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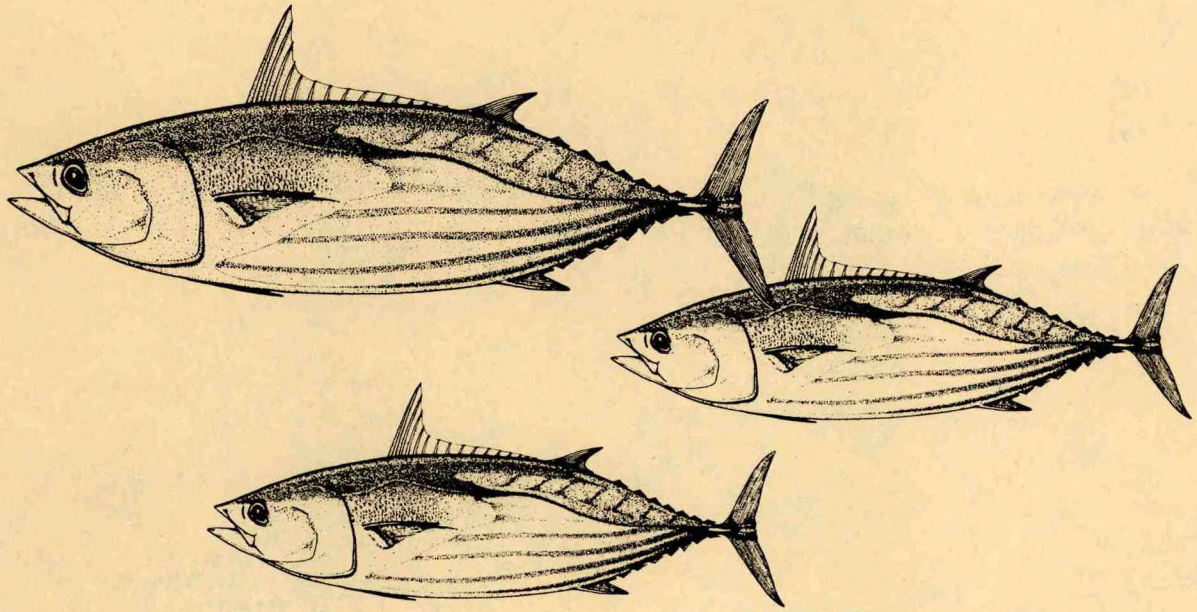

Director's Report to the 42nd Tuna Conference

On Tuna & Tuna-Related Activities at the
Southwest Fisheries Science Center
for the Period May 1, 1990
to April 30, 1991

ADMINISTRATIVE REPORT LJ-91-08

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Compiled by the
Editorial Group
Southwest Fisheries Science Center

MAY 1991

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TABLE OF CONTENTS

I. EXECUTIVE SUMMARY 1

II. ECONOMIC OVERVIEWS 7

- Statistics of the U.S. Canned Tuna Industry Compiled for the First Three Quarters of 1990 7

III. INDIAN OCEAN FISHERIES 9

- Update on the Seychelles Purse Seine Fishery 9

IV. PACIFIC OCEAN FISHERIES 11

Pacific Albacore 11

- Summary of 1988-89 U.S. Pacific Albacore Fisheries Data 11
- Albacore Troll Fishery - High Seas Drift Net Interaction 11
- Albacore Drop-Out Experiment 12
- Japanese Albacore Data Confirms Population Decline Deduced From U.S. Data 12
- South Pacific Albacore Longline CPUE Declines 13
- Launching of Albacore Reproduction Biology Project 14
- Work on Albacore Catch Forecasting Continues 14

Hawaii's Fisheries 15

- 1990-91 Developments in the Hawaii Longline Fishery 15
- WPRFMC Meetings 15

South Pacific Tuna Fisheries 16

- Sampling of Tunas Under the South Pacific Tuna Treaty 16

Tuna Behavior and Physiology Studies 16

- Kewalo Research Facility Hosts International Cooperative Tuna Studies 16
- Manuscripts Completed on the Cardiac Physiology of Tunas 17

Pacific Billfish Programs 17

- Gardiner Foundation Billfish Tagging Awards for 1989 17
- Thirty-Fourth Annual Hawaiian International Billfish Tournament 18

