications of having been caught in a drift gillnet. The remaining albacore (3.1%) showed various signs of damage. The amount of net-damaged fish in 1991 was much less than observed during the 1990 program, when 12.1% of the albacore were net marked. A higher proportion of new net damage was noted in the western portion of the fishing area than in the eastern portion. This increase in damaged fish is presumed to result from the proximity of the sampling to the foreign gillnet fisheries.

Data collected from the U.S. North Pacific albacore fishery under a contract to the Pacific States Marine Fisheries Commission were added to SWFSC data bases by Gary Rensink of Sakagawa's La Jolla SWFSC division and by Forrest Miller of the Inter-American Tropical Tuna Commission (IATTC). Papers summarizing the data were written by Norm Bartoo, Dave Holts, and Laura Halko. Data collected are useful in determining and monitoring the status of albacore stocks in the North Pacific.

Hawaii Fisheries

Distribution of Tuna Larvae near Oahu

The first study of scombrid larvae using nets that sample discrete depth strata while simultaneously measuring hydrographic variables has been completed. Results are presented in a Southwest Fisheries Science Center (SWFSC) Administrative Report (number HI-91-11) by George Boehlert, leader of the Fisheries Oceanography Research Program, and Bruce Mundy, fishery biologist.

The researchers found that different genera had different patterns of offshore distribution; *Katsuwonus* larvae were more abundant at offshore stations while *Thunnus* larvae were more plentiful at nearshore stations. Some larvae, however, such as keo keo or frigate mackerel, showed no consistent onshore-offshore pattern. Nearshore concentrations of tuna larvae have been reported in earlier studies by others in Oahu and French Polynesia. The importance of nearshore areas as tuna nurseries is unknown; the abundance and survival of tuna larvae in the limited nearshore area need to be compared to those found in the vast offshore area.

Boehlert and Mundy also found generic differences in vertical distribution but noted that all *Thunnus* larvae occurred in the upper water column (0-84m). No consistent evidence of vertical migration was found except that *Thunnus* larvae were captured in the neuston (0-1m) at night but not during the day. They found that temperature appears to play an important role in the seasonal and vertical distribution of *Thunnus* larvae off Oahu; *Thunnus* larvae were never found at temperatures below 24.2°C and skipjack and frigate mackerel larvae were not found below 21.8°C.

The report by Boehlert and Mundy provides a detailed data record for further analysis of the patterns observed. Their report contains the first results from a larger study on the vertical distribution of all taxa of fish larvae near Oahu.

Effect of Ocean Currents on Pelagic Fish

Richard Brill, David Holts, Randolph Chang, Scott Sullivan, Heidi Dewar, and Francis Carey employed ultrasonic depth-sensitive transmitters to monitor the horizontal and vertical movements of striped marlin, expendable bathythermographs to determine depth-temperature profiles, and an acoustic Doppler current profiler to determine oceanic current patterns. Their data provide the first description of the movements of pelagic fish with simultaneously gathered oceanic current information. Movements of billfishes have been implicitly assumed to be uninfluenced by currents, but their data on striped marlin's horizontal movements and on the ocean currents clearly show that striped-marlin movements are strongly influenced by current patterns and that some individuals spend most of their time simply drifting. Furthermore, their vertical movement data show that the depth distribution of striped marlin is limited, not by an absolute temperature, but rather by water that is 8° colder than the upper mixed layer where these fish spend the majority of their time.

Longline-Fishery Logbook Data

Computer programming of a Hawaii longline-logbook inventory system was completed early in 1992 by Operations Research Analyst Stacey S. Yoshimoto of the Fishery Management and Performance Investigation (FMPI) division, at Southwest Fisheries Science Center's (SWFSC) Honolulu Laboratory. The inventory allows a more-accurate collection of logbooks on a timely basis and also provides a data base for analyzing fleet activity. A separate set of programs edits and summarizes the logbook data.

Updates of South Pacific albacore longline catch-per-unit (CPUE) indices, provided routinely by Jerry Wetherall and Marian Yong, are based on logbook data submitted to NMFS voluntarily by captains of Korean and Taiwanese longliners based in Pago Pago, American Samoa. The indices are used to monitor trends in the spawning stock. To ensure longline-logbook data quality, FMPI personnel visited the islands of Hawaii and Kauai in June 1992 to identify the longline fishing vessels off loading in those ports and the major buyers of longline, bottomfish, and small-boat pelagic fishes. In addition, new laminated species identification cards available with annotations in English, Korean, and Vietnamese, were given to longline vessel captains to increase logbook accuracy.

Preliminary and annual summaries of the western Pacific domestic longline fishery in 1991 have been completed, according to Fishery Technician Robert Dollar. Throughout 1991, 140 vessels were active, took 1,666 trips, and set 12.2 million hooks. Broadbill swordfish, 61,000, made up the largest component of the landings in 1991, followed by 39,500 bigeye tuna, and 38,000 mahimahi. Sharks, 71,000, constituted the largest component of the catch, but only 4,500 were kept.

Approximately half the fishing effort was within the 200-mile Exclusive Economic Zone (EEZ) of the main Hawaiian Islands, where bigeye tuna made up the largest portion of the landings. About 15% of the fishing effort was within the 200-mile EEZ of the Northwestern Hawaiian Islands (NWHI) where broadbill swordfish made up the largest portion of the landings. About one-third of the effort was outside Hawaii's EEZ with most landings being broadbill swordfish.

The 1991 catch-and-effort by the longline fishery cannot be directly compared with data from previous years because the logbook program in which fishermen are required to report such data has only been in effect since mid-November 1990. However, the average weights from the dockside and wholesale market monitoring in Honolulu suggest that landings of broadbill swordfish more than doubled in 1991--to about 8.7 million lbs (round weight). Landings of bigeye tuna (3.4 million lbs) were about the same as during the previous year, while landings of yellowfin tuna (1.5 million lbs) were down substantially. True bluefin tuna were landed in small numbers by longline vessels. However, the average size of these bluefin was relatively small (100-200 lbs round weight).

A more-detailed assessment of the 1991 western Pacific domestic longline fishery will be available in an annual report prepared by the staff of the FMPI.

Troll and Handline Fisheries Examined for Evidence of Interaction with Domestic Longline Fishery

A preliminary study examining data from Hawaii's troll and handline fisheries for evidence of interaction with the domestic longline fishery has been completed by Fishery Biologist Christofer Boggs. Initiated because of concern that longline catches might have become great enough to impact the local abundance of fish, annual (1983-89) and monthly (January 1987 to June 1990) summaries of catch and number of trips in Hawaii's commercial troll and handline fisheries, provided by the Hawaii Division of Aquatic Resources (HDAR), were used to examine catch-per-trip over time in these two fisheries. Troll and handline catch-per-trip were also examined in relation to Hawaii's longline catches as given by the National Marine Fisheries Service (NMFS) market monitoring data from January 1987 to June 1990; the analysis was broken down by season to remove a potential source of bias.

Yellowfin tuna catch rates gave the appearance of declining with increasing longline catch. Although the decline could well be due to other factors, decreasing catch-per-trip over the last few years was real, being reflected in the data from many gear types. However, the decline did not result in troll or handline catch rates substantially lower than in 1983, before the longline fishery expansion. Also important was the absence of any clear relationships between longline catch and catch rates for blue marlin, striped marlin, mahimahi, ono, bigeye tuna, and swordfish. Data available for the present study were through June 1990 and Hawaii's domestic longline fishery has doubled in size since then, making the potential for fishery interaction greater now than during the study period.

A review of the status of the small-vessel pelagic fisheries at a greater-than-annual resolution indicated that some overall declines may have occurred that were not apparent from the annual time series. The average annual catch-per-trip values for 1988-89 compared with the 1983-85 average indicated that, in 1988-89, troll catch rates were higher for both marlin species but were lower for yellowfin tuna, mahimahi, and ono; handline catch rates were lower for all species except bigeye tuna. However, these changes were small compared to changes seen over a longer time period (1962-89). Boggs' study, "A preliminary examination of catch rates in Hawaii's troll and handline fisheries over a period of domestic longline fishery expansion," (SWFSC Administrative Report H-91-05), explains that the range of Hawaii's pelagic fisheries is limited and that catch-per-unit effort (CPUE) is characterized by wide fluctuations which may obscure or mimic fishing interaction. Therefore, still needed is a more thorough approach which addresses the major problems with the available fisheries data and which considers biological, environmental, and economic factors.

Research on Impact of North Pacific High-seas Driftnet Fisheries on Tuna Stocks

Jerry Wetherall and Marian Yong continued research on the impacts of North Pacific high-seas driftnet fisheries on tuna stocks. The research, being conducted in collaboration with La Jolla Southwest Fisheries Science Center (SWFSC) scientists, includes the estimation of driftnet bycatch levels, based on data collected by an international cadre of observers deployed on the driftnet fleets, and effort statistics provided by Japan, Korea, and Taiwan. Preliminary results were presented at a meeting on driftnet impacts in Sidney, British Columbia, Canada, in June 1991. Final analysis awaits the compilation of data from the 1991 observer programs and delivery of corresponding effort statistics.

As part of a larger effort to determine the true impacts of drift gillnets on the North Pacific albacore stock, Richard Brill of the Honolulu SWFSC and David Holts of the La Jolla SWFSC examined whether the net-scarred albacore caught by the U.S. troll fleet suffer a higher-than-normal rate of natural mortality. Their study found no significant differences between net-scarred and normal fish's measures of condition, short-term and long-term growth rates, or indications of systemic infection. This seems to indicate that the fish which escape from drift gillnets and live long enough to resume feeding (i.e., to be recaptured by trolling vessels) probably do not suffer increased natural mortality. A variety of fates, however, may befall albacore that become entangled in high-seas drift gillnets. Their study compared animals that have never become entangled with those that were probably not badly injured and lived long enough to begin feeding. The percentage of albacore becoming entangled in drift gillnets and falling out dead or so badly injured that they succumb before they become vulnerable to troll vessels may well be significant and remains to be determined.

Hook Timers and Time-depth Recorders Used to Measure Depth of Capture of Pelagic Species

"Depth, capture time, and hooked longevity of longline-caught pelagic fish: timing bites of fish with chips," a paper by Fishery Biologist Christofer H. Boggs, describes research using hook timers and time-depth recorders (TDRs) attached to longline gear to measure the depth of capture of pelagic species off Hawaii in January 1989 and January-February 1990. Data on the effects of depth on the selectivity and efficiency of longline gear are essential for stock assessment work using catch-per-unit effort (CPUE) by different gear types. Furthermore, targeting specific depths can improve longline catches of target species such as bigeye tuna and reduce catches of billfish and other species that may be important to small-scale fisheries operating in the same area.

In Boggs' study, hook timers were used to measure the time-of-capture and to provide data on the survival times of hooked fish. Accurate estimates of settled gear depth were made by attaching TDRs to the longline. Recorded longline depths differed greatly from predicted depths, indicating that TDRs are essential for describing depth distributions of fish catch by longline. Without hook-timer data, many fish appeared to be caught at depths greater than they were actually caught.

Boggs' research showed that the efficiency of deep gear was estimated to be 3-4 times as great as regular gear in catching bigeye tuna but only half as efficient in catching striped marlin and spearfish. A proposed new gear configuration was predicted to be only about 25% as efficient as regular gear in catching striped marlin and spearfish. Eliminating shallow hooks, he says, could substantially reduce the bycatch of *Tetrapturus* spp. and other recreationally important billfish without reducing fishing efficiency for bigeye tuna.

Bigeye tuna, striped marlin, and spearfish survived from up to 5-9 hours after capture, and over 50% of the 12 most-frequently-caught taxa were alive when retrieved. Some live fish (29 bigeye tuna and 35 striped marlin) were tagged and released after long poles had been used to insert the tags and to cut the leader while fish remained in the water. Two bigeye tuna and one striped marlin were recaptured 3-10 months later, indicating that fish released from longline gear are viable and that the release of some species could be an effective management option.

Western Pacific Regional Fisheries Management Council

Industry Economist Samuel G. Pooley of the Honolulu Laboratory summarized NMFS research on the interrelationship of longline landings, troll-handline catch rates, and market prices. The summary was based on two reports.

The first report, "Hawaii pelagic fishery catch and effort: 1990 results," compiled by Pooley and Operations Research Analyst Stacey S. Yoshimoto, reported on the Fishery Management and Performance Investigation's (FMPI) Hawaii market-monitoring data which was designed to identify trends in catch-per-trip by small-scale troll and handline vessels in Hawaii. The report will be used by the Western Pacific Regional Fishery Management Council (WPRFMC) in preparing amendments to the fishery management plan for pelagic species.

According to the report, there is a strong correlation between data collected from trollers and handliners based on Oahu and the study conducted by Fishery Biologist Christofer Boggs which showed evidence of interaction between Hawaii's troll and handline fisheries and Hawaii's domestic longline fishery.

Pooley's second report, entitled "Revised market analysis: Hawaii yellowfin tuna," examines the relationship between yellowfin-tuna prices and longline landings. No trends were found in average monthly yellowfin tuna prices from 1987 to 1990 for Oahu-based or outer-island-based trollers and handliners or for longline fishing vessels. A strong seasonal peak in prices was identified, based on the peak market season of December-April.

Neither of these reports provided strong support for the WPRFMC's proposed regulation of the longline fleet, and it was stressed that additional research is required to identify these interrelationships. At a subsequent WPRFMC meeting, the proposed moratorium on new entry into Hawaii's longline fishery was approved.

The Honolulu Laboratory hosted an external review of NMFS programs related to the Western Pacific Regional Fishery Management Council (WPRFMC). The review, which was held June 10-15, 1991, was attended by a panel of external fisheries scientists. Scientists at the Honolulu meeting reviewed research programs that support the fishing conservation and management requirements of the Maguson Fishery Conservation and Management Act in the central and western Pacific. Data collection and status of the fisheries in Hawaii, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands were discussed. Honolulu Laboratory Director George Boehlert and task leaders of several research programs provided background information on fishing dynamics, stock assessment, and research that supports management of crustaceans, bottomfish and seamount groundfish, precious corals, non-scombrid pelagic fishes, and tuna.

A perspective of the fishery data and monitoring needs of the WPRFMC was provided by William Paty, chair of the WPRFMC and the State of Hawaii Board of Land and Natural Resources, and by Dorothy Lowman, staff economist for the WPRFMC.

Hawaii's Commercial Fishery, 1990

The Fishery Management and Performance Investigation (FMPI), responsible for monitoring Hawaii's commercial fishery through a variety of logbook and shoreside monitoring programs, estimates total commercial landings in Hawaii for 1990 were the same as in 1989 although revenue was up 2% (less than the rate of inflation). The tremendous growth in the longline fleet over the previous 3 years led to rapidly increasing landings by that fleet. Landings in 1990 were 35% higher than in 1989, but landings of Main Hawaiian Islands' (MHI) pelagic species (billfish, sharks, mahimahi, ono, and tuna) fell marginally (7%). Both fisheries, however, had increased landings of yellowfin tuna. The pole-and-line skipjack boat fleet had a particularly bad year, with landings down 65%. The MHI bottomfish fishery also had a substantial decline (down 30%). The Insular and Pelagic Resources Investigations are evaluating these trends and analyses will be used by the WPRFMC to plan monitoring teams.

Based on a new estimation procedure for dealing with MHI landings of pelagic species, the FMPI also revised its estimates of 1989 landings, slightly increasing the total landings to 22.5 million lbs ($47.2 million). Due to reduced monitoring resources, the FMPI prepared a proposal to limit the current 5-days-per-week auction monitoring to systematic once-a-week sampling beginning in 1992.

Pacific Billfish Programs

Trends in Billfish Angler Catch Rates

Since 1969, as part of the stock-assessment and fishery-impact-analysis program, NMFS has conducted an annual postcard survey to obtain a sample of billfish catch-per-unit effort (CPUE) for the major recreational billfish fishing locations in the Pacific. A postcard survey is currently being conducted to determine catch rates for 1991 and results for 1990 have been tabulated.

In 1990, the total number of fishing days reported by billfish anglers responding to the survey was 15,606, resulting in a catch of 5,827 billfish for a catch rate of 0.42 billfish per day. For the locations having normally high catch rates for striped marlin, the CPUE increased. The 1990 CPUE for Baja California, Mexico, was 0.73 fish/day, up from 0.67 fish/day in 1989. Off Ecuador, CPUE increased from 0.61 in 1989 to 0.80 fish/day in 1990. The trend in CPUE that is of interest to many anglers is the blue-marlin fishing about Hawaii. It remained at a level of 0.24 fish per angler day, approximately the same as recorded in 1989. An increasing CPUE had been recorded for Hawaii during the 4 previous surveys. In the western Pacific, blue marlin catch rates for Guam showed an increase to 0.32 fish per day up from 0.23 fish per day recorded in 1989.

These results as well as a complete review of catch rates recorded for other parts of the Pacific, Indo-Pacific and Indian Ocean will be included in the *1992 Billfish Newsletter* scheduled for release in May, 1992.

V. DOLPHIN RESEARCH AT THE SOUTHWEST FISHERIES SCIENCE CENTER

Age at Sexual Maturity Examined as a Possible Compensatory Mechanism for Offshore Spotted Dolphins

Potential biological indicators of population status are being investigated by the Biological Assessment Program. Compensatory responses in the life history of the dolphin species exploited, and thereby potentially reduced in abundance, by the yellowfin tuna purse-seine fishery were predicted to have occurred. Specifically, the age at attainment of sexual maturity (ASM) has been found to be negatively correlated with population abundance in some dolphin and whale populations, and a study to analyze ASM as a possible index to population condition for the spotted dolphin was conducted. Two stocks of the offshore spotted dolphin, northern and southern, were selected for comparison as they have been subjected to different rates of exploitation; the northern stock has been the most severely exploited and reduced in abundance. Consequently, an earlier ASM was predicted for the northern stock, relative to the southern stock, while a decreasing trend was expected for each stock between 1974 and 1988, if population abundance were found to be declining.

Life history specimens with both teeth and reproductive data available were randomly selected for preparation of teeth for ageing from the available samples of female spotted dolphins. The targeted sample size was 50 dolphins per year for the years 1974-1988. The total sample size was 971 specimens (564 from the northern stock and 407 from the southern stock).

No significant trend in ASM over the study period, 1974-1988, was detected for the northern stock of the offshore spotted dolphin. For the southern stock, trends were not determined, as only three years of data were available for annual estimates of ASM. All data were pooled over years, and the ASMs for the two stocks were compared with a t-test. The pooled estimates of ASM were 11.12 years (SE=0.2289) and 9.78 years (SE=0.2645) for the northern and southern stocks, respectively; these estimates were statistically significantly different (p).

No significant differences between the stocks were detected in the fraction of mature females in the sample or in the fraction of mature females that were pregnant, lactating, or simultaneously pregnant and lactating. The pregnancy rates were 0.27 for the northern stock and 0.34 for the southern stock. A higher pregnancy rate had been expected for the northern stock relative to the southern stock.

These life history parameters for the northern stock (high ASM and possibly low pregnancy rate) imply a low reproductive rate, relative to the southern stock. Therefore, the results do not support the original hypothesis of a model of population compensatory responses correlated with population abundance.

Results of this study suggest alternate models. There may be inherent differences between the northern and southern stocks of spotted dolphin due to genetic divergence between the stocks. Morphologically, the two stocks are recognized as distinct. The breeding seasons are also different for these two stocks. The patterns of reproductive seasonality may be due to the different oceanographic environments, the north being more constant and the south more variable.

Other possible explanations as to why the results of this study were not as predicted include (1) a change in carrying capacity, (2) a change in physiological processes (i.e., physiological "stress" caused by the fishery), and (3) no change in ASM over the population densities observed. On the other hand, the model of compensatory responses resulting from a decline in abundance may be appropriate but has not been identified because the available sample sizes are too few in number, the available data are biased, or there is an unaccounted-for time lag in response.

Three studies dealing with the status of dolphin stocks were reported on by Sue Chivers at the Status of Stocks Workshop. The first paper, co-authored with Doug DeMaster (LJ-91-29), gave the results of an experiment testing a variety of life history parameters as potential biological indices of population status (size relative to carrying capacity) for the four target species in the eastern tropical Pacific (ETP). The compensatory response model for predicting biological indices was not consistently supported by the species and stocks analyzed. The second paper, co-authored with Andrea Bright (LJ-91-30), analyzed post-natal growth rates of northern and southern stocks of the offshore spotted dolphin. Size-at-age relationships were investigated to infer changes in population abundance. Their analysis was based on the hypothesis that the northern and southern stocks of spotted dolphins would have increased growth rates for the years between 1973 and 1989 due to increases in per capita availability of resources which accompany the decrease in stock size of dolphins caused by the ETP tuna fishery during this time period. The third paper, co-authored with Al Myrick (LJ-91-31), tested for trends and stock differences in the age at sexual maturity (ASM) for northern and southern offshore spotted dolphins, as detailed above.