V. DOLPHIN RESEARCH AT THE SOUTHWEST FISHERIES SCIENCE CENTER 19

- Introduction 19
- U.S. Tuna Canners and 'Dolphin-Safe' Tuna 19
- Data Show Decline in Fishery-Related Dolphin Mortality in 1990 19
- Dolphin Survey Design Workshop Held 20
- Latest in Alternative Fishing Methods 20
- Comparing Tuna Vessel Data With Research Vessel Data 21
- TOPS Model Used to Evaluate Two Sampling Methods for Detecting Dolphin Population Trends 21
- Statistical Power and Detectable Trends 22
- Comparison Made of U.S. Eastern Tropical Pacific Tuna Purse Seine Day and Night Set Mortality Rates 22
- Completion of Fifth Annual Survey to Monitor Trends in Dolphin Abundance 23
- Photography Used to Calibrate Observer Estimates 24
- Second Year of Tissue Sample Collection 24
- Bioacoustics as a Tool for Differentiating ETP Dolphin Stocks 24
- Optimal Strategy by Dolphins for Detection Avoidance 25

VI. OTHER TUNA-RELATED RESEARCH AT SWFSC 27

- Brill Presents Lecture at International Conference 27
- Fishermen Honor Laurs 27
- Theoretical Models of Longline Fishing Development 27
- Tag Analysis and Assessment of Fishery Interaction 28

VII. SWFSC PUBLICATIONS ON TUNA AND TUNA-RELATED SUBJECTS 29

Director's Report to the 42nd Tuna Conference

I. EXECUTIVE SUMMARY

This report describes tuna-related research activities 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 not a comprehensive account, but rather an informal statement of major activities and events that have taken place since May 1990. Highlights of the previous year are provided in this executive summary.

The SWFSC's tuna-related research is going through a transitional period, which will continue through the coming year. New programs were begun in 1990, including those dealing with albacore and effects of drift gillnet fishing, while other programs are nearing completion or undergoing changes. We reassessed and charted a new direction for the dolphin monitoring program to improve our stock assessment work and keep pace with changing legislative mandates and recent developments in the yellowfin tuna fishery in the eastern tropical Pacific Ocean. Last year we also began reassessing our role in providing tuna research support to Councils and international bodies within the new context of the October 1990 reauthorization of Magnuson Fishery Conservation and Management Act (MFCMA), which for the first time places tunas under Fishery Council jurisdiction in the Pacific. A planning session involving representatives from the State Department, NMFS Office of International Affairs, NMFS Southwest Region, the Western Pacific Fisheries Management Council, NMFS Office of Fisheries Conservation and Management, and the Southwest Fisheries Science Center was held in early April 1991 in La Jolla. The participants focused on the design of a system to administer the planning and execution of tuna management and research in the western Pacific. A new system was proposed that will, if approved, soon be developed more fully to facilitate NMFS's supporting role within this framework.

Albacore

In 1990-91, work on albacore focused on gathering, compiling and analyzing information on the status of Pacific albacore stocks and effects of drift gillnetting on albacore and associated pelagic species. Tuna researchers with Gary Sakagawa's **Pelagic Fisheries Resources Division** in La Jolla, and Jerry Wetherall's **Pelagic Resources Investigation** in Hawaii were occupied with work relating to observer programs as well as special directed studies.

Within Sakagawa's Pelagic Division, David Au has been preparing an important stock assessment document for North Pacific albacore using data from both the U.S. and Japanese fisheries. The report will be presented at the 12th North Pacific Albacore Workshop, July 23-25, 1991, in Shimizu, Japan. 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.

Also at La Jolla, further evidence of the decline in the 1980s of the North Pacific albacore was revealed in a collaborative study undertaken by Pierre Kleiber within the Pelagic Fisheries Resources Division and Hideki Nakano of Japan's National Research Institute of Far Seas Fisheries. In analyzing Japan's fishing effort data for the albacore pole-and-line fishery, they found further proof that the United States and Japan share the same albacore resource, that fishermen became more efficient at finding albacore in the 1980s, and that this increased efficiency initially masked a steep decline in the albacore resource.

In another La Jolla study, Norm Bartoo, head of the **Stock Assessment and Fishery Impact Analysis Program**, and Dave Holts conducted a series of albacore gillnet drop-out

experiments. This special study was initiated last year as part of the SWFSC's driftnet impact program, to better estimate the proportion of fish that drop out of the net before or during net retrieval, and how sea conditions influence drop-out rates. In addition to open-water work, Bartoo and Holts, with consultation from Hideki Nakano, did a simulation study in a computer-controlled wave generation tank capable of simulating full-sized, wind-driven seas corresponding to up to 23 knots of wind. A cooperative cruise with the Honolulu Laboratory to further investigate gillnet drop-out rates of albacore is planned this summer in the North Pacific Transition Zone.