The growth rates paper also compared stocks because each has been subjected to different rates of exploitation. Chivers and Bright found the southern stock of offshore spotted dolphins to be approximately 1 cm longer at 1 year of age and 2 cm longer at 2 years of age than animals from the northern stock. Monthly growth rate estimates were not significantly different between the stocks. The difference in length-at-age may be due to the length-at-birth that is estimated to be 2 cm longer for the southern stock. It is interesting that mean length at sexual maturity and mean asymptotic total adult body length for the southern stock animals are 2 cm shorter than for the northern stock. Together, the ASM results lend supporting evidence for the hypothesis that there are heritable differences between the northern and southern offshore spotted dolphin.

Incidental Kill of Small Cetaceans

The incidental kill of small cetaceans for 1990 was summarized and submitted to the International Whaling Commission's annual meeting in May 1991, by Kelly Peltier, Ruth Miller, and Susan Chivers of the Biological Assessment Program. Observers placed aboard yellowfin tuna purse seiners recorded information about fishing activities as well as geographic location, species, and number of cetaceans killed.

One hundred and seven trips were made by U.S.-registered vessels with biological technicians on board in 1990; 69 of these trips reported dolphin kills. Observers were placed aboard all U.S.-registered vessels fishing during 1990, the second year in a 3-year program to observe all fishing trips. The observed incidental kill was 5,083 small cetaceans (spotted, spinner, common, bottlenose, rough-toothed, and unidentified dolphins).

The observed incidental kill of small cetaceans for 1990 (5,083) by U.S.-registered vessels was greatly reduced from the observed incidental kill of 1989 (12,548). The decline was primarily due to the U.S. tuna canneries' policy, initiated in June 1990, of not buying tuna caught in conjunction with dolphins. This policy caused a decrease in the incidental take of small cetaceans in the ETP by U.S.-registered vessels. In 1990, only 64% of all observed trips reported kills while in 1989, 88% reported kills. However, because of the U.S. tuna canneries' policy, there was also a reduction in the number of U.S. purse-seine vessels fishing in the eastern tropical Pacific (ETP). In the first quarter of 1990, the U.S.-registered purse-seine fleet consisted of 31 vessels. By the end of the last quarter of 1990, the U.S.-registered purse-seine fleet was reduced to 17 vessels and most of these were not fishing on dolphins.

The life history data collected for 1990 represent 26% of the observed total kill. This is the third year of increase and compares to 18% in 1988 and 24% in 1989. The fraction of the kill collected for life history data complete with reproductive information is 8% for both males and females, which is slightly higher than the previous 2 years at 7%.

Using Biological Indicators to Infer Changes in Population Abundance for the Eastern Tropical Pacific Dolphin Species

Fishery Biologist Sue Chivers presented a paper, co-authored with Wildlife Biologist Douglas DeMaster, at the Ninth Biennial Conference on the Biology of Marine Mammals, held in Chicago, Illinois, December 5-9, illustrating the problems with using biological indicators to infer changes in dolphin population abundance. The biological data collected on the dolphin species incidentally caught during tuna purse-seine fishing operations in the eastern tropical Pacific (ETP) were used for the analysis. Chivers and DeMaster hypothesized that the significant declines in abundance evident for populations of the central stock of the common dolphin and the eastern and whitebelly stocks of spinner dolphins would be positively correlated with the percentage of mature females pregnant and the percentage of mature females simultaneously pregnant and lactating. An index of population status was derived from the available information on trends in population abundance. The correlations with population status were as predicted for the central common and southern spotted dolphins. For all the other stocks, the range of population status index was narrow and no correlations were found with life history data collected between 1974 and 1990; each of these stocks was reduced in population abundance well below 80% of carrying capacity before biological data were collected.

As a result of these analyses, Chivers and DeMaster recommend that if biological indicators are to be used to monitor changes in population status, life history data collection must begin when the population is near carrying capacity. Biological indicators are also useful to corroborate changes in carrying capacity and are therefore valuable even if not initially collected when exploitation first begins.

Aerial Photographs Used to Estimate Dolphin School Sizes: Precision and Consistency

Beginning in 1987, annual eastern tropical Pacific (ETP) dolphin population surveys were complemented with photographic sampling done with aerial reconnaissance cameras mounted on a Hughes 500-D helicopter. The helicopter is operated from the NOAA ship *David Starr Jordan*.

The method, precision, and consistency by which dolphin school sizes are estimated from aerial photos was recently examined by Fishery Biologist Jim Gilpatrick. Photographed schools are counted independently by three readers with the count mean used to calibrate estimates of the same schools made by shipboard observers. The precision of photo count estimates in this study were described as well as temporal trends in counts done during an 80-day period. Counts were precise with the coefficient of variation (CV) for school size estimates ranging from 1.24% to 14.58%. Most (or 92%) of the schools were counted with precision of 9.0% CV or better. The average percent error for individual readers ranged between 3.51% and 4.57%. Reader counts were consistently random about the means, and estimates did not vary significantly with time. Precision is improved at the start of a counting "period" when a "warm-up" practice count session is conducted.

Use of Aerial Photographs to Identify Common Dolphin Stocks

Using measurements made on an STK stereo comparator, an analysis of aerial photographs identifying geographic forms of common dolphins has been made by La Jolla Fishery Biologists Wayne Perryman and Morgan Lynn. They have found at least four morphologically distinct geographic forms in the eastern tropical Pacific (ETP). They compared length data for common dolphins from the northern, central, and southern regions and found significant differences in average length for adult animals and for "adult females," which are defined as animals accompanied by a calf. They found they could easily distinguish between the large, long-beaked neritic form and the much smaller, short-beaked common dolphins that occur sympatrically off Baja and southern California. Additionally, they found that common dolphins sampled within the central region were significantly longer than those from the northern or southern areas. Northern common dolphins were about 5 cm shorter on average than the southern animals, but the data were inconsistent. They also calculated birth month for calves, assuming linear growth during the first year, and found that reproduction appears to be pulsed in the northern and southern regions and evenly distributed in the central area. Their work demonstrates a new, non-invasive method for obtaining unbiased life history and morphological data.

Genetic Sequencing Used to Distinguish Between Two Forms of Common Dolphin

An investigation using genetic sequencing information to differentiate between two types of common dolphins was carried out by Andy Dizon of the La Jolla Laboratory, Patricia Rosel of the Scripps Institution of Oceanography, and John Heyning of the Los Angeles County Museum of Natural History. The experiment stems from the uncertainty existing among taxonomists and marine mammal managers as to the proper taxa level to apply to the two unique-but-overlapping forms inhabiting these waters. At present, they are managed as a single unit.

Using the polymerase chain reaction, the researchers amplified the control region of mtDNA from 29 samples and determined the nucleotide sequence of 440 base pairs spanning the most variable portion of the control region. Phylogenies were then made from the sequences using the common dolphin from the Black Sea in addition to the killer whale and Commerson's dolphin as outgroups.

The results of the research indicate that for the region sequenced, the long-beaked form is genetically homogenous and distinct from the short-beaked form. They also found that the short-beaked form is more closely related to the Black Sea animals.

Status of Small Cetaceans in Eastern Tropical Pacific

Since the passage of the Marine Mammal Protection Act, over 1.25 million dolphins are estimated to have been killed incidentally during yellowfin tuna purse seining operations in the eastern tropical Pacific (ETP). The major species affected are the spotted dolphin and the spinner dolphin. Common dolphins are also taken in significant numbers.

Doug DeMaster gave a presentation at the Wildlife 2001: Populations Conference held in Oakland, California, July 29-31, 1991, entitled "Status of dolphin stocks in the eastern tropical Pacific." The paper, authored by DeMaster, E. F. Edwards, P. Wade, and J. E. Sisson, reviews the status of these populations relative to stock structure, current population size, levels of fishery-related mortality, and trends in abundance. Also discussed was a proposed management strategy based on managing mortality levels so that they would not exceed some fraction of expected net production rather than using the strategy of managing mortality based on trends in relative abundance.

The manuscript summarized preliminary findings made to date, which consist of a series of five surveys (1986-90) using dedicated research vessels, analysis of marine mammal sightings data collected by observers aboard U.S. and non-U. S. tuna vessels, and analysis of life history data collected by observers aboard U.S. tuna vessels. Preliminary results indicate that there are no statistically significant trends in abundance for any of the stocks in recent years.

Program for Developing Dolphin-safe Fishing Methods

The NMFS Southwest Region has established the eastern tropical Pacific (ETP) gear program aimed at development of alternative methods for tuna fishing that will reduce or eliminate the incidental mortality of dolphins. The program has been established at the SWFSC in La Jolla to develop refinements to existing gear and fishing methods and to develop new gear and techniques that will help maintain the ETP tuna purse-seine fishery while reducing or eliminating dolphin mortality.

Southwest Regional employee John Young is on special assignment to the Marine Mammal Division in La Jolla where he has been working with Doug De-Master and Liz Edwards to develop alternative fishing methods. Two of his projects thus far have involved fish aggregating devices (FADs) and light detecting and ranging devices (LIDARs). Young is currently working on a project with the Inter-American Tropical Tuna Commission (IATTC) on FAD research, with funding provided by Bumble Bee Seafoods, Inc.

In March 1992, the Center developed and presented for review a comprehensive Dolphin-Safe Research Program for investigating alternative tuna-fishing methods and gear which do not affect dolphins. De-Master and Edwards assembled a series of proposals for consideration which included recommendations for studies on sonic tracking of pure schools of tuna and dolphins, radio tracking dolphins, and examining food habits of tuna and dolphins.

Dolphin Population Abundance Program

Estimation of dolphin population abundance was addressed at the eastern tropical Pacific (ETP) Dolphin Stock Assessment Program Status Workshop held in November 1991. Tim Gerrodette used a cross-validation approach to assess several methods of adjusting research-vessel observer estimates of dolphin school size compared with accurate counts of 171 dolphin schools based on high-quality aerial photographs. For 10 out of 23 observers, estimates of school size were improved by calibrating against schools of known size. For the other 13, estimates could not be significantly improved. A weighted mean of the observers' calibrated estimates provided the best combined estimate of school size, based on minimum squared error. Overall, Gerrodette found that dolphin school size was accurately estimated by observers on research vessels although there was considerable variability in the estimates.

Paul Wade and Gerrodette completed an analysis of five years (1986-1990) of abundance data collected during the monitoring of porpoise stocks research-vessel surveys in the ETP. Their findings were presented at the 1991 International Whaling Commission (IWC) Scientific Committee meetings as well as at the November 1991 Stock Assessment Workshop. Their study presents a stratified analysis which gives estimates of relative abundance of nine stocks of the four target species (spotted, spinner, striped, and common dolphins), using line-transect methods. They found no significant trends in population size for any dolphin stock during 1986-1990 although the statistical power of detecting trends was low.

Wade has also been involved in conducting an assessment of the status of the eastern spinner dolphin stock in the ETP. He used current estimates of abundance from research vessel surveys in combination with estimates of mortality from tuna vessel observer data to estimate the pre-exploitation or historical population size for the eastern spinner stock, using the back-calculation technique (SWFSC Admin. Report LJ-91-12). A range of values was used for the current population size, for the maximum net productivity level (MNPL), for z (the shape parameter that sets maximum net productivity level), and for the number of animals killed relative to the estimated mortality. He found that relative population sizes (current population size divided by historical population size) ranged from 0.18 to 0.73. In most cases, relative population size was well below MNPL. His results indicated that the stock of eastern spinner dolphins is probably depleted. These findings were also discussed at the November workshop.

Power to Detect Linear Trends in Dolphin Abundance: Estimates Derived from Tuna-vessel Observer Data 1975-1989

The power of detecting trends in dolphin abundance using tuna-vessel observer data (TVOD) has been investigated by Elizabeth Edwards and Peter Perkins. Weighted linear regressions were calculated for 5-, 8-, and 10-year series of abundance indices, derived from TVOD collected 1975-1989, for 8 stocks of eastern tropical Pacific (ETP) dolphins. Statistical power of conclusions about the absence of trend was calculated for those series with statistically insignificant regressions ($P > 0.10$; 2-sided alternative). Detectable trend was then calculated for each series as a function of series length and estimated standard error of the estimated trend for each series. Estimates of power and detectable trend were derived using the non-central t distribution assuming Type I (a) and Type II (b) error levels = 0.10.

Power estimates for the eight stocks of ETP dolphins for apparent rates of change between 0 and 100% per year were generally low (10-50%), even for 10-year series. Detectability of trends increased dramatically with increases in series length, but decreased to ecologically or managerially relevant levels (about 5% per year) only for northern spotted dolphins and only for series 8-10 years in length. For all other stocks, detectable trends were rarely less than 25% per year, regardless of series length.

Detecting relatively small linear trends in dolphin abundance using TVOD and standard weighted linear regression techniques is apparently not feasible except perhaps for northern spotted dolphins. More versatile, curvilinear smoothing methods will probably prove to be more effective.

Dolphin Ecology Program

Interannual variability in dolphin habitats in the eastern tropical Pacific (ETP) has been analyzed by Steve Reilly and Paul Fiedler. They first used a canonical correspondence analysis which is an eigenvector ordination technique, including direct gradient analysis, to investigate habitat use by the four target dolphin species in the ETP during 1986-1990. These data were collected during the annual monitoring-of-porpoise-stocks research vessel surveys. They also analyzed the results of a canonical correspondence analysis of data from research vessel surveys and tuna vessel sightings. From these analyses, they have found ways that environmental data may be used to reduce bias in dolphin-abundance estimates based on tuna vessel observer data (TVOD).

Completion of First California Marine Mammal Survey

On November 5, 1991, the NOAA research vessel *McArthur* entered port in San Francisco, completing the fourth and final leg of the first California Marine Mammal Survey. The cruise was conducted in four legs, lasting between 19 and 24 days each, and most of the survey effort was conducted within 200 nautical miles of the California coast. All survey effort was conducted north of Mexican waters and south of the Oregon border.

The overall objectives of the project were to estimate abundance and to understand distribution of dolphins and whales which are commonly found in California waters and incidentally killed in U.S. commercial gillnetting operations. The survey was designed to collect data for estimating the density, size, and species composition of dolphin and whale aggregations in order to make mean and minimum estimates of their population sizes. Physical, biological, and oceanographic data regarding habitat of marine mammals were also collected in order to better understand marine mammal distributions.

Preliminary calculations indicate that 733 schools of cetaceans were sighted. Of the total schools sighted, 40% were seen on Leg 1, 25% on Leg 2, 22% on Leg 3, and 13% on Leg 4 of the 5544 nautical miles of trackline that were surveyed.

Common dolphins were the most frequently encountered dolphin (156 sightings) and blue whales were the most frequently encountered large whale (64 sightings). Biopsy samples, environmental data samples, sonobuoy recordings, and photographs that were taken are currently being analyzed and will be used during an upcoming workshop discussing the status of cetacean stocks. Final reports will be distributed by July 1992.

Dolphin Mortality in U.S. Tuna Fishery Declines in 1990 and 1991

According to data collected by on-board observers from the National Marine Fisheries Service (NMFS), the 1990 dolphin kill was well below the allowable annual quota of 20,500 and was the lowest on record for the U.S. fleet. The estimated number of dolphins killed in the U.S. eastern tropical Pacific (ETP) tuna purse seine fishery in 1990 was 5,083, down 60% from the estimated 1989 kill of 12,643.

According to the NMFS, the major reasons for the marked decrease in dolphin kill in 1990 were the reduction in the size of the U.S. fleet in the eastern Pacific and an increase in the fishing effort on non-dolphin-associated tuna by the remaining U.S. vessels, both consequences of the U.S. tuna canners' decision in April 1990 to purchase only "dolphin safe" tuna.

In 1990, observer coverage was 100%; observers were on board 92 U.S. tuna purse seiner fishing trips monitoring 1,845 sets on dolphins. Forty-four of those trips were with NMFS observers while the remainder (48 trips) were with the Inter-American Tropical Tuna Commission observers.

The dolphin kill-per-set rate in 1990 was 2.8, down 22% from the 1989 rate of 3.6. It was the lowest rate achieved by the U.S. fleet since 1979, when the kill-per-set rate was 2.7. The dolphin kill-per-ton of tuna rate in 1990 was 0.14, down 26% from the 1989 rate of 0.19. This is the lowest per-ton rate on record. The average tuna catch per observed dolphin set in 1990 was 19.1 short tons (t), virtually the same as in 1989.

Based on preliminary data covering the first 6 months of 1991, the dolphin kill and kill-per-set rates continued to fall: 373 dolphins were killed in 147 sets for a kill-per-set rate of 2.5. Of the 12 U.S. purse seiners that were active in the ETP and permitted to set on dolphins during the first half of 1991, only 5 actually made dolphin sets.

VI. OTHER TUNA-RELATED RESEARCH AT SWFSC

Atlantic Ocean Catch Statistics Updated

Donna Da Rodda, computer programmer at the La Jolla Laboratory, has completed updating the Southwest Fisheries Science Center's Atlantic tuna catch data base. The data base now contains data for the period 1950 to 1989, or the latest data available from the International Commission for the Conservation of Atlantic Tunas. Catches are for tuna and tuna-like species caught by countries using a variety of gears in the Atlantic Ocean. The data base is stored in a commercial data-base package, FOXBASE, and can also be accessed through DBASE.

The data base can be used to generate catch trends by querying the data base in DBASE and plotting the results in LOTUS. For example, the following statistics were obtained by querying the data base for catch trends for the major tropical and temperate-tuna species: total Atlantic catches of yellowfin tuna increased to a high of 160,412 metric tons (t) in 1983, skipjack tuna to a high of 153,035 t in 1982, and bigeye tuna to a high of 74,277 t in 1985. Both bigeye and yellowfin tuna catches increased in 1989 over those in 1988, whereas skipjack catches decreased. Bluefin tuna catches decreased from a high of 37,047 t in 1955 to lows of 14,492 t in 1972 and 14,532 t in 1973, and they have fluctuated between 18,000 and 29,000 t since then. Albacore catches rose to 90,353 t in 1964 and 90,732 t in 1965, and in recent years, to 86,247 t in 1986; however, they dropped to 61,411 t in 1989.

The data base can also be used to assess proportion of catches by gear or country. An example of yellowfin tuna catches by gear shows that the largest portion of the 1989 catch was taken by purse seiners. This is an increase of 4% from the average proportion taken by purse seiners during 1984 to 1988.

Tuna Movement Based on Tag Recapture Data

Operations Research Analyst Carlos Salvadó has completed a general theoretical model for analyzing movement of tunas and for estimating the population dynamics parameters by means of tag recapture data. The model uses the Green function, and it considers each release of tagged tunas, performed in a short time and in a short area (zone), a point source of tagged tuna which may be used for studying the migration of the population. The population dynamics of the tunas is better understood when tagged fish are released throughout the core range of the population.

This model is stochastic and is equivalent to a Markovian process of movement of tunas from zone to zone. The Green function is a measure of the probability of movement of tunas from one location to another. The parameters in the model include catchability, natural death rate, and advective velocity and diffusivity and can be estimated by maximum-likelihood methods or by computing the movements of the Green function. This latter technique is simpler and requires less computations.

The next phase of study is under way and will involve a series of simulations to determine the sensitivity of parameter estimates to errors in input values and data and application of the model to North Pacific albacore data.

VII. SWFSC PUBLICATIONS ON TUNA AND TUNA-RELATED SUBJECTS

May 1, 1991 to April 30, 1992

Published

Barlow, J., and P. Boveng. 1991. Modeling age-specific mortality for marine mammal populations. Mar. Mammal Sci. 7(1):50-65.

Boggs, C. H., and J. F. Kitchell. 1991. Tuna metabolic rates estimated from energy losses during starvation. Physiol. Zool. 64(2):502-524.

Bowlby, C. E., P. D. Scoggins, R. T. Watson, and M. L. Reddy. 1991. Hawaiian monk seal, *Monachus schauinslandi*, at Kure Atoll, 1982-83. U.S. Dep. Commer., NOAA Tech. Memo, NOAA-TM-NMFS-SWFSC-155, 29 p.

Brill, R. W., and P. G. Bushnell. 1991. Effects of open- and closed-system temperature changes on blood oxygen dissociation curves of skipjack tuna, *Katsuwonus pelamis*, and yellowfin tuna, *Thunnus albacares*. Can. J. Zool. 69:1814-1821.

Brill, R. W., and P. G. Bushnell. 1991. Metabolic and cardiac scope of high energy demand teleosts, the tunas. Can. J. Zool. 69:2002-2009.

Bushnell, P. G., and R. W. Brill. 1992. Oxygen transport and cardiovascular responses in skipjack tuna *Katsuwonus pelamis*, and yellowfin, *Thunnus albacares exposed* to acute hypoxia. J. Comp. Physiol. B 162:131-143.

Bushnell, P. G., and R. W. Brill. 1991. Responses of swimming skipjack, *Katsuwonus pelamis*, and yellowfin, *Thunnus albacares*, tunas to acute hypoxia, and a model of their cardiorespiratory function. Physiol. Zool. 64(3):787-811.

Dizon, A. E., S. O. Southern, and W. F. Perrin. 1991. Molecular analysis of mtDNA types in exploited populations of spinner dolphins, *Stenella longirostris*. Rep. Int. Whal. Comm. (Special Issue 13), SC/S89/Gen11, pp. 183-202.

Edwards, E. F., and P. M. Kleiber. 1991. CHARTOPS: Simulating short-term use of the tuna purse seine fleet to survey dolphin schools in the eastern tropical Pacific Ocean. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-163, 22p.

Gerrodette, T., and W. G. Gilmartin. 1991. Demographic consequences of changed pupping and hauling sites of the Hawaiian monk seal. Conserv. Biol. 4(4):423-430.

Hill, P. S., R. C. Rasmussen, and T. Gerrodette. 1991. Report of a marine mammal survey of the eastern tropical Pacific aboard the research vessel *David Starr Jordan*, July 28-December 6, 1990. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-158, 133p.

Hill, P. S., R. C. Rasmussen, and T. Gerrodette. 1991. Report of a marine mammal survey of the eastern tropical Pacific aboard the research vessel *McArthur*, July 28-December 6, 1990. U.S. Dep. Commer., NOAA Tech. Memo, NOAA-TM-NMFS-SWFSC-159, 142p.

Myrick, A. C., Jr. 1991. Some new and potential uses of dental layers in studying delphinid populations, pp. 251-279. *In Fishes.*

K. Pryor and K. S. Norris (editors), Dolphin societies: discoveries and puzzles. Univ. California Press, Berkeley and Los Angeles.

Perrin, W. F. 1991. Why are there so many kinds of whales and dolphins? BioScience 41(7):460-461.

Perrin, W. F., P. A. Akin, and J. V. Kashiwada. 1991. Geographic variation in external morphology of the spinner dolphin, *Stenella longirostris*, in the eastern Pacific and implications for conservation. Fish. Bull., U.S. 89:411-428.

Petit, M., J. Stretta, S. M. Simier, and A. Wadsworth. 1989. Surface anomalies and tuna fishing. *In* MAPPEMONDE 89(3) Esditions GIP RECLUS. (Engl. transl. by W. G. Van Campen, 1991, 15p., Transl. No. 142; available U.S. Dep. Commer., NOAA, NMFS, SWFSC, Honolulu Lab, Honolulu, HI 96822-2396.)

Philbrick, V., P. Fiedler, S. Reilly, R. Pitman, L. Ballance, G. Thomas, and D. Behringer. 1991. Report of ecosystem studies conducted during 1990 ETP dolphin survey on research vessel *David Starr Jordan*. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-160, 117p.

Philbrick, V., P. Fiedler, S. Reilly, R. Pitman, L. Ballance, G. Thomas, and D. Behringer. 1991. Report of ecosystem studies conducted during the 1990 eastern tropical Pacific dolphin survey on the research vessel *McArthur*. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-161, 123p.

Sakagawa, G. T. 1991. Are U.S. regulations on tuna-dolphin fishing driving U. S. seiners to foreign-flag registry? N. Am. J. Fish. Mgmt. 11(3):241-252.

Sudekum, A. E., J. D. Parrish, R. L. Radtke, and S. Ralston. 1991. Life history and ecology of large jacks in undisturbed, shallow, oceanic communities. Fish. Bull., U. S. 89:493-513.

Approved by Science and Research Director, SWR, for Publication

Atkinson, S., W. G. Gilmartin, and B. L. Lasley. Testosterone response to a gonadotrophin-releasing hormone agonist in Hawaiian monk seals, *Monachus schauinslandi*. For consideration for publication in *Journal of Reproduction Fertility*.

Brill, R. W., P. G. Bushnell, D. R. Jones, and M. Shimizu. Effects of acute temperature change, *In vivo* and *in vitro*, on the acid-base status of blood from yellowfin tuna, *Thunnus albacares*. For consideration for publication in *Canadian Journal of Zoology*.

Brill, R. W., D. Heidi, and J.B. Graham. Basic concepts relevant to heat transfer in fishes, and their use in measuring the physiology thermoregulatory abilities of tunas. For consideration for publication in *Environmental Biology of Fishes.*

Gilmartin, W. G. Oahu's monk seal pup. For consideration for publication in *Aloha Magazine.*

Gilmartin, W. G., T. C. Johanos, and T. Gerrodette. Estimates of population size for the Hawaiian monk seal, *Monachus schauinslandi*, 1983-88. For consideration for publication in *Marine Mammal Science.*

Wade, P. R. Estimation of historical population size of eastern spinner dolphins. For consideration for publication in *Fishery Bulletin, U.S.*

Administrative Reports

Bartoo, N., D. Holts, and C. Brown. 1991. Report on the 1990 cooperative North Pacific albacore observer project. SWFSC Admin. Rep., La Jolla, LJ-91-09, 16p.

Boehlert, G. W., and B. C. Mundy. 1991. Vertical and onshore-offshore distribution of tuna larvae (Pisces, Scombridae) off Oahu, Hawaii. SWFSC Admin. Rep., Honolulu, H-91-11, 40p.

Boggs, C. H. 1991. A preliminary examination of catch rates in Hawaii's troll and handline fisheries over a period of domestic longline fishery expansion. SWFSC Admin. Rep., Honolulu, H-91-05, 62p.

Bright, A. M., and S. J. Chivers. 1991. Postnatal growth rates: A comparison of northern and southern stocks of the offshore spotted dolphin, *Stenella attenuata.* SWFSC Admin. Rep., La Jolla, LJ-91-30, 26p.

Chivers, S. J., and D. P. DeMaster. 1991. Potential biological indices evaluated for four species of eastern tropical Pacific dolphin. SWFSC Admin. Rep., La Jolla, LJ-91-29.

Chivers, S. J., and A. C. Myrick, Jr. 1991. Comparison of age at sexual maturity for two stocks of offshore spotted dolphins subjected to differential rates of exploitation. SWFSC Admin. Rep., La Jolla, LJ-91-31, 33p.

Coe, J. M., and C. W. Oliver. 1991. An assessment of a federal regulation to curtail "sundown" sets involving marine mammals by the U.S. tuna purse-seine fleet. SWFSC Admin. Rep., La Jolla, LJ-91-20, 42p.

Dizon, A. E., W. F. Perrin, and P. A. Akin. 1991. Stocks of dolphins (*Stenella* spp. and *Delphinus delphis*) in the eastern tropical Pacific: a phylogeographic classification. SWFSC Admin. Rep., La Jolla, LJ-91-33.

Dizon, A. E., P. E. Rosel, and J. E. Heyning. 1991. Molecular phylogeny of two forms of common dolphin. SWFSC Admin. Rep., La Jolla, LJ-91-32.

Dollar, R. A. 1991. Summary of swordfish longline observations in Hawaii, July 1990-March 1991. SWFSC Admin. Rep., Honolulu, H-91-09, 13 p.

Dollar, R. A., R. Y. Ito, K. E. Kawamoto, and K. C. Landgraf. 1991. Summary of swordfish longline observations in Hawaii, July-October 1990. SWFSC Admin. Rep., Honolulu, H-91-03.

Edwards, E. F., and D. P. DeMaster. 1991. Workshop Report: Survey design review panel: ETP dolphin monitoring program, July 10-11, 1990. SWFSC Admin. Rep., La Jolla, LJ-91-15, 23p.

Edwards, E. F., and P. Perkins. 1991. Power to detect trends in dolphin abundance: Estimates from tuna-vessel observer data 1975-1989. SWFSC Admin. Rep., La Jolla, LJ-91-34.

Fiedler, P. C., and S. B. Reilly. 1991. Interannual variability in dolphin habitats and abundances estimated from tuna vessel sightings in the eastern tropical Pacific, 1975-1989. SWFSC Admin. Rep., La Jolla, LJ-91-35.

Gerrodette, T. 1991. Calibration of shipboard estimates of dolphin school size from aerial photographs. SWFSC Admin. Rep., La Jolla, LJ-91-36.

Gerrodette, T., P. C. Fiedler, and S. B. Reilly. 1991. Including habitat variability in line-transect estimation of abundance and trends. SWFSC Admin. Rep., La Jolla, LJ-91-37.

Hamm, D. C., M. M. C. Quach, and L. K. Timme. 1991. Fishery statistics of the western Pacific, Vol. VI. SWFSC Admin. Rep., Honolulu, H-91-01.

Herrick, S. F., and J. G. Lee. 1991. Current trends in worldwide tuna production and trade. SWFSC Admin. Rep., La Jolla, LJ-91-43.

Heyning, J. E., and W. F. Perrin. 1991. Re-examination of two forms of common dolphins (genus

Delphinus) from the eastern North Pacific; evidence for two species. SWFSC Admin. Rep., La Jolla, LJ-91-28, 50p.

Ito, R. Y. 1991. Western Pacific pelagic fisheries in 1990. SWFSC Admin. Rep., Honolulu, H-91-10.

Kleiber, P., and H. Nakano. 1991. Analysis of catch per effort in Japanese pole-and-line albacore fishery. SWFSC Admin. Rep., La Jolla, LJ-91-11, 14p.

Oliver, C. W. 1991. 1979-1980 tuna/porpoise data-editing criteria for range, blankness, and logical error statements: porpoise data management system. SWFSC Admin. Rep., La Jolla, LJ-91-06, 192p.

Oliver, C. W. 1988-1991 field studies on pinnipeds at San Clemente Island. SWFSC Admin. Rep., La Jolla, LJ-91-27, 30p.

Oliver, C. W. 1991. Documentation of the 1959-1988 editing criteria for porpoise life-history data: porpoise data management system. SWFSC Admin. Rep., La Jolla, LJ-91-07.

Oliver, C. W. 1991. Trip report for a marine mammal aerial survey over the Southern California Bight (April 13-15, 1982). SWFSC Admin. Rep., La Jolla, LJ-91-23, 37p.

Palka, D. 1991. Accounting for school bias size using a bivariate-hazard-rate detection function in line-transect surveys of dolphins from the eastern tropical Pacific Ocean. SWFSC Admin. Rep., La Jolla, LJ-91-38.

Perrin, W. F., G. D. Schnell, D. J. Hough, J. W. Gilpatrick, and J. V. Kashiwada. 1991. Re-examination of geographical and cranial variation in the pantropical spotted dolphin, *Stenella attenuata*, in the eastern Pacific. SWFSC Admin. Rep., La Jolla, LJ-91-39.

Perryman, W. L., and M. S. Lynn. 1991. Identification of geographic forms of common dolphins, *Delphinus delphis*, from aerial photographs. SWFSC Admin. Rep., La Jolla, LJ-91-40.

Perryman, W. L., and M. S. Lynn. 1991. Length distribution of striped dolphins from aerial photographs: Are stocks identifiable? SWFSC Admin. Rep., La Jolla, LJ-91-41.

Reilly, S. B., and P. C. Fiedler. 1991. Interannual variability in dolphin habitats in the eastern tropical Pacific, 1986-1990. SWFSC Admin. Rep., La Jolla, LJ-91-42.

Rensink, G. M. 1991. Summary of the 1989-90 U.S. South Pacific albacore fisheries data. SWFSC Admin. Rep., La Jolla, LJ-91-14, 21p.

Rensink, G. M., and F. R. Miller. 1991. Summary of the 1990 North Pacific albacore fisheries data. SWFSC Admin. Rep., La Jolla, LJ-91-21, 33p.

Sakagawa, G. T., and P. Kleiber. 1991. Fisheries and stocks of yellowfin tuna in the Pacific and Indian Oceans--status and review of assessment methods. SWFSC Admin. Rep., La Jolla, LJ-91-16, 28p.

Thompson, C., T. Dickerson, G. Walls, and J. Morgan. 1991. Status of the California coastal pelagic fisheries in 1990. SWFSC Admin. Rep., La Jolla, LJ-91-22, 24p.

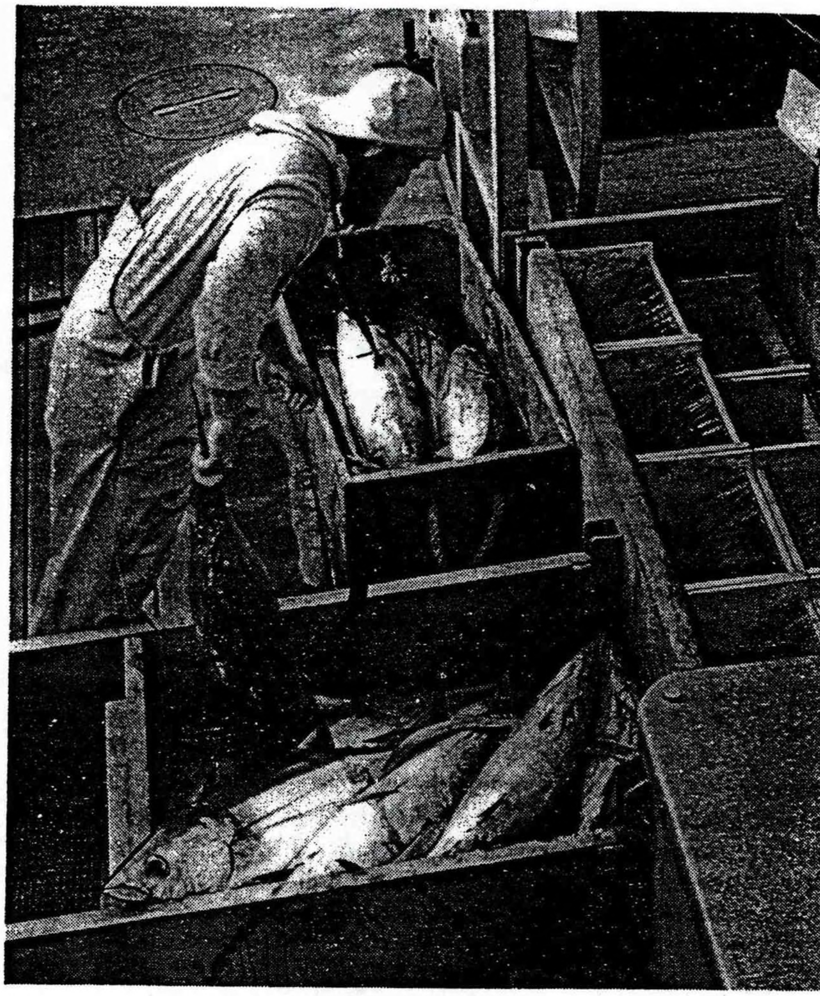
TSchug, D. M. 1991. The prospects for an international fisheries management regime for South Pacific albacore. SWFSC Admin. Rep., Honolulu, H-91-02.

Wade, P. R. 1991. Estimation of historical population size of eastern spinner dolphins. SWFSC Admin. Rep., La Jolla, LJ-91-12.

VIII. APPENDIX

SOUTH PACIFIC ALBACORE

The albacore, *Thunnus alalunga*, is an oceanic scombroid found in the Pacific, Atlantic, and Indian oceans. In the Pacific it occurs in two populations occupying the Northern and Southern Hemispheres. There is no evidence of mixing between the North Pacific and South Pacific albacore populations, and the evidence of differences between them is considerable. Hence, they are treated as separate stocks for management purposes. Similarly, albacore in the Indian Ocean is considered to be a separate stock from South Pacific albacore although there is little confirming evidence. The South Pacific albacore stock ranges from equatorial waters to the southern boundary of the Subtropical Convergence Zone (STCZ, approximately 35-40°S) and between the South American coast and Tasmania.



Longlining for albacore.

The limited data available indicate that South Pacific albacore spawn in subequatorial waters between 10° and 20° south latitude primarily from November to April. Juveniles first recruit to surface troll and drift gillnet fisheries in the STCZ at about 45 cm fork length (FL) (18 in, 5 lb, age 1.5 years). Maturity is reached at 80-90 cm FL (32-35 in, 25-35 lb, age 5-6 years). The largest South Pacific albacore, about 120 cm FL (47 in, 70-80 lb, age approximately 12 years), are caught by the longline fishery. The distribution of catchable-sized albacore varies seasonally. During July-November they appear to inhabit primarily the lower and middle latitudes, then extend their range to the STCZ during the southern summer. Albacore favor sea temperatures in the range of 15-20°C, and their distribution and availability are closely linked to oceanographic conditions. Higher catch rates are expected in areas with a relatively shallow mixed layer and sharp temperature gradient.

South Pacific albacore exploitation began in 1952 with the post-World War II expansion of Japan's distant-water tuna longline fleet. U.S. canneries were built at Pago Pago, American Samoa, to process the catch of Japanese vessels based there. Longliners from the Republic of Korea and the Republic of China

(ROC, Taiwan) entered the fishery in 1958 and 1963, respectively, also landing a significant share of their catch in Pago Pago.

During the late 1960s, the Japanese longline fleet began to divert fishing effort from albacore to bigeye tuna and southern bluefin tuna and withdrew from South Pacific bases. Their albacore catch declined as the catch by Korean and Taiwanese longliners grew. During the two decades between 1968 and 1987, the total annual longline catch fluctuated between approximately 21,000 mt and 38,000 mt, averaging about 32,000 mt, with no long-term trend. The longline fishery harvests primarily large, mature albacore exclusively for canning.

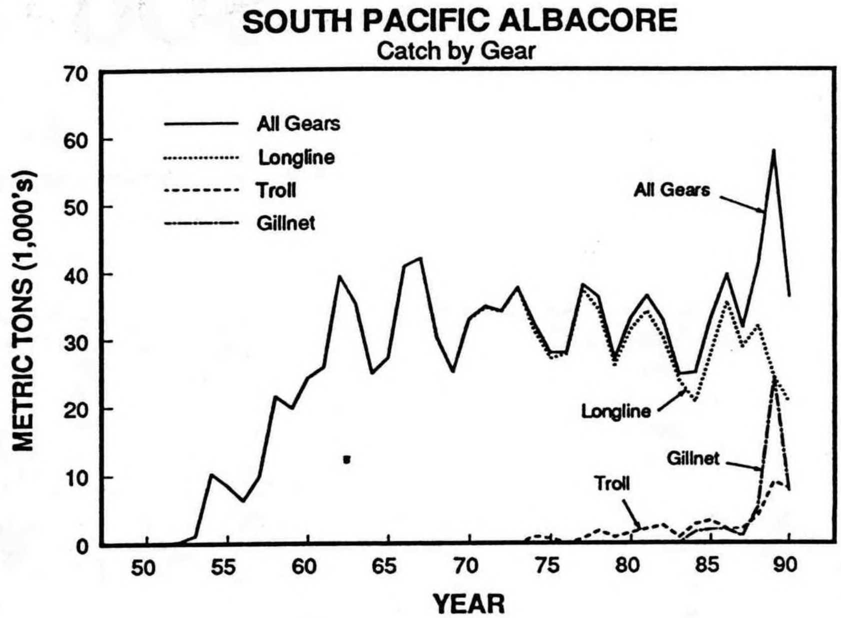


Figure 10. South Pacific albacore catch by gear type.

Surface fishing yields mostly small, immature albacore. Until the early 1980s, the surface catch of South Pacific albacore was minor; coastal trollers and sportfishing boats in New Zealand and Australia landed 2,500 mt or less each year. During the 1980s, prospects for expanding surface albacore fisheries into offshore waters of the STCZ were explored by research vessels and commercial fishing interests from Japan, France, United States, New Zealand, and Taiwan. By the 1988-89 surface fishing season (November-April) over 9,000 mt of albacore were being caught in offshore STCZ grounds by drift gillnet fleets from Japan and Taiwan and a troll fleet from the U.S. (primarily), New Zealand, and Canada. As both gillnet and troll fleets expanded further in the 1988-89 season, the surface catch exploded to nearly 33,500 mt, including about 24,500 mt taken by gillnet vessels. The total 1989 catch, including about 24,500 mt caught by longliners and small amounts by other surface gear, rose to a record 57,824 mt, worth approximately US $115 million ex-vessel. Most of the surface catch, including all of the drift gillnet catch and U.S. troll catch, has been taken in international waters beyond the jurisdiction of South Pacific island states. The longline catch, however, is taken both in international waters and within South Pacific 200-mile exclusive economic zones.

Regional concerns quickly arose over the ecological effects of drift gillnet fishing and the impacts of the increased surface catch, primarily by gillnet vessels, on the South Pacific albacore stock and the established longline fisheries. In November 1989, South Pacific delegates met in Wellington, New Zealand, to adopt a convention prohibiting the use of drift gillnets in the South Pacific region by signatory nations and discouraging use of the gear by others. In response, Japan and Taiwan reduced their South Pacific driftnet fleets by two-thirds in the 1989-90 fishing season and the driftnet catch declined (Figure 10). Korea announced that it would cease exploratory driftnet fishing in the region and not pursue driftnet fishery development plans.

In December 1989, U.N. General Assembly Resolution 44/225 was issued, supported by South Pacific nations, Japan, and the United States, calling for a moratorium on South Pacific drift gillnet fishing by July 1, 1991, to be in effect until appropriate conservation and management arrangements for South Pacific albacore are established. Subsequently, Japan announced a total withdrawal of its drift gillnet fleet from the region one year in advance of the moratorium date. Taiwan, its fishing season already completed by the July 1 deadline, has said it will comply with the moratorium.