Starting in 1990, Bartoo's Stock Assessment and Fishery Impact Analysis Program also conducted an observer program in cooperation with the Western Fishboat Owners Association to document gillnet-inflicted damage on albacore in the troll catch over a wide fishing area of the North Pacific Ocean. This was also a collaborative effort between Gary Sakagawa's division in La Jolla and Jerry Wetherall's investigation in Hawaii. Results showed that approximately 12% of the albacore had gillnet marks, either fresh scars or healed scars from earlier net encounters. As would be expected, rates varied considerably with fishing area and proximity to gillnet fishing areas.

We also continue to be active in providing statistical and research support on South Pacific albacore and for the South Pacific Albacore Research (SPAR) group. Sakagawa and Wetherall attended the South Pacific Albacore Assessment Workshop in Noumea, New Caledonia, supplying information on the U.S. troll fishery and a sampling design for studying albacore reproductive biology. They also attended the SPAR III meeting where participants reported on research results and fishery developments, and where the SWFSC provided statistics on the fisheries it monitors. Wetherall and Sakagawa were also science advisors to the U.S. delegation to the Third Consultation on Arrangements for South Pacific Albacore Fisheries Management.

Work on albacore reproductive biology began at the La Jolla Laboratory in 1990 within the Pelagic Division's Stock Assessment and Fishery Impact Analysis Program. Norm Bartoo and Darlene Ramon have been working, in collaboration with foreign scientists, to examine the spawning biology of Pacific albacore and its relation to recruitment. Histological sections of albacore ovaries have been provided from several sources, including the South Pacific Commission, the Honolulu Laboratory, and the National Research Institute of Far Seas Fisheries in Japan. They hope to determine the seasonality, duration, and location of spawning, and stock relationships between North and South Pacific albacore. The work on South Pacific albacore is part of a U.S. commitment to SPAR.

The *Albacore Fish Bulletin*, formerly produced by the **Coastal Fisheries Resources Division** during the West Coast albacore season, will be discontinued, but plans are to incorporate albacore news items into the SWFSC's *Tuna Newsletter* and eventually merge the two mailing lists. Mike Laurs, head of the Coastal Division's **Fisheries Environmental Investigations Program**, was honored on November 6, 1990, in Reno, Nevada, by members of the U.S. albacore fishing industry for his 20 years of contributions to worldwide albacore research.

At the Honolulu Laboratory, scientists were closely involved with Pacific albacore issues. The program, **North Pacific Driftnet Impacts Research Program**, headed by Jerry Wetherall, is devoted to evaluating the high-seas fisheries targeting squid and albacore in the North Pacific Transition Zone. The Driftnet Impact Program uses fishery statistics collected through NMFS foreign observer programs, and biological data from sea surveys and experiments. As part of a larger NMFS driftnet research effort, the program supports NMFS policy and management staffs in the Southwest Region and Washington, D.C., and other parties with concerns about the high-seas fisheries, including the U.S. albacore industry.

This past year, Wetherall's group has been busy processing and analyzing data from the international squid driftnet observer program. Honolulu is handling all albacore, marine turtles, and "incidental species" data gathered by observers on the vessels; the Alaska

Fisheries Science Center handles the remaining data on marine mammals and salmonids; and the U.S. Fish and Wildlife Service assesses seabirds. His group also worked on computer programs to process the by-catch and extrapolate total fish catch levels from squid fishery observer data; took part in a cooperative squid driftnet research cruise; obtained albacore samples from the Honolulu fish auction for age, growth, and reproductive work; collaborated with La Jolla on the troll fishery observer program; and assisted in logistics for placing observers on squid fishing vessels.

Also during the year, the Honolulu Laboratory's **Fishery Management Research Program** produced a SWFSC Administrative Report by Don Schug entitled "The prospects for an international fisheries management regime for South Pacific albacore," which evaluates the current negotiations intended to establish an international management regime for the South Pacific albacore fishery.

At the Pacific Fisheries Environmental Group, 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.

Finally, SWFSC researchers are preparing for the International North Pacific Fisheries Commission (INPFC) Conference in Tokyo in November 1991, which will include a comprehensive, 1-day symposium on driftnetting in the North Pacific and results of research. The SWFSC plans to present its results on the troll fishery observer program, gillnet drop-out studies, analyses of incidental catches, and troll-gillnet interaction studies.

Tuna-Related Fishery Data Bases

The SWFSC staff handles extensive and complex fishery data bases from tuna fisheries around the world. At the La Jolla Laboratory, the **Multispecies Data Collection and Evaluation Program**, led by 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 and data collected by tuna-dolphin observers for use in marine mammal stock assessments. Most recently, Coan has been working 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.