Until the recent expansion of surface fisheries, assessment of the South Pacific albacore stock focused on the adult segment of the population targeted by the longline fleet. Catch and catch per unit effort (CPUE) statistics suggested a steady decline in the adult stock as the longline fishery developed. Production models fitted to historical longline catch and CPUE statistics in the late 1970s and early 1980s indicated a maximum sustainable yield

Table 1. Estimated South Pacific albacore catch (1000's metric tons) by year and fishing method, 1981-1990.

Fishing method	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Longline	34.24	30.27	23.84	20.64	27.87	35.63	28.77	31.91	24.38	20.60
Gillnet	0	0	0.03	1.58	1.93	1.94	0.92	5.27	24.45	7.57
Troll	2.08	2.43	0.74	2.77	3.25	2.01	1.98	3.93	8.90	8.01
Other	0.20	0.20	0.20	0.10	0.10	0.20	0.20	0.20	0.20	0.20
TOTALS	36.53	32.90	24.82	25.10	33.15	39.68	31.77	41.21	57.82	36.28

for the longline fishery of 33,000-35,000 mt/year (Table 1) in the presence of the small (ca. 2,000 mt/year) surface fishery prevailing then. Thus, the longline fishery yield was considered to be at its maximum sustainable level (Table 2). Because of inadequate data and lack of knowledge of South Pacific albacore population dynamics, there are no reliable estimates of the potential aggregate yield from all fisheries or the effects of higher surface catches on longline catch rates. However, further reductions in longline CPUE are expected due to expanded surface fisheries. In addition to concerns over surface-longline fishery interactions, questions exist about the effects of further spawning stock reduction on recruitment.

In 1986, scientists from the United States (NMFS), New Zealand, France, Japan, Taiwan, Korea, the South Pacific Commission Tuna and Billfish Program, and various South Pacific nations established the South Pacific Albacore Research (SPAR) group. The informal SPAR arrangement provides for exchange and compilation of South Pacific albacore fishery data and for collaboration in fishery monitoring, stock assessment, and research. SPAR workshops have been convened in New Zealand (1986), Fiji (1989), and New Caledonia (1990). The SPAR group successfully promoted cooperative oceanographic and albacore trolling surveys in the STCZ, albacore tagging programs, and studies of albacore age and growth and reproductive biology. Research is being conducted by the staff at the Honolulu Laboratory and the South Pacific Commission to develop a length-age structured model of stock and fishery dynamics for assessment of yield potentials and fishery interactions.

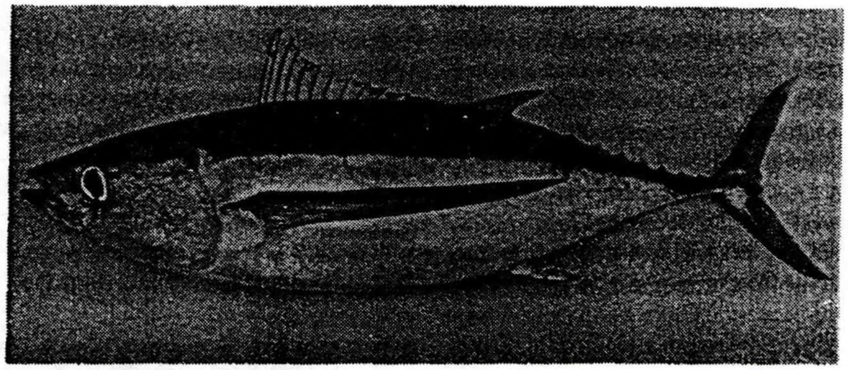
In tandem with the Wellington Convention on drift gillnets, government and industry officials from the South Pacific region and distant-water fishing nations have met in New Zealand, Fiji, Solomon Islands, and New Caledonia to exchange views on a South Pacific albacore management regime. Such talks are continuing, and scientific guidance is being provided by SPAR.

Table 2. Resource Summary- South Pacific albacore.

Average catch (1988-90)	=	45,000 mt
Long-term potential catch:		
-Longline fishery MSY with 2,000 mt surface fishery (estimated by production model)	=	33,000-35,000 mt
-Potential yields for other fishery scenarios	=	Unknown
ABC (1990)	=	>35,000 mt
Importance of recreational fishery	=	Minor
Management	=	Multilateral regime under discussion
Status of exploitation	=	Unknown overall, but adults appear to be fully exploited
Size at 50% recruitment	=	60 cm- surface 90 cm- longline (male and female)
Size at 50% maturity	=	85-90 cm (male and female)
Assessment approach	=	Production model applied to longline gear taking adults; age-based models for more comprehensive assessments under dev.
Fishing strategy	=	None
F (1990)	=	Unknown

M= 0.2 $F_{0.1}$= Unknown F_{max}= Unknown

NORTH PACIFIC ALBACORE



The North Pacific albacore resource is considered to be a separate stock from the South Pacific albacore, based on tagging and fishery data. The northern stock is among the best understood of the Pacific tunas. Adults (ages 5 to at least 10 years; ≥85 cm fork length, FL) are distributed from the North Pacific Transition Zone (NPTZ), (mixing zone between the subarctic and subtropical fronts) approximately between 35°N latitude and 43°N latitude, to the equator, with concentrations in a band between 35°N and 10°N latitude. Juveniles are distributed from Asia to North America, mostly in the NPTZ.

Spawning in the North Pacific takes place during the summer in the subtropical areas between 10°N and 20°N latitude. Samples of small albacore suggest that recruitment to the fisheries may occur principally off Japan in the spring and to a lesser extent in other areas.

Juvenile albacore make extensive annual migrations between Japan and North America. In general, it appears that the bulk of the juvenile albacore recruiting into the North Pacific fisheries first enter the Japanese western Pacific fisheries off Japan and then move eastward. Tagging of juveniles (ages 1 to 5) indicates fish tagged off Japan appear in the North American fishery, moving across the NPTZ. Albacore tagged off North America appear to move across the Pacific during the fall and are recaptured in the Japanese late winter/spring fisheries near Japan. These fish then migrate back to North America. There are few returns of mature fish. Some of the albacore may recruit to North America in the spring and then follow the migration pattern described.

Albacore (>30 cm FL), remain in the upper trophic level feeding opportunistically on squid, crustaceans and small fish. Known principal predators include sharks and billfishes. Albacore appear to compete for food with sharks, billfishes, other tuna, and others including marine mammals.

The dynamics of the albacore population are not completely understood. The instantaneous natural mortality rate, M, is thought to be between 0.2 and 0.4. Maximum size, L infinity, is approximately 120 cm FL. This corresponds to a maximum age in the unexploited population of approximately 12 years. Size at maturity is approximately 85 cm (age 5+). Fecundity is estimated to be between 0.8 to 2.6 million eggs per spawning cycle (year), substantially less than for tropical tunas.

Table 3 shows the catch history of North Pacific albacore by gear and country.

In the North Pacific, albacore are fished primarily by longline (Japan, Taiwan, and Korea), pole-and-line (Japan), drift gillnet (Japan, Taiwan, and Korea) and by trolling (U.S.). The longline gear is operated in the lower latitudes. This gear accounts for about 20% to 25% of the current catches. All the surface gear are operated in the more temperate regions and account for 75% to 80% of the reported catches.

The U.S. fishery in the North Pacific extends from the mid-North Pacific to North America. The number of U.S. vessels varies depending on the year, from about 300 to 2,000; many of which also fish salmon and other species. The U.S. fishery has operated on the stock since the early part of the century. Albacore is a major target for both the private rec-

Table 3. Catches of North Pacific albacore in metric tons by fisheries, 1952-1990.

YEAR	JAPAN						TAIWAN		KOREA[1]	UNITED STATES						CANADA	GRAND TOTAL
	Bait[2]	Long[3] line	Gillnet	Purse Seine	Other Gear	Sub Total	Long Line	Gillnet[4]	Long Line	Bait	Troll[5]	Sport	Gillnet	Purse Seine	Sub Total	Troll	
1952	41,786	26,687		154	237	68,864					23,843	1,373			25,216	71	94,151
1953	32,921	27,777		38	132	60,868					15,740	171			15,911	5	76,784
1954	28,069	20,958		23	38	49,088					12,246	147			12,393	-	61,481
1955	24,236	16,277		8	136	40,657					13,264	577			13,841	-	54,498
1956	42,810	14,341		-	57	57,208					18,751	482			19,233	17	76,458
1957	49,500	21,053		83	151	70,787					21,165	304			21,469	8	92,264
1958	22,175	18,432		8	124	40,739					14,855	48			14,903	74	55,716
1959	14,252	15,802		-	67	30,121					20,990	0			20,990	212	51,323
1960	25,156	17,369		-	76	42,601					20,100	557			20,657	5	63,263
1961	18,636	17,437		7	268	36,348				2,837	12,061	1,355			16,253	4	52,605
1962	8,729	15,764		53	191	24,737				1,085	19,760	1,681			22,526	1	47,264
1963	26,420	13,464		59	218	40,161				2,432	25,147	1,161			28,740	5	68,906
1964	23,858	15,458		128	319	39,763	26			3,411	18,392	824			22,627	3	62,419
1965	41,491	13,701		11	121	55,324	261			417	16,545	731			17,693	15	73,293
1966	22,830	25,050		111	585	48,576	271			1,600	15,342	588			17,530	44	66,421
1967	30,481	28,869		89	520	59,959	638			4,113	17,826	707			22,646	161	83,404
1968	16,597	23,961		267	1,109	41,934	698			4,906	20,444	951			26,301	1,028	69,961
1969	32,107	18,006		521	1,480	52,114	634			2,996	18,839	358			22,193	1,365	76,306
1970	24,376	15,372		317	794	40,859	1,516			4,416	21,041	822			26,279	354	69,008
1971	53,198	11,035		902	367	65,502	1,759			2,071	20,537	1,175			23,783	1,587	92,631
1972	60,762	12,649	1	277	646	74,335	3,091			3,750	23,608	637			27,995	3,558	108,979
1973	69,811	16,059	39	1,353	533	87,795	129			2,236	15,667	84			17,987	1,270	107,181
1974	73,576	13,053	224	161	959	87,973	570			4,777	20,187	94			25,058	1,207	114,808
1975	52,157	10,060	166	159	254	62,796	1,494		319	3,243	18,975	640			22,858	101	87,568
1976	85,336	15,896	1,070	1,109	285	103,696	1,251		971	2,700	15,932	713			19,345	252	125,515
1977	31,934	15,737	688	669	379	49,407	873		65	1,497	10,005	537			12,039	53	62,437
1978	59,877	13,061	4,029	1,115	2,097	80,179	284		174	950	16,682	810			18,442	23	99,102
1979	44,662	14,249	2,856	125	1,158	63,050	187		27	303	6,801	74			7,178	521	70,963
1980	46,743	14,743	2,986	329	1,209	66,010	318		15	382	7,574	168			8,124	212	74,679
1981	27,426	18,020	10,348	252	904	56,950	339		600	748	12,694	195			13,637	200	71,726
1982	29,615	16,762	12,511	561	732	60,181	559		1,070	425	6,661	257			7,343	104	69,257
1983	21,098	15,103	6,852	350	125	43,528	520		1,233	607	9,512	87			10,206	225	55,712
1984	26,015	15,111	8,988	3,380	518	54,012	471		1,041	1,030	9,378	1,427		3,728	15,563	50	71,137
1985	20,714	14,320	11,204	1,533	407	48,178	109		2,169	1,498	6,431	1,176	2	-	9,107	56	59,619
1986	16,096	12,945	7,813	1,542	650	39,046	-			432	4,708	196	3	-	5,339	30	44,415
1987	19,091	14,642	6,698	1,205	189	41,825	-	7,700		158	2,766	74	5	-	3,003	104	52,632
1988	6,216	13,904	9,074	1,208	177	30,579	38	11,366		598	4,212	64	15	-	4,889	155	47,027
1989	8,629	12,899	7,437	2,521	1,421	32,907	504	4,200		54	1,860	160	4	-	2,078	200	39,889
1990[6]	12,500			2,315		14,815				115	2,603	24	29	71	2,842	305	17,962

1. Korean gillnet catches are missing. Korean longline catches calculated from FAO statistics and Korean catch/effort data.
2. Japanese bait catches include fish caught by research vessels.
3. Japanese longline catches for 1952-60 exclude amount taken by vessels under 20 tons. Longline catches in weight are estimated by multiplying annual number of fish caught by average weight statistics. Catches from 1958-68 were readjusted in 1988.
4. Taiwanese gillnet catches are personal communication from Institute of Oceanography, National Taiwan University.
5. U.S. troll catches from 1952-60 include fish caught by baitboats; from 1961-85 include fish landed in Hawaii. U.S. troll catches (1984-88) include gillnet
6. Figures for 1990 are preliminary.

reational fishermen and the commercial party boats operating in southern and central California waters. In years when abundance was high, in excess of 1,000 mt was landed by recreational fishermen. In recent years albacore has not been as available.

Table 4. Resource summary - North Pacific albacore.		
Average catch (1988-90)	=	59,000 mt
Long-term potential catch (MSY)	=	90,000-120,000 mt
ABC (1990)	=	Unknown
Importance of recreational fishery	=	100-1,000 mt
Management	=	None
Status of exploitation	=	Probably overfished
Size at 50% recruitment	=	50 cm (females) 50 cm (males)
Size at 50% maturity	=	86 cm (females) 86 cm (males)
Assessment approach	=	Age, CPUE based
Fishing strategy ($F_{35\%}$)	=	None
F (1990)	=	Unknown

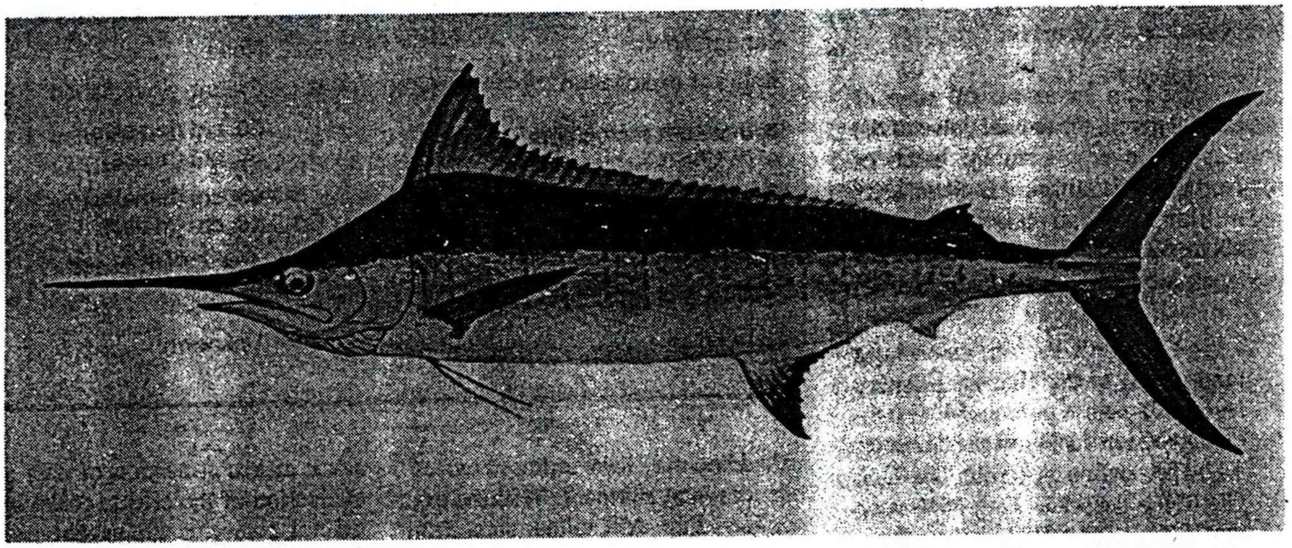
Based on an ex-vessel value of $2,200 per mt the annual value of the 1980-90 average annual catch of North Pacific albacore is about $121 million, with an annual value of about $264 million expected if the stock recovers to produce at MSY.

In the North Pacific, catch rates (and effort) in the U.S. troll fishery and the Japanese pole-and-line fishery have been declining concurrently with the decline in catch. The U.S. CPUE has declined about 50% since the 1960s. The CPUE for the Japanese fisheries has declined somewhat less. Previous assessments estimated MSY or Long-Term Potential Yield (LTPY) between 90,000 and 120,000 mt and estimated the stock was producing at or above LTPY in the 1970's. This high production, coupled with the addition of a drift gillnet fishery (for which catch and effort statistics are incomplete), leads to the current assessment that the stock may be overfished and may have suffered recent declines in recruitment. With the exception of the drift gillnet data, data for this stock are complete and generally available.

The North Pacific albacore stock is affected by high seas drift gillnets; however, the impact of the gillnet fishery on the status of the stocks is not clear since reliable data from these fisheries are not yet available.

In the North Pacific, the presumably overfished condition of the stock makes collection of data and evaluation of the effects of the drift gillnet fisheries an urgent issue. Presently there is no management regime for the North Pacific albacore fisheries. The creation of an international management forum for the stock is an outstanding issue, particularly if the fishing nations wish to encourage recovery of the stock. Currently, only an informal scientific forum, the North Pacific Albacore Workshop, is held biannually.

BLUE MARLIN



Courtesy of the Inter-American Tropical Tuna Commission (IATTC) from *Tuna and Billfish- Fish Without a Country.*

Blue marlin, *Makaira mazara*, is a tropical epipelagic species, distributed throughout the Pacific where surface waters are warmer than 24°C. Its swimming depth is shallower than striped marlin, *Tetrapturus audax*, based on relative efficiencies of deep and regular longline fishing gear. Sonic tracking indicates blue marlin spend most of their time at depths of <60 m. Apparent distribution changes seasonally, extending poleward to about 35°N and 35°S with spring warming, and then returning to between 10°N and 10°S during winter cooling. Spawning occurs throughout the year along the equator, extending poleward as far as 30°N and 30°S latitude in each hemisphere during summer. It has been assumed that there is a single Pacific-wide stock.

Blue marlin sometimes reach sizes greater than 900 kg, and most individuals over 130 kg are females, there being pronounced sexual dimorphism in this species. Pacific-wide, most longline-caught fish weigh between 70-170 kg. The smallest sexually mature males are about 35-44 kg and females begin maturing at about 47-61 kg. Growth has been estimated both from progression of length frequency modes and presumed annual external ridges on otoliths, with divergent results. For example, male fish measuring 175 cm eye-fork length (50 kg) are estimated to be 3.5 years old based on progression of modes and 8 years old based on otoliths. Eight-year-old females are larger, either 230 cm (100 kg, from progression of modes) or 300 cm (280 kg, from otoliths). The only estimates of natural mortality (0.2 for males and 0.5 for females) are based on growth models.

Table 5. Pacific blue marlin landings (mt) and domestic catch rate (mt/100 trips).

Category	YEAR											
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total Pacific	16,581	19,029	19,408	15,398	14,317	19,667	16,109	18,286	19,519	18,421	NA	NA
U.S. Western Pacific region	199	228	265	259	215	239	242	355	443	487	782	699
U.S. troll catch/100 trips	1.81	1.45	1.72	1.85	1.08	1.29	0.92	1.04	1.07	1.36	1.71	NA

Blue marlin are caught primarily as a bycatch of longline fisheries targeting tuna or other marlin species although blue marlin are valued as food fish in Japan and domestically in the central Pacific, where they have become an increasingly larger component of the domestic longline catch. Pacific-wide landings by commercial fisheries remained stable, between 15,000 and 20,000 mt from 1979 to 1988, with the bulk coming from Japanese longliners which landed 11,000-19,000 mt in 1979-85 and had peak landings in 1981. Combined longline landings by Taiwan and Korea decreased from about 2,800 mt in 1976 to about 400 mt in 1985. The Japanese drift gillnet fishery landed 200-1,200 mt in 1975-86 and had peak landings in 1981. The combined domestic longline and commercial troll fisheries in the Pacific increased their blue marlin landings from below 270 mt during 1979-85 to 700-800 mt in 1989-90, with most of the increase due to longliners increasing fishing effort and decreasing fishing depth (Figure 11). Most blue marlin landed by domestic fisheries are of adult size (>50 kg). Blue marlin are especially important to recreational fishermen throughout the Pacific, where this large marlin is a premium trophy fish.

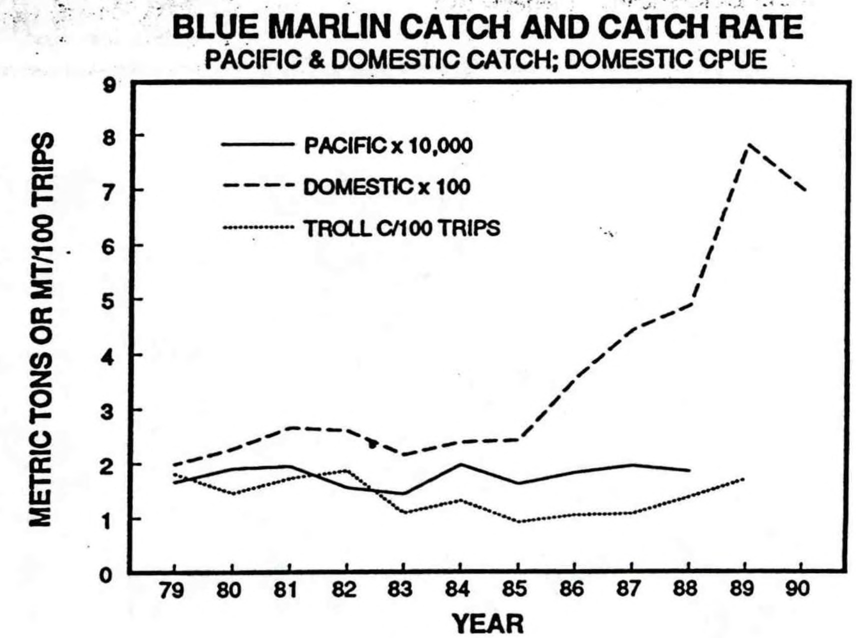


Figure 11.

Table 6. Resource summary - blue marlin.

Average annual catch (1988-90)	=	17,795/383 mt (Pacific/domestic)
Long-term potential catch (MSY)	=	23,500 mt
Importance of recreational fishery	=	High
Management	=	FMP for the pelagic fisheries of the Western Pacific region
Status of exploitation	=	Overutilized
Assessment approach	=	GPM

The only index of abundance that is reasonably current is from the domestic commercial troll fishery which shows a decline in catch per trip from 1979 to 1985 and an increase from 1985 to 1989. Older Japanese data for the Pacific, standardized to account for changes in longline fishing depth, show a sustained decline in catch per unit effort (CPUE; metric tons per effective hooks per 5° square) from 1952 through 1977, followed by a small net increase from 1977 to 1985. Plots of yield versus fishing effort indicated a relatively flat production curve where increases in effort beyond the 1985 level would not lead to increased catches. Fitting a generalized production model to comparable (flat-topped) data suggested that the resource continued to be overutilized as in previous assessments and that additional increases in effort would result in further declines in catch. Although longline fishing effort by Japan has decreased since 1985, longline effort by other nations has increased. It is not known how current effort levels compare with earlier years.

Localized apparent abundance of blue marlin, at least for Hawaiian waters, is highly correlated with stock-wide abundance. Japanese longline CPUE in the central Pacific is correlated with troll and longline catch per trip in Hawaii, suggesting that the availability of blue marlin to local fishermen is strongly influenced by factors other than fishing pressure in local waters. Nevertheless, the catch rate of blue marlin by Hawaii longliners has been found to be significantly negatively correlated with Japanese longline effort in adjacent waters (1962-78 data).

No international management regime exists for blue marlin, nor is there any international agreement for exchanging data to monitor the fisheries. Domestically, a federal fishery management plan for the western Pacific includes blue marlin. The future status of the stock is unknown, because of lack of knowledge. If longline fishing effort increases or increasingly targets species living in the upper 100 m of the ocean in waters near the exclusive economic zone, there will likely be declines in blue marlin available to recreational fishermen. Management agencies may promote conservation of this resource for recreational fisheries. However, effective management will require the establishment of international agreements to exchange data, assess the stock, and perhaps reduce the longline bycatch of blue marlin.

EASTERN TROPICAL PACIFIC TUNAS

Yellowfin and skipjack tunas are generally tropical in distribution and are found from the equatorial side of the North Pacific Transition Zone (NPTZ) to the equatorial side of the South Pacific Subtropical Convergence Zone (STCZ). They are principally fished by purse seine in two distinct regions of the Pacific, the eastern Tropical Pacific (ETP) and the central-western Pacific (C-WP); also by longline Pacific-wide.

The biology and population dynamics of ETP yellowfin have been extensively investigated and reported by the Inter-American Tropical Tuna Commission (IATTC). Yellowfin are upper trophic level predators, feeding opportunistically on fish and cephalopods. The majority of yellowfin females mature at 120 cm, although considerable variance exists. Males may mature as small as 50 cm. The sex ratio is approximately 1:1. Juvenile yellowfin may serve as prey for billfishes and sharks as well as other large predators. Small yellowfin tuna less than 85 cm are frequently found schooling with similar sized skipjack. Fish larger than 85 cm are frequently found in association with dolphins. Natural mortality for yellowfin is thought to be about 0.8 per year.

Skipjack tuna biology and population dynamics have received less attention than those of yellowfin. Skipjack are distributed throughout tropical waters. Spawning occurs between October to March, generally toward the mid-Pacific. Prey is different for skipjack than that de-

Yellowfin Tuna

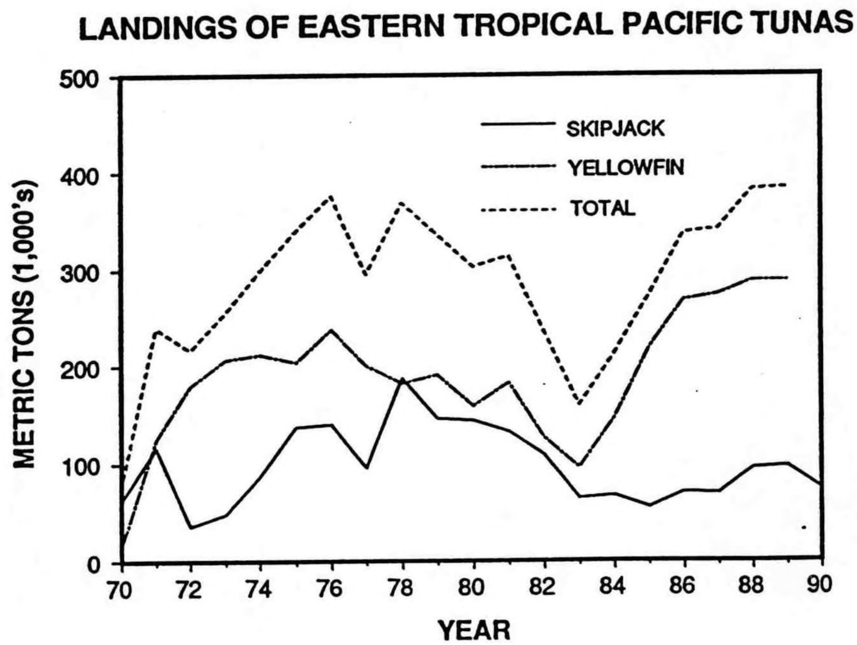


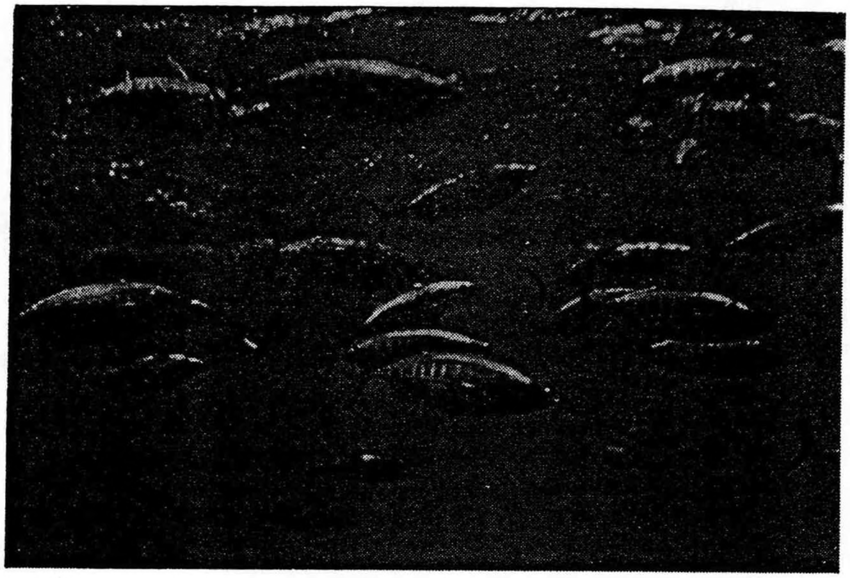
Figure 12.

WESTERN TROPICAL PACIFIC TUNAS

The tropical tunas, yellowfin and skipjack, are principally fished by purse seine in two distinct regions of the Pacific, the eastern tropical Pacific (ETP) and the central-western Pacific (CWP) and by longline Pacific-wide. Skipjack and yellowfin tuna are distributed throughout the tropical and subtropical Pacific waters both north and south of the equator. In the CWP, they are fished between 20°N and 20°S latitude and west of 150°E longitude to southeast Asia.

The stock structure of skipjack in the central and western Pacific is not well defined. Results of genetic studies indicate the gene pool is not panmictic Pacific-wide. However, blood-based genetic data suggest multiple population groups spawning across the Pacific which have considerable interchange; there are no isolated genetic stocks.

Tagging data show that although skipjack move extensive distances in all directions, most of the tag returns are within 200 miles. The maximum age of skipjack is approximately 5 years, although catches of fish older than 3 years are rare. Evidence from tagging data indicate that the population has an extremely high turnover rate, as high as 200% per year. Fishing mortality in the CWP in 1983 was as low as .05 of the turnover rate (at catch levels of 100,000 mt) and may currently be as low as .35 of the turnover rate (at a catch level of 750,000 mt).



Skipjack tuna

LANDINGS OF CENTRAL WESTERN PACIFIC TUNAS

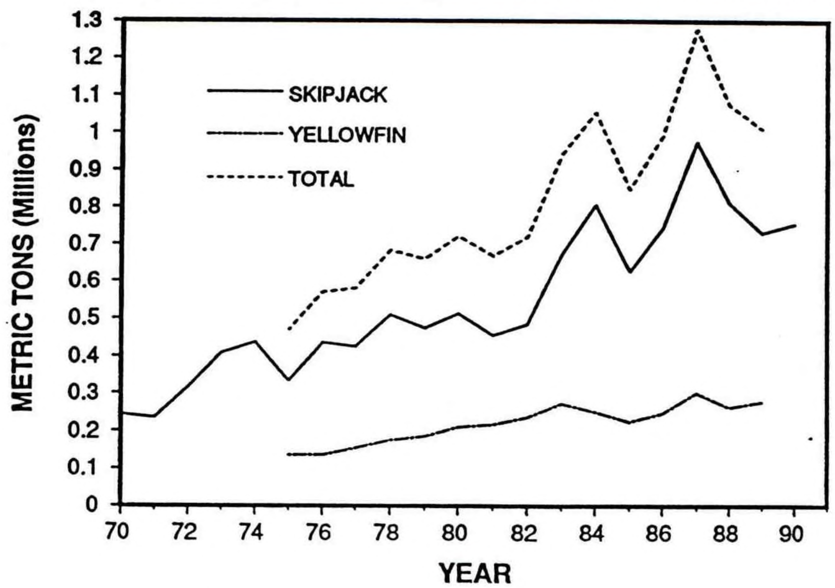


Figure 13.

scribed for yellowfin, with crustaceans making up more than 50% of the diet. Skipjack grow rapidly. Rates of up to 28 cm per year for the first year, and half of this rate during the second year, are common. The maximum age of skipjack is approximately 5 years, although catches of fish older than 3 years are rare.

The ETP tropical tuna fisheries are generally concentrated between 20°N and 20°S latitude and have been extensively documented. The predominant fishing gear is the purse seine; other gears include longline and pole-and-line. The major fishery participant is Mexico; others include the U.S., Vanuatu, Venezuela, Panama, Spain, and Ecuador.

From 1970 to 1980 the fishery expanded and was dominated by the U.S. A series of events in the 1980s made fishing in the ETP less profitable, and considerable fishing effort left the ETP, leaving Mexico, with over 50 purse seiners, as the dominant fleet. The U.S. purse seine fleet operated about 35 purse seiners in the ETP in 1989, but the number decreased to about 10 in 1990 and 8 vessels in 1991, due to industry responses to public concern over the incidental kill of dolphins. The total number of U.S. and non-U.S. purse seiners operating in the ETP in 1990 was approximately 125.

Yellowfin catches have averaged over 265,000 mt during the last 5 years. Recent detailed assessments for yellowfin indicate that long term potential yield (LTPY) for the ETP is about 250,000 mt. This yield is greater than previously reported and is due to a period of high recruitment in the late 1980's and a shift in fishery operations raising yield-per-recruit. This species is fully utilized.

Skipjack catches averaged 80,000 mt in the last 5 years (Figure 12). The consensus is that the skipjack resource is underexploited, although its long-term potential yield is not known.

Based on a average ex-vessel price of $800 per metric ton (for both skipjack and yellowfin), the annual commercial value of the ETP yellowfin-skipjack resource is about $275 million.

In the ETP there is no resource-wide, unified fishery management scheme; each coastal nation-state regulates fishing within its EEZ. Until 1980, the IATTC regulated the fishery with a recommended quota management system. Since then, the fishing countries have not adopted the IATTC management recommendations, and fishing continues unregulated.

Table 7. Resource summary - ETP yellowfin.

Average catch (1985-90)	=	265,000 mt
Long-term potential catch (MSY)	=	250,000 mt
ABC (1990)	=	Unknown
Importance of recreational fishery	=	1000 mt, seasonal, local
Management	=	Unregulated
Status of exploitation	=	Fully utilized
Size at 50% recruitment	=	35 cm (females) 35 cm (males)
Size at 50% maturity	=	90 cm (females) 90 cm (males)
Assessment approach	=	Age, CPUE based
Fishing strategy ($F_{35\%}$)	=	None
F (1990)	=	Unknown

Table 8. Resource summary - ETP skipjack.

Average catch (1985-90)	=	80,000 mt
Long-term potential catch (MSY)	=	Unknown
ABC (1990)	=	Unknown
Importance of recreational fishery	=	Minor, seasonal, local
Management	=	Unregulated
Status of exploitation	=	Underutilized
Size at 50% recruitment	=	35 cm (females) 35 cm (males)
Size at 50% maturity	=	40-50 cm (females) 40-50 cm (males)
Assessment approach	=	CPUE, tagging based
Fishing strategy ($F_{35\%}$)	=	None
F (1990)	=	Unknown

Although yellowfin tuna have been studied extensively in the ETP, fewer investigations have been conducted in the CWP. Currently, an extensive tagging program is being conducted in the CWP by the South Pacific Commission to examine the dynamics of CWP yellowfin. Yellowfin are considered highly migratory from tagging evidence. Smaller sizes of yellowfin are typically surface schooling and often occur in mixed schools with skipjack.

The fishery in the CWP has many components. Fishing gears include purse seine, ringnet, handline, pole-and-line and longline. In the CWP the major fishery participants include the U. S., Japan, Korea, Taiwan and others, including island countries in the area. Virtually all the skipjack catch is taken by surface fisheries, primarily purse seine and pole-and-line, while about half the yellowfin catch is taken by longline and handline fisheries. Purse seines, dominated by the U.S. and Japan, take between 30% and 50% of the yellowfin catch. In 1989 the total number of purse seiners in the CWP was more than 120. In 1990 and 1991 approximately 50 U.S. seiners operated in the CWP.

Among the tunas, catches of skipjack are the highest. Skipjack and yellowfin tuna catch totals from the CWP for the period 1970 to 1990 are shown in Figure 13. Recent average yield (RAY) of CWP Pacific skipjack (Table 2) is 767,000 mt. The present consensus is that the Pacific skipjack resource is underexploited although the long-term potential yield (LTPY) is unknown. The recreational catches of skipjack are small.

Total yellowfin tuna catches from the CWP for the period 1970 to 1989 are shown in Figure 13. RAY for CWP is about 280,000 mt. LTPY for the CWP is unknown because there has not yet been a comprehensive analysis of catch rates of yellowfin tuna for the CWP purse seine fishery. However, catch rates are relatively steady and the incomplete analyses done to date suggest the fishery may be nearing full production.

Based on an average ex-vessel price of $800 per metric ton (for both skipjack and yellowfin) the annual commercial value of the CWP skipjack resource is about $550 million and for yellowfin, $225 million.

In the CWP, there is no overall resource management program although the Forum Fisheries Agency (FFA), an organization of 16 South Pacific island countries that has claimed jurisdiction over tuna resources in this region, has instituted licensing of fishing effort of distant-

Table 9. Resource summary - WP yellowfin tuna.

Average catch (1980-90)	=	249,000 mt
Long-term potential catch (MSY)	=	Unknown
ABC (1990)	=	>280,000 mt
Importance of recreational fishery	=	Small
Management	=	None
Status of exploitation	=	Unknown
Size at 50% recruitment	=	35 cm (females) 35 cm (males)
Size at 50% maturity	=	90 cm (females) 90 cm (males)
Assessment approach	=	CPUE based
Fishing strategy ($F_{35\%}$)	=	None
F (1990)	=	Unknown

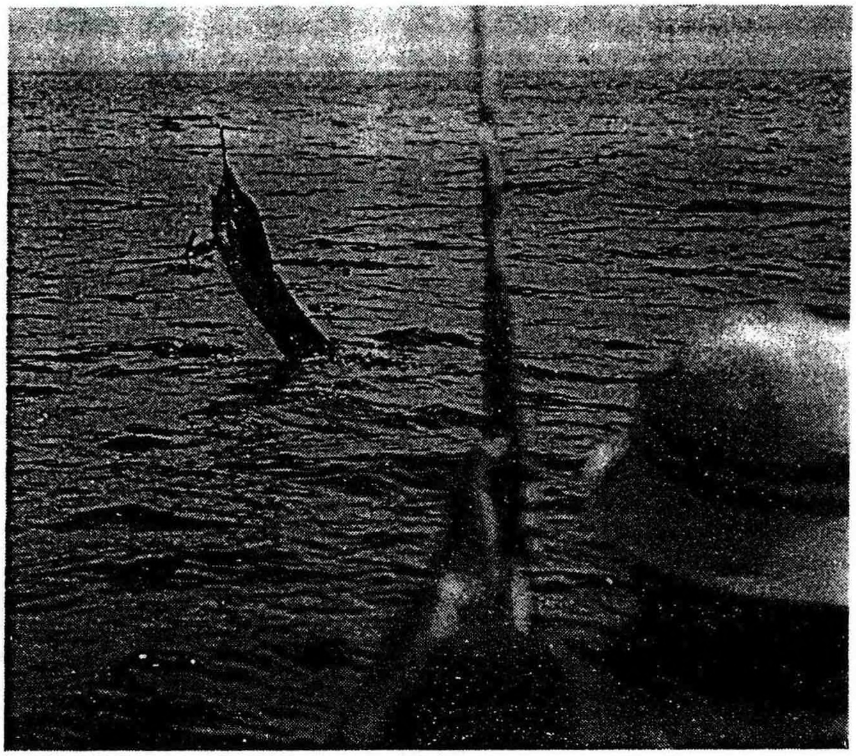
Table 10. Resource summary - WP skipjack tuna.

Average catch (1980-90)	=	694,000 mt
Long-term potential catch (MSY)	=	>767,000 mt
ABC (1990)	=	>767,000 mt
Importance of recreational fishery	=	Small
Management	=	None
Status of exploitation	=	Underutilized
Size at 50% recruitment	=	35 cm (females) 35 cm (males)
Size at 50% maturity	=	40-50 cm (females) 40-50 cm (males)
Assessment approach	=	Tagging based
Fishing strategy ($F_{35\%}$)	=	None
F (1990)	=	Unknown

water fishing fleets. The U.S. fleet is currently limited to 50 purse seiners, under the terms of the South Pacific Regional Tuna Treaty.

The primary issue facing tropical tuna assessment and management in the Pacific is the lack of consensus on a plan for gathering statistics and reporting and on structuring a fishery management/resource conservation organization that includes all stakeholders. This lack of data precludes definitive assessments. The issues of resolving stock structure as well as securing basic biological data need to be addressed.

STRIPED MARLIN



Striped marlin, *Tetrapturus audax*, is an epipelagic fish occurring in waters from about 45°S to about 45°N latitude in the western Pacific and from about 30°S to about 35°N latitude in the eastern Pacific. Individuals may reach a maximum size of about 290 cm eye-fork length (260 kg), but sizes differ with area. The largest fish are found in the southwestern Pacific, with longline-caught fish ranging from 40-80 kg. Size at first maturity is about 150 cm eye-fork length (30 kg). In the western Pacific, striped marlin are found mostly in subtropical waters. Both adult abundance and spawning are concentrated in latitudinal bands between 10° and 30° north and south of the equator and west of 130°W longitude. Spawning occurs primarily during the early summer in each hemisphere. Striped marlin is the dominant marlin in the central north Pacific and in the eastern Pacific where there is no equatorial gap in abundance. For stock assessment purposes, it has sometimes been assumed that there are separate northern and southern stocks. Age and growth rates have been only poorly quantified, based on progression of length-frequency modes, and the only estimates of natural mortality (0.5-1.3) have been based on such growth rate estimates.

Most striped marlin are caught by longline fisheries targeting tuna. However, striped marlin are commercially valuable, being a major component of landings by the U.S. longline fishery in the Pacific (Hawaii) where this species is among the fish most affordable to domestic consumers. Also, striped marlin is the most desirable billfish for sashimi in Japan. Drift gillnet fisheries operat-

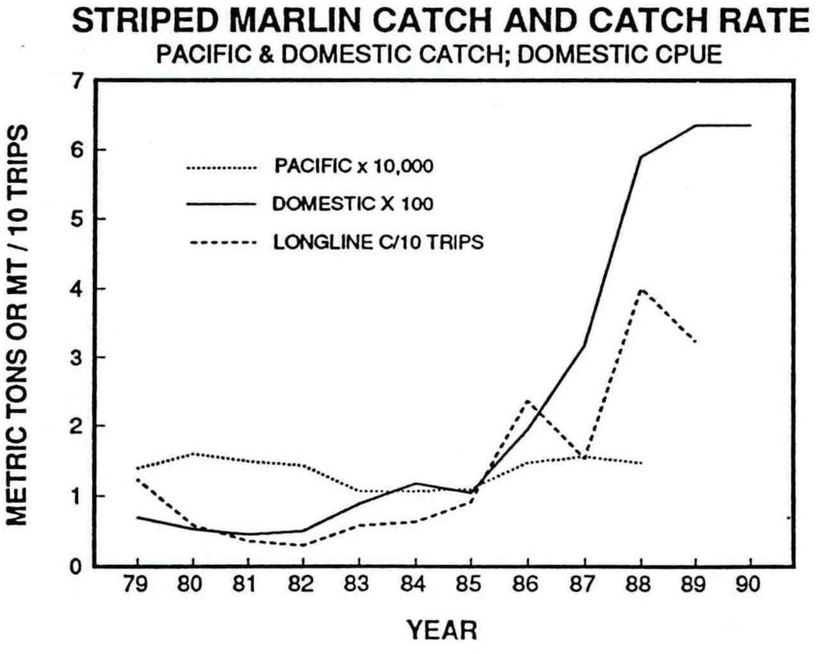


Figure 14.

Table 11. Pacific striped marlin landings (mt) and catch rate (mt/10 trips).

Category	YEAR											
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total Pacific	13,862	15,870	14,857	14,173	10,683	10,690	11,052	14,700	15,495	14,659	NA	NA
U.S. Western Pacific region	70	53	46	51	89	118	105	195	318	590	635	635
U.S. longline catch/10 trips	1.23	0.59	0.36	0.30	0.58	0.64	0.92	2.37	1.53	4.01	3.24	NA

ing in the northwestern Pacific catch substantial quantities of striped marlin but less than during the 1970s because of a shift in targeting towards albacore, *Thunnus alalunga*. The coastal harpoon fisheries in Japan, Taiwan, and California no longer land any striped marlin. Recreational fishing for striped marlin is important in the eastern Pacific off California and Mexico, but elsewhere in the Pacific, anglers are more interested in the larger blue marlin, *Makaira mazara*, or black marlin, *M. indica*.

Pacific-wide landings of striped marlin have been stable, in the range of 10,000-15,000 mt from the early 1970s through 1988, with no particular trend in recent years (Figure 14). Previous landings were higher, the decline probably reflecting a change in longline fishing towards using deeper gear to target bigeye tuna, *Thunnus obesus*. The bulk of the Pacific-wide landings were by Japanese longliners, but Japanese gillnet landings amounted to about 1,800-6,500 mt in 1975-86, making this the largest North Pacific fishery for striped marlin during this period. Taiwanese and Korean longliners landed relatively small amounts of striped marlin from 1975 to 1985 (100-1,000 mt/year combined) although these fisheries have increased operations since 1985 while the Japanese longline fishery has decreased. The U.S. longline fishery based in Hawaii increased its striped marlin landings from below 200 mt during 1979-85 to around 600 mt during 1988-90. This fishery tends to harvest fish smaller than adult size (50% of the catch weighs less than 30 kg). The domestic fishery underwent a fourfold expansion from 37 vessels in 1983 to about 150 in 1990. Nevertheless, domestic landings still amount to <5% of the Pacific-wide total, and landings by other U.S. fisheries in the Pacific are small in comparison.

The only reasonably current index of abundance from the domestic longline fishery showed a threefold increase in landings per trip from 1985 to 1989. This index is badly confounded by an increase in the amount of fishing gear deployed per trip, a decrease in fishing depth, and other changes. However, there is no evidence of any major trend in stock-wide abundance based on older data. The most recent stock assessments using Japan's longline data through 1985, corrected for changes in fishing depth, showed wide variations in catch per unit effort (CPUE) with no apparent trend or impact of fishing effort on CPUE in the northern stock. A weak relationship between fishing effort and CPUE was found for the southern stock, suggesting that it was optimally exploited at the 1985 level of fishing effort. An analysis assuming a single Pacific-wide stock using data through 1980 suggested that the combined stock could be further exploited. Although an up-to-date definitive stock assessment is lacking, no evidence suggests that the stocks are fully utilized. On a local scale, longline fishing pressure may be intense enough to cause temporary declines in the availability of striped marlin to nearby fisheries. When a Japanese longline fishery targeting striped marlin within Mexico's 200-mile exclusive economic zone (EEZ) was excluded by new regulations in 1976, trolling CPUE by recreational anglers increased rapidly and then began to decline again when joint-venture longline fishing resumed in the area. Similarly, striped marlin catch rates by Hawaii longliners (1962-78 data) were found to be negatively correlated with Japanese longline effort in adjacent waters.

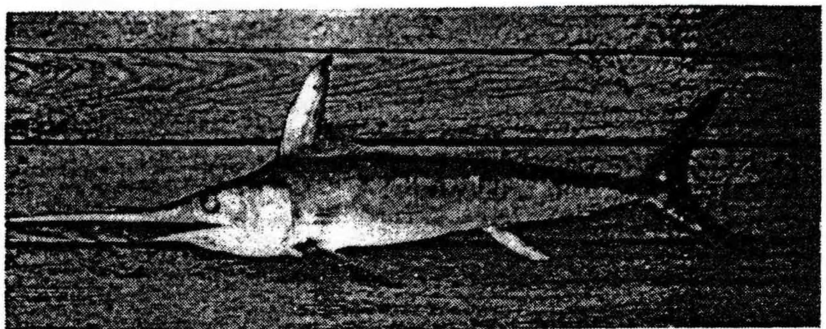
No international management regime exists for striped marlin, nor is there any international agreement for exchanging data to monitor the fisheries. State and federal agencies in the United States exercise a few management options. For example, California prohibits the sale of striped marlin, so the domestic harpoon and driftnet fisheries no longer target the species. A preliminary fishery management plan (FMP) and subsequent versions of the FMP for pelagics by the Western Pacific Regional Management Council (WPRFMC) required foreign longliners fishing in western Pacific EEZs to enter port and take on observers. This regulation virtually stopped all foreign fishing in the U.S. EEZ in 1980. Most recently the WPRFMC ruled that domestic longline vessels must submit logbooks and has obtained an emergency moratorium freezing the number of vessels in the Hawaii domestic longline fishery. If the moratorium is extended for 3 years, as intended, this will slow further in-

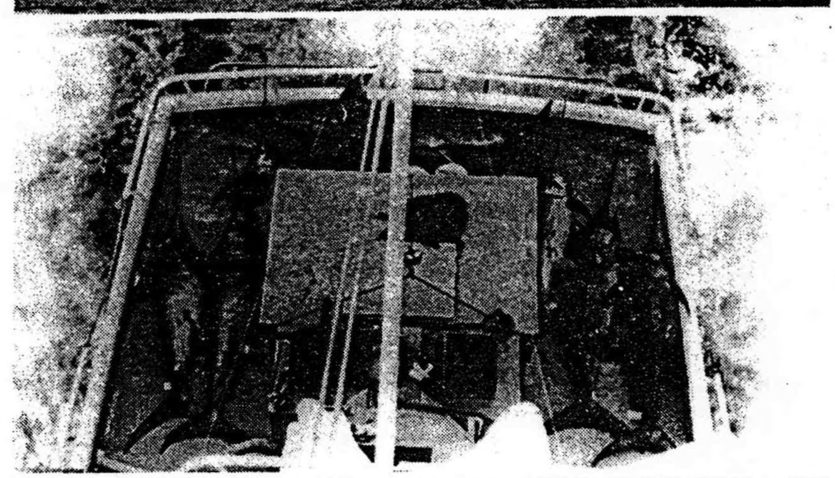
Table 12. Resource summary- striped marlin.		
Average catch (1980-90)	=	13,575/258 mt (Pacific/domestic)
Long-term potential catch (MSY)	=	Unestimated
Importance of recreational fishery	=	Low in W. Pacific; high off West Coast
Management	=	FMP for the pelagic fisheries of the Western Pacific region
Status of exploitation	=	Probably underutilized
Assessment approach	=	GPM attempted

creases in the domestic landings of striped marlin, and logbook data will permit the calculation of meaningful indices of abundance for the first time since foreign longline data became unavailable after 1980.

The lack of proper fisheries statistics and stock assessments makes it impossible to draw conclusions regarding the status of striped marlin stocks. The conservative exploitation of this resource will require the establishment of international agreements to exchange data and manage the fisheries.

SWORDFISH





The swordfish, *Xiphias gladius*, is a large pelagic fish (to approximately 500 kg) distributed throughout the temperate, subtropical, and tropical waters of the Pacific Ocean. It is found in oceanic as well as coastal waters. Spawning occurs in subtropical and tropical waters in the spring, with progressively older and larger fish found in the more poleward extremes of the distribution. There is evidence of sexually dimorphic growth, but growth is not well-documented, particularly in the Pacific. Virtually nothing is known about the movement of swordfish in the Pacific, but predominantly north-south movement is expected, based on the Atlantic model.

The domestic fishery along the eastern border of the Pacific has evolved from what was predominantly a harpoon fishery to what is now almost exclusively a driftnet fishery. The average dressed size of the California landings has been around 1.5 m. In Hawaii, the night longline fishery for swordfish started in 1989, with the introduction of chemical light sticks from the Atlantic fishery. Fish from about 10 to 400 kg are landed in this fishery. Swordfish landings in other U.S. Pacific island fisheries are virtually nonexistent. In other areas of the Pacific, oceanic longline fishing has been conducted primarily by Japan in temperate waters of the North Pacific; coastal fisheries occur off Japan, Taiwan, Mexico, Chile, and Australia.

Total Pacific landings since 1980 have averaged under 20,000 mt per year, but the trend has been upward in recent years (Figure 15). The West Coast drift gillnet fishery expanded about 890% in 1980-85, reaching 2,300 mt in 1985. Subsequently the fishery declined with the landings equaling 1,300 mt in 1989. The incidental take of swordfish in Hawaii fluctuated between 16 and 40 mt, but jumped to 1,600 mt in the second year of the directed fishery.

The most recent stock assessment in 1989 using data only through 1980 indicated that the resource on a Pacific-wide basis may be somewhat underutilized. However, the assessment should be considered provisional for the following reason. Data are unavailable to standardize the fishing effort statistics in response to known historical changes in longline fishing strategies. The fishery historically started as what was predominantly a night longline fishery and then changed to a day fishery. Recently, deep longline gear has come into use. Comparing Pacific catches with the harvests obtained in the Atlantic would suggest that the Pacific stock is substantially underutilized, although it should be remembered that the Atlantic stock is now regarded as overutilized, if not overfished.

Current management mechanisms by the State of California and the federal government in the central and western Pacific are probably sufficient to manage the fisheries in

Table 13. Pacific swordfish landings (mt).

Category	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total Pacific	19,179	16,616	18,937	18,649	18,770	17,085	19,426	20,558	22,569	25,624	NA	NA
U.S. Western Pacific Region	17	24	17	36	40	28	16	23	22	39	298	1645
U.S. West Coast	266	543	518	767	1213	1993	2357	1745	1243	1127	1298	NA

their respective jurisdictions. However, with the swordfish stock boundary encompassing the north, if not the entire Pacific, these management mechanisms are not capable of managing the resource. No international management mechanisms exist for swordfish in the Pacific.

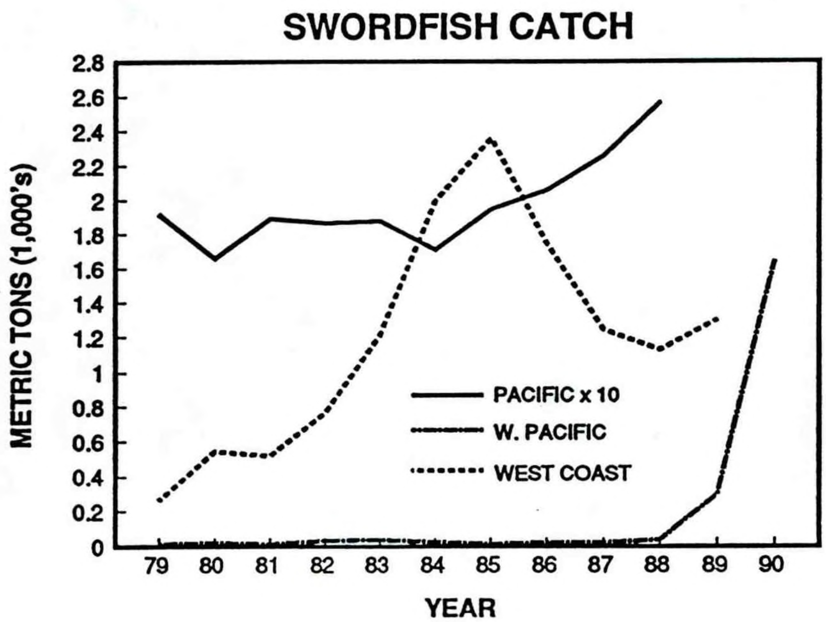
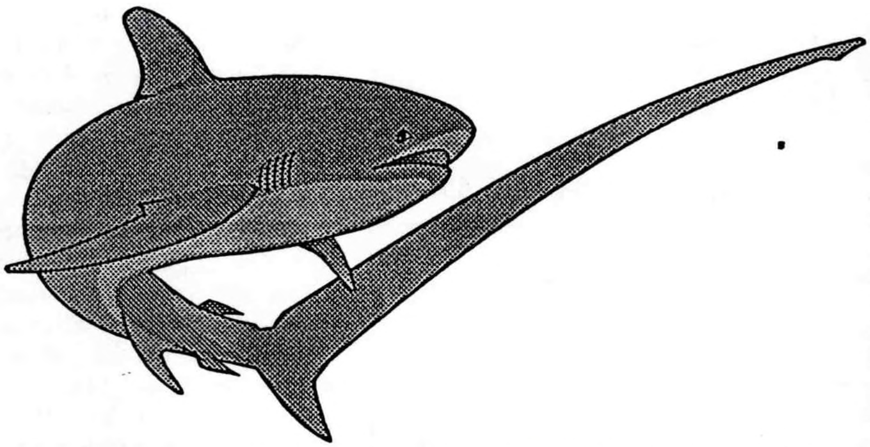


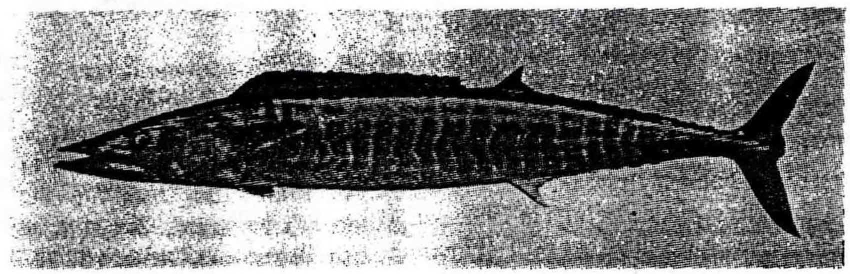
Figure 15.

With the demonstrated fishing power of the U.S. longline swordfish fleet and its ability to target resource concentrations in the Atlantic which has resulted in rapid declines in local abundance (particularly of large, commercially desirable individuals), the continuing high market demand for swordfish, and the subsequent decline in the Atlantic fishery, considerable concern exists regarding the consequences of unregulated expansion of Hawaii's fishery. However, with the initiation of a moratorium on the entry of new longline vessels into Hawaii's fishery in 1991 and the curtailment of growth of the California fishery, the status of the resource within the U.S. Pacific exclusive economic zone is not likely to change substantially in the near future. The impact of the growth of other coastal fisheries on the U.S. fisheries is not known.

Table 14. Resource summary - swordfish.		
Average catch (1980-90)	=	19,804/1,363 mt (Pacific/domestic)
Long-term potential catch (MSY)	=	19,000 mt (provisional)
Importance of recreational fishery	=	Very minimal
Management	=	FMP for the pelagic fisheries of the Western Pacific region
Status of exploitation	=	Probably underutilized
Assessment approach	=	GPM

OTHER LARGE PELAGICS





Top left- thresher shark, bottom left- wahoo, and above- mahimahi.

Included in this unit are a number of bony and cartilaginous pelagic fishes. The teleosts include the dolphin or mahimahi, *Coryphaena hippurus*; wahoo, *Acanthocybium solandri*; shortbill spearfish, *Tetrapturus angustirostris*; sailfish, *Istiophorus platypterus*; and black marlin, *Makaira indica*. Sharks include oceanic members of the requiem, thresher, and mackerel shark families.

The bony fish members of this group inhabit epipelagic waters of the tropics and subtropics in the Central and Western Pacific. Hence, their occurrence is not common as far north as California in the eastern Pacific. Directed domestic troll fisheries exist throughout the western Pacific region for mahimahi and wahoo. The largest domestic harvest occurs in Hawaii, although it is minor compared to the harvest of other pelagic species. In contrast, the Guam troll fishery lands more mahimahi and wahoo than other pelagic species because of a local lack of preference for tunas. Significantly larger foreign fisheries for mahimahi occur off central America, Taiwan, and Japan. Other fishing gear taking these bony fishes incidentally include tuna longline and pole-and-line in the U.S. exclusive economic zone (EEZ) and tuna purse seine, other types of surround nets, and driftnet outside the EEZ. Shortbill spearfish is a common component of the Hawaii longline catch, but the major incidental take of this species is to the north in foreign longline fisheries. Sailfish and black marlin are uncommon in all domestic fisheries in the Pacific, with the major foreign catches occurring in the tropical or subtropical continental margins of the Pacific. Recreational landings of these bony fishes in Hawaii are thought to be substantial, but current estimates are not available. A State of Hawaii-operated recreational survey, which was designed with federal funding, is now (1991) in the pilot testing stage.

Mahimahi landings make up the largest portion of the landings of this group of miscellaneous pelagics.

Total (foreign and domestic) landings are considerably larger than domestic landings. Pacific landings have been variable since 1979 with the two largest values recorded in 1987 and 1988 (Figure 16). Hawaii landings have been increasing since 1979, particularly after 1984.

The world record for the largest mahimahi is 39.5 kg (87 lb). During 1988-89, the largest fish landed in Hawaii was 145.7 cm fork length (FL) and weighed 29.8 kg (65.5 lb). Generally, recent landings in Hawaii consist of fish 2.3-22.7 kg (5-50 lb). Males frequently weigh twice that of females for a given length after sexual maturity. Ovarian tissue examinations revealed that the smallest mahimahi known to have spawned in the wild was 86.1 cm FL (ca. 5 kg) or about 7-8 months old. Spawning occurs throughout the year in tropical waters and in a long extended season of about 9 months in the subtropics. Mahimahi is a batch spawner and has been observed to spawn every other day in captivity. The spawning frequency of wild fish has not yet been determined. Spawning occurs over the continental shelf and around islands in mid-ocean. Growth is rapid, and in its first year a male can attain 20 kg and a female 14 kg.

The major domestic shark fishery occurs off the west coast of the continental United States; only minor catches occur in the western Pacific region. The West Coast fishery, developed in the mid-1970s, harvests thresher, Pacific angel, soupfin, and shortbill mako, among other species. The fishery now is primarily off California although fisheries off Washington and Oregon occurred in 1983, 1984, and sporadically in other years. Drift gillnet is the primary commercial gear, but recreational fishing is also important in the area. Sportfishing for shark is virtually nonexistent in the Western Pacific region.

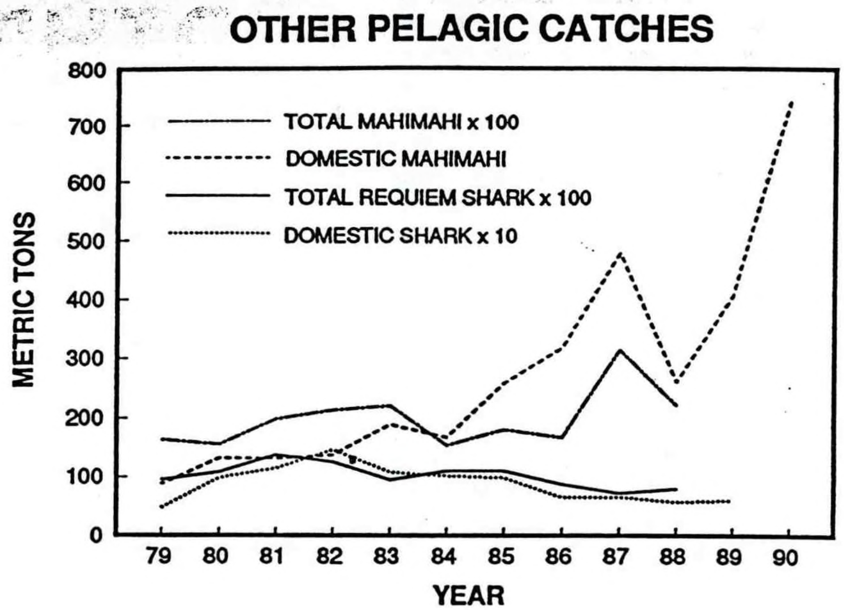


Figure 16.

Harvest levels of shark in the Pacific are not well documented, but even so, reported foreign landings of requiem sharks are considerably greater than the domestic harvest of all sharks (Figure 16). Landings may be declining slightly. The U.S. shark harvest (primarily California landings) reached a high in 1982 and has since declined by 60% (Figure 16).

Based on extensive tuna longline and surface trolling data, wahoo appear to prefer shallow depths and are more abundant close to land than in the open ocean. Wahoo are not very abundant in the Central Pacific, but they are highly valued as are other seerfish in other parts of the world. The maximum size is 210 cm FL or 83 kg (183+ lb); Hawaii fish range between 71 and 174 cm FL. Spawning may occur throughout the year near the equator, but it is limited to the summer in the subtropics. Wahoo begin spawning at about 100 cm FL.

The shortbill spearfish occurs in temperate and tropical waters of the Pacific. Longline catch data indicate that this species occurs roughly between 40°N and 35°S latitude in the Pacific. Although this species does not appear to be generally abundant, longline catch rates increase in the Northwest Pacific between 15°N and 30°N latitude from November through February. Shortbill spearfish are known to grow to 52 kg (114 lb). Spawning occurs throughout the year with a peak during the summer.

The pelagic requiem sharks (Carcharhinidae) are the silky shark, *Carcharhinus falciformis*; oceanic whitetip shark, *C. longimanus*; dusky shark, *C. obscurus*; and blue shark, *Prionace glauca*. These species are tropical, except for blue sharks which are also found in temperate waters. Most requiem sharks have up to 15 pups in a litter, which is relatively small compared to blue sharks which have up to 135 in a litter. These sharks are incidentally caught on tuna or swordfish longlines in the central Pacific and are also targeted by the U.S. west coast pelagic driftnet fisheries.

Thresher sharks consist of the pelagic thresher, *Alopias pelagicus*; bigeye thresher, *A. superciliosus*; and thresher shark, *A. vulpinus*. The latter is the most commercially sought. These species have two to four in a litter, usually two. They are a major component of the west coast driftnet fishery, while being taken only occasionally by swordfish and tuna longline gear in the central Pacific.

The mackerel sharks (Lamnidae) are the shortfin mako, *Isurus oxyrinchus*, and the longfin mako, *I. paucus*. These species are generally tropical with only juveniles entering the west coast driftnet fishery. The shortfin mako has 4 to 16 pups in a litter, whereas the longfin mako has two. The shortfin mako is prized on the Pacific West Coast as a game fish where it is caught by trolling. Makos are taken by tuna and swordfish longline gear in the central Pacific.

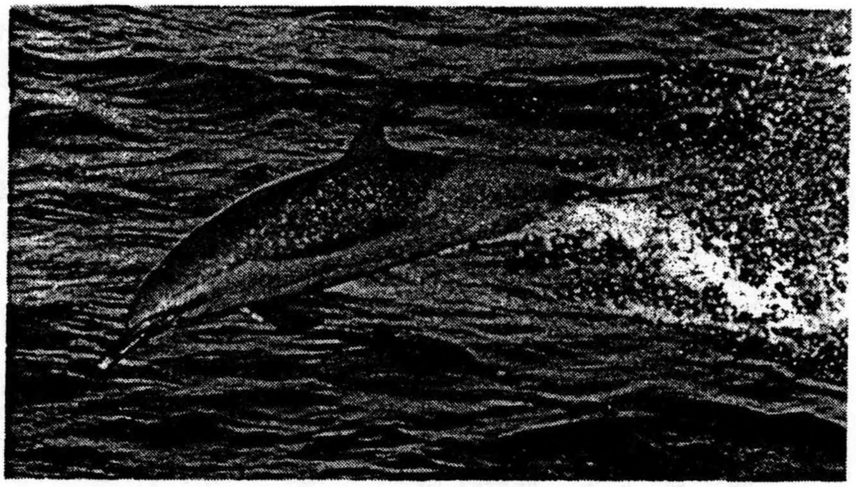
Table 15. Resource summary- other large pelagics.

Average catch (1980-90)	=	43,270/1,347 mt (Pacific/domestic)
Long-term potential catch (MSY)	=	Unknown
Importance of recreational fishery	=	Important for mahimahi, wahoo, and shortbill spearfish in western Pacific; important for sharks on the West Coast
Management	=	FMP for the pelagic fisheries of the Western Pacific region; Calif., Oreg., and Wash. state regulations
Status of exploitation	=	Not well known
Assessment approach	=	GPM

Little is known about the stock composition or population dynamics of any of these species (Table 15). Because of the low fecundity of the sharks, those resources that have been examined have shown little resiliency to harvest. Because of its high fecundity, early maturation, and multiple batch spawning, mahimahi is probably reasonably resilient to harvest, but considerable fluctuation in harvest level is likely because of the few number of year classes in most fisheries.

Spotted dolphins - *Stenella attenuata*

Three stocks of spotted dolphins are currently known to interact with the Eastern Tropical Pacific tuna purse seine fishery: northern offshore, southern offshore, and coastal. A fourth stock, the Hawaiian stock also exists in the ETP, but is not known to interact with the fishery, and therefore, will not be discussed here. Recent information on seasonal movement patterns and patterns of morphological variation suggest that spotted dolphins move outside the previously defined limits of their ranges. Therefore, identification of these stocks should not be made based solely on geographic location alone, but should take into account a combination of morphology and distribution. Definition of stock structure within the spotted dolphin species is currently underway using genetic, taxonomic and distributional data.



The spotted dolphin resembles the common and striped dolphin in overall body shape. Adults range from 1.6 to 2.6 meters long, and weigh up to 100 kg or more, depending on the stock involved. At birth, spotted dolphins are about 80 cm long and are unspotted. In adults, the ventral spots have fused and lightened, giving the animal a uniform gray appearance below. The light spots above persist and are on the average largest and most numerous in the relatively large-bodied coastal stock. The northern offshore and the southern offshore stocks are relatively smaller, more lightly built, have smaller teeth, and, on the average, are less spotted. Stock differentiation between the northern and southern stocks has been made based on external morphology and skull measurements. Spotted dolphins are extremely gregarious and are often found in offshore aggregations of more than 1,000 animals, frequently in mixed herds with spinner dolphins. The coastal form is usually encountered in herds of less than 100 animals.

Northern offshore spotted dolphin

The northern offshore stock is distributed from just below the equator around the Galapagos Islands north to Cabo San Lucas, Mexico to about 145°W. They have been seen as far inshore as 20 km from the coast but are generally distributed farther offshore. Northern offshore animals are on average larger than the southern form, and smaller than the coastal form. Most of what is known about spotted dolphins comes from studies of the offshore race, which is the cetacean most heavily involved in the ETP yellowfin tuna fishery. The life history of the northern offshore stock has been studied intensively. Breeding takes place during prolonged spring and fall seasons. Gestation lasts for 11.5 months, nursing for about 11 months. Since most females "rest" for a few months following lactation, the average calving interval is greater than two years. It is currently thought that dolphin populations under conditions of no incidental take should be increasing at approximately 2-6% per year.

Using research vessel data for the years 1986 though 1990, the northern offshore spotted dolphin population abundance has been estimated. Since 1986, the population size for this stock has varied between 658,300 and 2,205,500 with coefficients of variation (CV) between 29 and 36 percent. Figure 26 graphi-

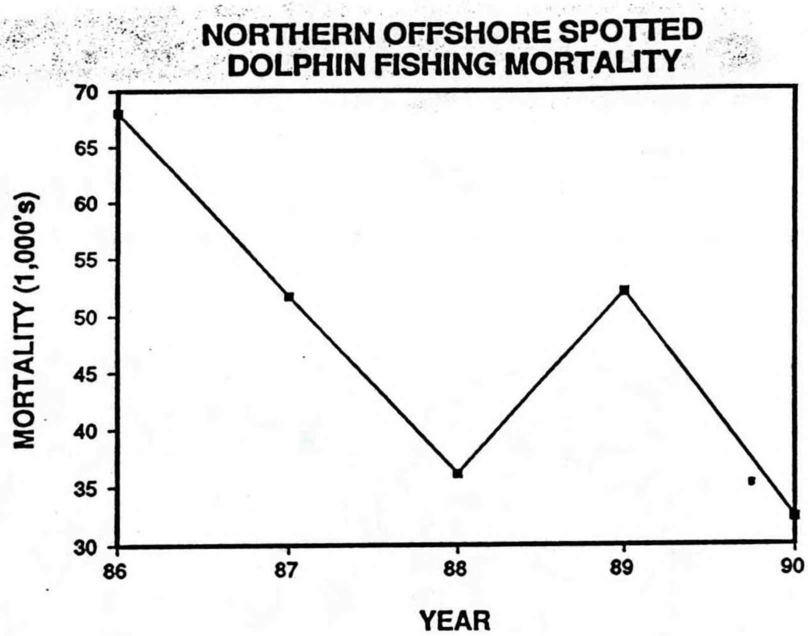


Figure 26.

cally presents total fishing mortality for these same years. These estimates are for the U.S. and foreign fleets combined. The average annual fishery-caused mortality between 1986 and 1990 was around 48,000 animals. Currently, population estimates are plagued with bias and variability, but if it is assumed that the MOPS research vessel estimates are conservative (i.e., negatively biased), then a maximum rate of take can be estimated by dividing the annual estimates of fishing mortality by annual estimates of population abundance. The fishing mortality rate (expressed as a percent) for the northern offshore stock varied between 2.4% and 4.5% over the last five years; however, there is evidence that these rates may be overestimations because of sampling bias.

Over the past 5 years, significant trends in abundance have not been detected based on sighting data collected by observers on U.S. and non-U.S. fishing vessels. Too few data points have been determined from the research vessel surveys (referred to as the Monitoring of Porpoise Stocks (MOPS) cruises) to determine trends in abundance and the analyses of the life history data have not yet been completed. Because the current level of incidental fishing mortality is at a level similar to the expected rate of increase, it is not surprising that significant positive or negative trends in abundance have not been detected in recent years.

Future work on the northern spotted dolphin will be directed at determining its status. Population size estimates based on research vessel surveys, trends analyses based on tuna vessel observer data, and condition index analyses based on life history material will continue. In addition, greater effort to identify the sub-specific population structure of the ETP stocks will be undertaken using recently developed genetic methods of DNA analyses.

Southern offshore spotted dolphin

Analysis of skull morphology and reproductive behavior have justified the separation of the southern offshore stock from the northern offshore stock. It has been found that skulls of spotted dolphins from south of the equator are on average, larger and have smaller temporal fossa than those of animals from north of the equator. The southern stock tends to be, on average, shorter than the northern stock. In addition, calving season in the south is relatively short, March to May.

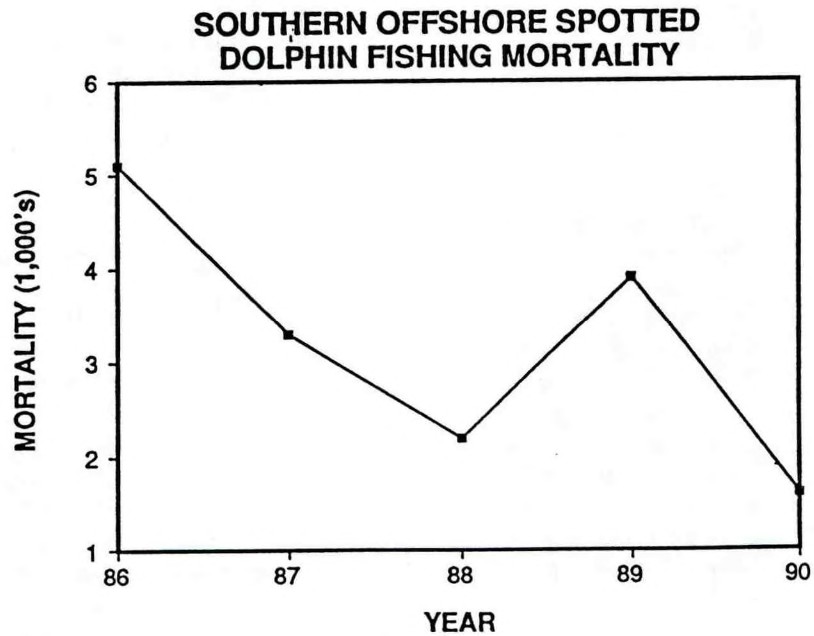


Figure 27.

Using research vessel data for the years 1986 though 1990, the southern offshore spotted dolphin population abundance has been estimated. Since 1986, population estimates for this stock have varied between 85,800 and 475,800, with coefficients of variation (CV) between 48 and 86 percent. The average annual fishing mortality between 1986 and 1990 was around 3,200 animals (Figure 27). Dividing the annual estimates of mortality by conservative (i.e., MOPS) annual estimates of population abundance yields fishing mortality rates (expressed as a percent) for the southern offshore stock between 0.3% and 1.9% over the last five years. As with the northern offshore stock, it is likely that these estimates of mortality are positively biased.

Over the past 5 years no significant trends in abundance have been seen.

Table 28. Resource Summary- Northern Offshore Spotted Dolphin

Average incidental mortality (1986-1990)	=	48,000 for U.S. and international fleets combined
1990 stock size estimate	=	658,300
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	Currently there are no significant trends
Age at sexual maturity	=	11 years (females) 15 years (males)
Size at sexual maturity	=	178 cm (females) 186 cm (males)
Assessment approach	=	Trends in relative abundance

Table 29. Resource Summary- Southern Offshore Spotted Dolphin

Average incidental mortality (1986-1990)	=	3,200 for U.S. and international fleets combined
1990 stock size estimate	=	87,700
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	10 years (females) Not available for males
Size at sexual maturity	=	175 cm (females) Not available for males
Assessment approach	=	Trends in relative abundance

Coastal spotted dolphin

The coastal form ranges into the Gulf of California to about 28°N latitude. This coastal stock is normally confined to waters within 50 km of the coast. It occurs continuously along the Mexican, Central American, and South American coasts to well south of the equator. Frequently it is seen around the Tres Marias Islands off Mexico and on the way in and out of Panama, Punta Arenas, and Costa Rica. This stock is larger and more robust than other stocks and exhibits more spotting in all age groups. Light-colored spotting is so extensive that they are sometimes called "silver-backs".

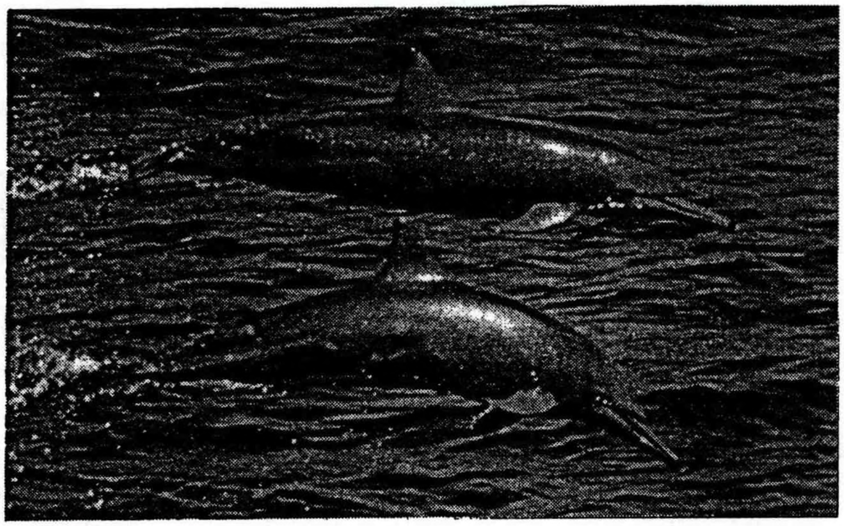
Table 30. Resource Summary- Coastal Spotted Dolphin

Average incidental mortality (1986-1990)	=	Not available
1990 stock size estimate	=	Not available
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	Not available
Size at sexual maturity	=	Not available
Assessment approach	=	Currently being analyzed

Estimates of fishery-caused mortality for the coastal stock are considered unreliable because of the difficulty in separating the offshore and coastal forms, and because of the low level of effort in nearshore waters. Estimates of abundance are currently unavailable due to the low survey effort within the range of this stock.

Spinner dolphins - *Stenella longirostris*

There are four recognized stocks of spinner dolphins in the ETP: northern whitebelly, southern whitebelly, eastern and Costa Rican (now called Central American spinner dolphin). Due to the high degree of overlap in distributions between northern and southern whitebelly spinner dolphin stocks, it has been suggested that northern and southern whitebelly stocks be combined into a single management unit. The stocks affected by the tuna purse seine fishery are the whitebelly and eastern stocks.



Adult spinner dolphins are about 1.5-2.2 meters long, with females on average about 4 cm shorter than males. Size varies among stocks. The Central American spinner which has just received subspecific status, is the longest, adults reaching lengths of 2 meters or more, while the immediately adjacent eastern spinner is the smallest. Central American and eastern spinner dolphins have a peculiar sexual dimorphism in body shape. In adult males, the dorsal fin is erectly triangular; in some cases it is even canted forward appearing to be on "backwards." Also distinct is the postanal hump composed largely of connective tissue. The combination of forward-leaning fin and large ventral hump give large males an appearance unique among the dolphins. The stocks also differ widely from each other in body shape and in color patterns.

Spinners often occur in very large herds, and it is not unusual to find them mixed with spotted dolphins. Both species experience significant fishing mortality in the ETP as a result of tuna purse seine operations. The two stocks most involved are the eastern and whitebelly spinners. The spinner's common name is derived from its habit of leaping clear of the water and spinning on its longitudinal axis rotating as many as seven times in one leap.

Eastern spinner dolphins

Eastern spinner dolphins are, on average, about 3-4 cm smaller than whitebelly spinner dolphins. Patterns of skull size variation between populations were found to be opposite from patterns observed in northern and southern offshore spotted dolphins. That is, animals from the south tended to have larger skulls with a proportionately larger temporal fossa.

Abundance estimates for the eastern spinner stock based on the five MOPS surveys (1986-1990) ranged from 391,200 to 754,200 with CVs between 37 and 42 percent. U.S. fishermen are not allowed to set on pure schools of eastern spinner dolphins, but incidental mortality still exists. The total fishing mortality of eastern spinner dolphins for the years 1986-1990 ranged from 19,500 to 5,400 per year (Figure 28), averaging around 13,860 animals. The estimated level of mortality, expressed as a percent of the population size based on MOPS data, varied between 0.9% and 3.3% for 1986 to 1990. Preliminary analysis has not yet revealed any significant trends in abundance for eastern spinner dolphins over the last 5 years.

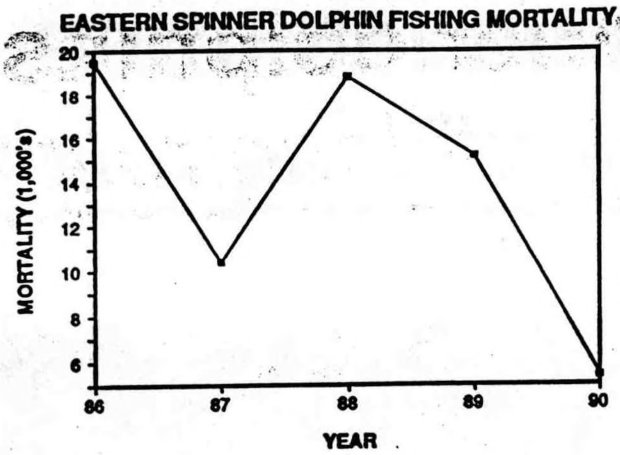


Figure 28.

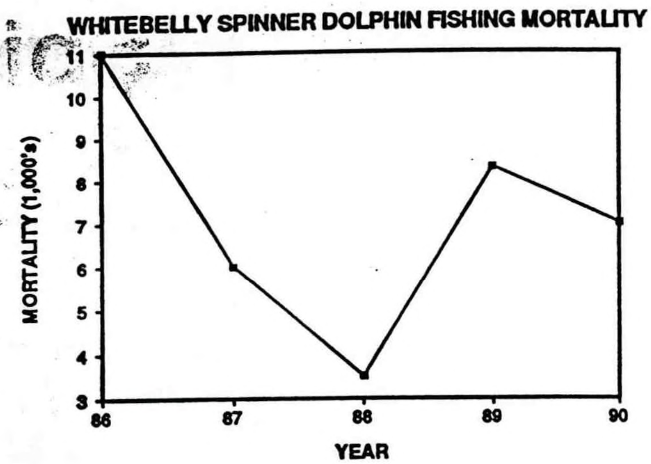


Figure 29.

Whitebelly spinner dolphin

Abundance estimates for the whitebelly spinner stock based on the five MOPS surveys (1986-1990) ranged from 363,300 to 1,398,400 with CVs between 38 and 64 percent. Incidental mortality for the whitebelly stock has been lower than for the eastern stock. Between 1986 and 1990, fishing mortality varied between 3,500 and 11,000 per year (Figure 29). The average mortality for these five years was around 7,160 animals incidentally taken. Percent fishing mortality ranged from 0.4% to 1.1%.

Table 31. Resource Summary-Eastern Spinner Dolphin

Average incidental mortality (1986-1990)	=	13,860
1990 stock size estimate	=	391,200
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	Currently being analyzed
Size at sexual maturity	=	165 cm (females) 170 cm (males)
Assessment approach	=	Back calculations and trends in relative abundance

Table 32. Resource Summary-Whitebelly Spinner Dolphin

Average incidental mortality (1986-1990)	=	7,160
1990 stock size estimate	=	363,300
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	Currently being analyzed
Size at sexual maturity	=	167 cm (females) 175 cm (males)
Assessment approach	=	Trends in relative abundance

Common Dolphins - *Delphinus delphis*

Presently, there are three recognized stocks of common dolphins taken by the U.S. fleet in the ETP (northern tropical, central tropical, and southern tropical). Stock abundance and mortality data are pooled according to observed distribution. Additional information indicates that a Baja neritic stock overlaps the distribution of the northern tropical stock within 100 nautical miles of the coast of Baja California, Mexico, and in the Gulf of California and, therefore, its range and biology should be studied. The extent to which patterns of distribution confound traditional stock identification methods is currently being examined by NMFS.

Fishing mortality levels for the three stocks are highly variable from year to year, but are considerably less in absolute numbers than mortalities of northern offshore spotted dolphins or eastern spinner dolphins. In recent years the central stock has suffered the greatest mortality of the three stocks (see Figure 31).

The maximum body length of the common dolphin is about 2.5 meters, though most individuals are less than 2.3 meters long. Males are slightly larger than females of the same age. Length at birth is about 80 cm. The beak of this dolphin is well-defined, and is often black with a white tip. The most distinctive external feature of this species is the color pattern on the sides. The light ventral field extends up into the cape, yielding a four-part pattern defined by a crisscross. The back is black, the belly white, the overlap of the cape by the ventral field is tan or yellowish tan, and the area behind the cape is gray. These dolphins are easily identified by their unique pigmentation pattern, but can be confused with striped and Fraser's dolphins.

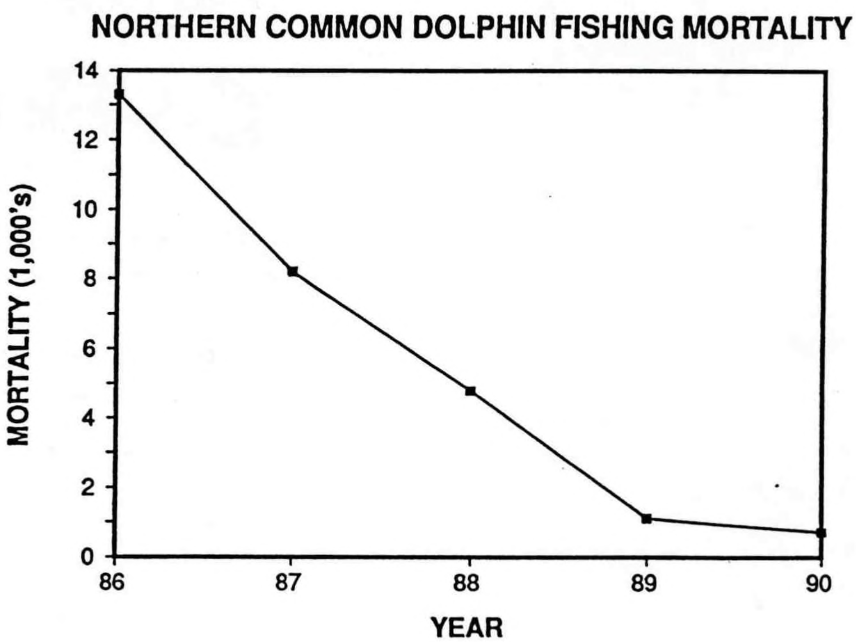


Figure 30.

Northern tropical common dolphin

Northern tropical common dolphins are distributed between latitudes 15°N and 28°N. They are often referred to as short-beaked common dolphins. Because of the overlap in distributions with the Baja neritic stock (long-beaked form), these two stocks have been pooled for abundance and mortality estimation. Abundance estimates based on MOPS data are between 23,500 and 1,272,400 for the northern tropical stock (CVs range from 50 to 77 percent). Annual mortality estimates have been as high as 13,300 in 1986 to a low of 700 in 1990 (Figure 30). The average fishing mortality for these five years was 5,600. The estimated level of fishing mortality, expressed as a percentage of the population size based on MOPS data, varied between 0.2 and 35.9 percent. To date, preliminary analysis has not revealed any significant trends in abundance for the northern tropical common dolphin. Future research will include a more intense survey effort to obtain more accurate abundance estimates for this stock.

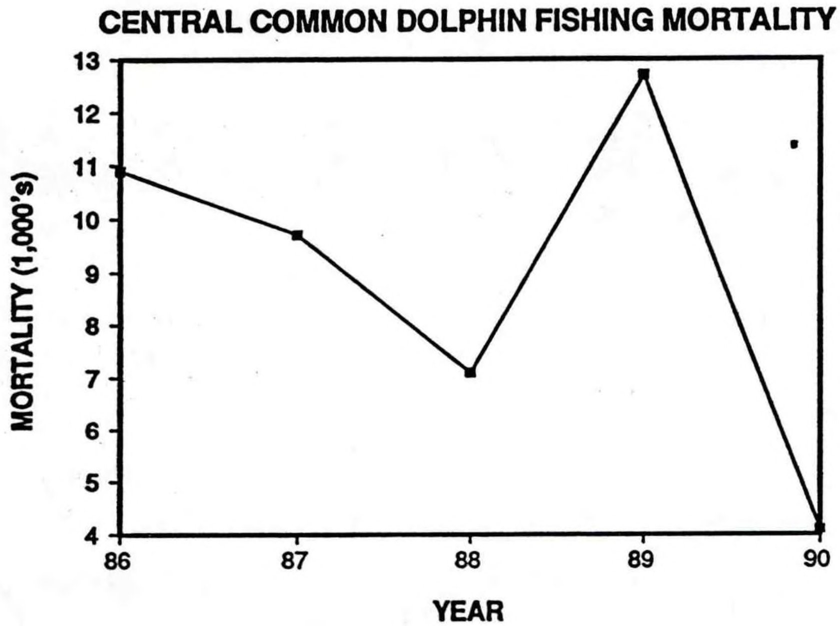


Figure 31.

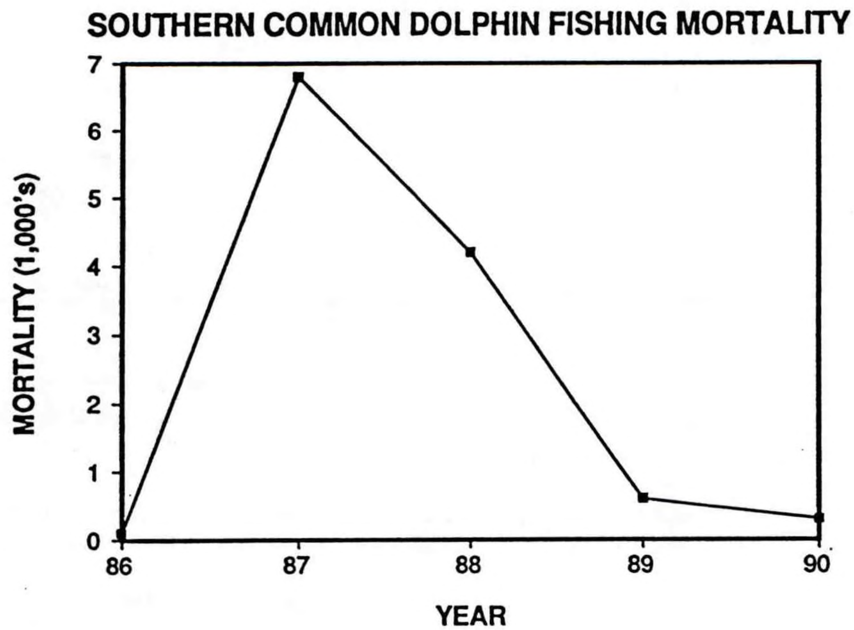


Figure 32.

Central tropical common dolphin

Central tropical common dolphins are distributed between latitudes 3°N and 15°N . They are also known as short-beaked common dolphins, but on average (i.e., mode) are longer than northern tropical common dolphins and have different skull characteristics. The central tropical stock is separated from the northern tropical stock by an 800 nautical mile-wide zone in which sighting effort has been heavy and sightings of common dolphins have been rare.

Abundance estimates for the central tropical dolphin stock were made based on MOPS data for the five survey years (1986-1990) ranging between 261,000 and 1,487,600 (CVs between 50 and 77 percent). In recent years, the central tropical stock has suffered the greatest fishing mortality of the three common stocks. The mortality estimates for the 1986-1990 period range between 4,100 and 12,700 with an average of 8,900 (Figure 31). The estimated level of fishing mortality, expressed as a percentage of the population size based on MOPS data, varied between 0.7 and 2.1 percent.

Southern tropical common dolphin

Southern tropical common dolphins are distributed between latitudes 3°N and 10°S. There is fairly good separation from the central tropical stock. Abundance estimates for the central tropical dolphin stock were made based on MOPS data for the five survey years (1986-1990) and ranged between 152,000 and 3,664,000 (CVs between 50 and 77 percent). The fishing mortality estimates for the 1986-1990 period range between 100 and 6,800 with an average of 2,400 (Figure 32). The estimated level of fishing mortality, expressed as a percentage of the population size based on MOPS data, varied between 0.0 and 0.3 percent.

Table 33. Estimate of total incidental dolphin mortality for U.S. and foreign vessels

YEAR	TOTAL INCIDENTAL MORTALITY
1971	261,928
1972	423,678
1973	264,977
1974	174,682
1975	194,457
1976	128,222
1977	51,353
1978	30,513
1979	21,467
1980	31,970
1981	35,089
1982	29,104
1983	13,493
1984	40,712
1985	58,847
1986	133,174
1987	99,188
1988	78,917
1989	96,979
1990	52,531

Table 34. Resource Summary- Northern Common Dolphin

Average incidental mortality (1986-1990)	=	5,600
1990 stock size estimate	=	177,700
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	Currently being analyzed
Size at sexual maturity	=	Currently being analyzed
Assessment approach	=	Trends in relative abundance

Table 35. Resource Summary- Central Common Dolphin

Average incidental mortality (1986-1990)	=	8,900
1990 stock size estimate	=	568,000
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	Currently being analyzed
Size at sexual maturity	=	Currently being analyzed
Assessment approach	=	Trends in relative abundance

Table 36. Resource Summary- Southern Common Dolphin

Average incidental mortality (1986-1990)	=	2,400
1990 stock size estimate	=	1,657,500
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	Currently being analyzed
Size at sexual maturity	=	Currently being analyzed
Assessment approach	=	Trends in relative abundance

For Further Information:

Wade, P.R. and T. Gerrodette. 1991. Monitoring trends in dolphin abundance in the eastern tropical Pacific: analysis of five years of data. Report to the International Whaling Commission SC/43/SM 13.

DeMaster, D.P., E.F. Edwards, P.R. Wade, and J.E. Sisson. 1991. Status of dolphin stocks in the eastern tropical Pacific. Proceedings of Wildlife 2001: Populations (in press).

Leatherwood, S., R.R. Reeves, W.F. Perrin, and W.E. Evans. 1982. Whales, dolphins and porpoises of the eastern North Pacific and adjacent Arctic waters - a guide to their identification. NOAA Technical Report NMFS Circular 444, 245 pp.

Perrin, W.F. and S.B. Reilly. 1984. Reproductive parameters of dolphins and small whales of the family Delphinidae. In: W.F. Perrin, R.L. Brownell Jr. and D.P. DeMaster (eds). Reproduction in whales, dolphins and porpoises. Reports of the International Whaling Commission, Special Issue 6. Cambridge. 495 pp.

Perrin, W.F., M.D. Scott, G.J. Walker, and V.L. Cass. 1985. Review of geographical stocks of tropical dolphins (*Stenella* spp. and *Delphinus delphis*) in the Eastern Pacific. NOAA Technical Report NMFS 28. 28 pp.

Smith, T.D. 1983. Changes in size of three dolphin (*Stenella* spp.) populations in the eastern tropical Pacific. Fishery Bulletin, U.S. 81:1-13.

Smith, T.D. 1979. Report of the status of porpoise stocks workshop. NMFS SWFC Administrative Report LJ-79-41.

Of the entire Hawaiian Islands population of Pacific Green Sea Turtles, 90% mate and lay eggs at French Frigate Shoals in the Northwestern Hawaiian Islands. The rare Leatherback Turtle, world's largest reptile, rarely leaves the water, but its presence is well-documented near the Northwestern Hawaiian Islands.

Interactions between Leatherback and Pacific Green Sea Turtles and fishing operations is documented as a problem worldwide. Turtles are snagged on baited hooks and entangled in lines and other gear. On land, basking turtles may be entangled in discarded fishing lines.

Protected Status

All sea turtles are protected under the Endangered Species Act and State of Hawaii regulations. Maximum fines are $25,000 for civil penalties and $100,000 and up to one year in jail for criminal convictions, or both (16 USC 1538/1540).

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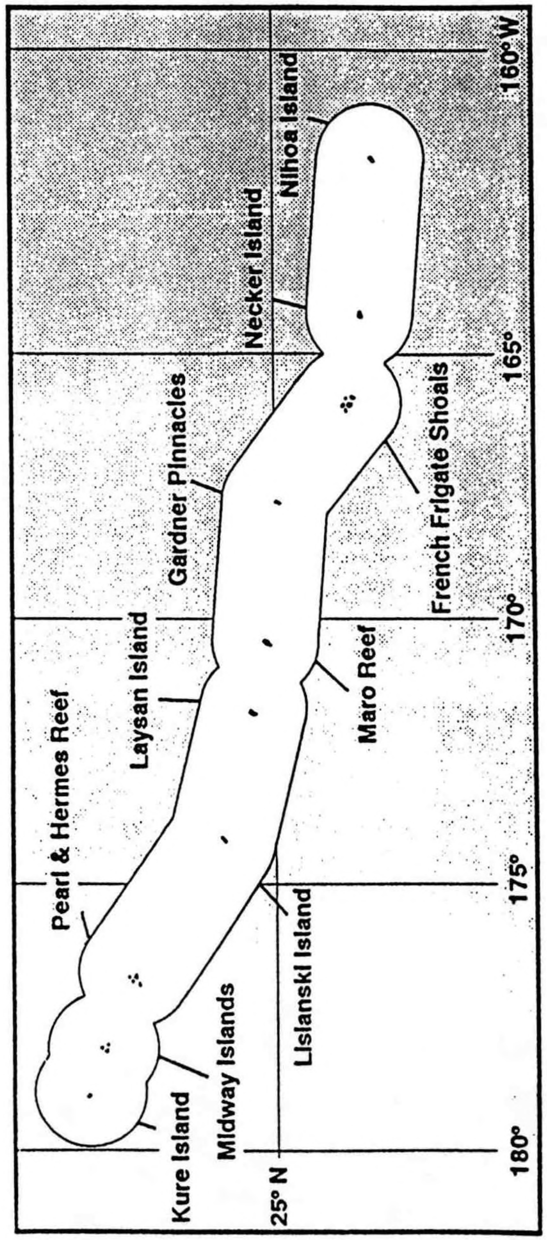
photograph courtesy of Susan Scott

Protected Species Zone

not intended for navigation



Northwestern Hawaiian Islands

Protected Species Zone

Closure to Longline Fishing

INTRODUCTION

Longline fishing has been practiced in Hawaii for decades. Historically, a fleet of small wooden-hulled sampans fished for yellowfin and bigeye tuna (ahi) from several ports throughout the islands. The nature of the fishery changed dramatically in the late 1980s when new fishing techniques, developed on the US east coast for broadbill swordfish, were adopted and the size of the fleet grew rapidly, mostly due to an influx of boats from the east coast and Gulf states.

Hawaii's longline fishing fleet now consists of about 150 vessels, 80 of them arriving in Hawaiian waters more recently than January 1990. The mostly steel-hulled vessels range in size from 50 to 100 ft and carry a crew of 3 - 6. Honolulu is the home port for most, and many travel 500 to 1300 miles in search of fish. They spend an average of about three weeks at sea per trip, targeting ahi and swordfish. Mahimahi, wahoo (ono), sharks and other pelagic species are also caught.

As fishing pressure increased, so did reports of interactions (injuries and deaths) between longline operations and several protected animal species, some of them endangered and found only in the remote Northwestern Hawaiian Islands. Several interactions were documented, prompting the Western Pacific Regional Fishery Management Council (Council) to take immediate management action.

MANAGEMENT ACTION

In response to documented injuries to endangered Hawaiian monk seals and several species of sea birds and sea turtles resulting from longline fishing operations in the Northwestern Hawaiian Islands, the Council asked a special inter-agency task force to recommend actions to prevent further harm to protected species. The task force concluded that physical separation was the best solution, and recommended closing certain areas of the Northwestern Hawaiian Islands to longline fishing.

At its February 1991 meeting, the Council voted to establish a "Protected Species Zone" -- an emergency 90-day closure to longlining of areas inhabited by Hawaiian monk seals. These areas include waters within 50 nm of the islands and banks of the Northwestern Hawaiian Islands, and certain 100-nm wide corridors used by monk seals when migrating between islands (See map). This emergency action became effective in April, 1991, for 90 days, and was extended another 90 days. In October, 1991, an amendment to the fishery management plan for pelagic species made the Protected Species Zone permanent.

HAWAIIAN MONK SEAL

Hawaiian monk seals are found only in the Hawaiian Archipelago. They are light gray to brown in color, and can grow to 7 ft long and 500 lb. The main breeding populations are found at eight locations in the Northwestern Hawaiian Islands from Nihoa Island to Kure Island, although several births have been recorded recently in the Main Hawaiian Islands. Their total population is estimated to be around 1200 individuals.

These seals frequently haul out on beaches near the vegetation line at the high water mark. They feed mostly at night on reef fishes, eels, octopus and lobster, at depths ranging from 30 to 480 ft. They are attracted to the bait or light sticks used in longline fishing operations. Injuries and deaths result when hooked or snagged seals drown, develop infections, or are weakened and fall prey to other predators such as sharks. Other seals are entangled in discarded fishing gear that has washed up on beaches where the seals haul out.

Protected Status

Hawaiian monk seals are protected by two federal laws, the Marine Mammal Protection Act and the Endangered Species Act, as well as State of Hawaii regulations. Violations can lead to civil penalties of up to $25,000, and criminal conviction carries fines of up to $100,000 and a maximum of one year in jail, or both (16 USC 1375, 16 USC 1538/1540).

SEA BIRDS

Three species of albatross are found in the Northwestern Hawaiian waters. The Laysan and Black-footed Albatrosses have resident breeding populations on the larger islands. Endangered Short-tailed Albatrosses nest on two islands south of Japan, and several individuals visit Midway each winter and spring, and are occasionally seen on other Northwestern Hawaiian Islands. The historical range of the short-tailed Albatross includes Hawaiian waters. The worldwide population of Short-tailed Albatrosses is only 400 individuals, including 85 breeding pairs.

Albatrosses are large seabirds which feed primarily on squid. They often follow fishing vessels, a behavior reinforced by the disposal of offal or unused bait. Albatrosses will also seize baited hooks as longline gear is set, often hooking the birds.

Protected Status

Laysan and Black-footed Albatrosses are protected under the Migratory Bird Treaty Act which allows fines to $5000 per violation and up to six months in jail, or both. Short-tailed Albatrosses are also protected under the Endangered Species Act with fines to $100,000 and one year in jail, or both (16 USC 703/716, 16 USC 1538/1540).

SEA TURTLES

Several species of sea turtles are found near the Northwestern Hawaiian Islands. The most common species are Pacific Green Sea Turtle, Hawksbill and Leatherback. These air-breathing reptiles travel great distances in search for food items. Researchers report that these turtles are attracted to natural bioluminescence, so they may also be attracted to chemical light sticks used by longline fishermen.