This year Al Coan, Ken Wallace, and Al Jackson completed a paper that describes differences in dolphin mortality rates in day and nights sets for U.S. purse seiners fishing in the eastern tropical Pacific. This was an expansion of an earlier study on the same subject, but this time data were analyzed by fishing area. Once again, mortality rates were found to be significantly higher in night versus day sets, and that stratification of the data by area did not change the results. They also did analyses to test the effects on dolphin mortality of eliminating night sets, using data collected from the fishery between 1979 and 1988. Sets that extended into darkness were eliminated to see if the remaining sets showed a significant decrease in dolphin mortality. Indeed, they found that total mortality rates decreased as much as 30% when night sets were eliminated.

Industry Economics and Global Trends

In the **Tropical Tuna Fishery Monitoring and Evaluation Program**, led by Gary Sakagawa, the staff monitors tropical tuna trade and fishery developments on a global scale to help interpret and evaluate fishery

statistics used to analyze stock condition. Data obtained from international sources are summarized in various publications, including the popular *Tuna Newsletter* edited by Al Jackson.

Statistics of the U.S. canned tuna industry were compiled for the first three quarters of 1990 by Al Jackson, Doug Prescott, and John Childers from the SWFSC in La Jolla, and Pat Donley and Mike Thabault of the Southwest Regional Office. 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.

Billfish

Perhaps the biggest issue relating to Pacific billfish was the rapid growth of the Hawaiian longline fishery. An associated issue was the expansion of these boats into areas frequented by protected Hawaiian monk seals. The **Honolulu Laboratory**, which had been monitoring developments in this fishery, began placing NMFS observers aboard cooperating longline vessels last summer to document any longline gear-protected species interactions, and also to collect data on fish catch and effort and biological information vital to swordfish stock assessment. This program accelerated after observers became mandatory in late November 1990. On March 1, 1991, the Western Pacific Regional Fishery Management Council recommended to close to longliners an area 50 miles around certain areas in the Northwestern Hawaiian Islands (NWHI) known to be frequented by monk seals. This action was taken to protect these endangered seals.

In response to the paucity of scientific information on Pacific swordfish, a prime target of the longline fishery, Honolulu Laboratory scientists conducted longline operations from the *Townsend Cromwell* in central North Pacific waters in January and February 1991. Age and growth, stock structure, and habitat utilization of swordfish were investigated. Also, pelagic fisheries data are collected from dockside interviews, the wholesale markets, and domestic longline fishing vessels through federally mandated logbooks and from observations of longline operations in the Northwestern Hawaiian Islands.

Honolulu Laboratory scientists wrote a measurable definition of recruitment overfishing for pelagic species and also revised the definition of optimum yield and a set of fishery management plan objectives to bring them into accordance with the definition of recruitment overfishing and the status of fishery development in the western Pacific region. These definitions and objectives became the substance of the Western Pacific Regional Fishery Management Council's Amendment 1 to the Fishery Management Plan for the Pelagic Fisheries of the Western Pacific Region, which was approved by the Secretary of Commerce in February 1991.

At the La Jolla Laboratory, the *Billfish Newsletter*, edited by James L. Squire, Jr., which gives results of the Pacific International Billfish Angler Survey and Cooperative Marine Game Fish Tagging Program, was distributed in April.

In 1990, contributed papers for the Proceedings of the Second International Billfish Symposium, held in Kailua-Kona, Hawaii, in 1988, were published by the National Coalition for Marine Conservation, Inc. This collection included the following contributions from the SWFSC: "Migration trends of striped marlin (*Tetrapturus audax*) in the Pacific Ocean by," by James L. Squire, Jr. and Ziro Suzuki; "Activity patterns of striped marlin in the Southern California Bight," by David Holts and Dennis Bedford; and "Striped marlin in the Northeast Pacific---A case for local depletion and core area management," by James L. Squire, Jr. and David Au.

Mathematical Modeling for Stock Assessment

The **Pelagic Ecosystem Model Development Program**, headed by Pierre Kleiber, continues to evaluate mathematical modeling techniques used in stock assessments, examining them for accuracy and relevancy to management of tuna and related fisheries. The staff also assists in designing and conducting stock assessments and planning sampling projects. Pierre Kleiber and Carlos

Salvadó, in collaboration with Alain Fonteneau of ORSTOM in France and Rick Deriso of the IATTC, have been working on a mathematical model for describing tuna movement dynamics using eastern Atlantic skipjack tuna tag-recapture data. After the model is formulated to predict catch rates of fish, it can be used to test the interaction of different fleets operating in either the same or differing economic zones. Kleiber also completed an analysis of Japan's albacore fishing effort data with Hideki Nakano, as mentioned above. Salvadó and David Au also collaborated in analyzing the dynamics of passive fishing gear (e.g., longline gear) in relation to fish population density and catch rates. This model will form the basis of studies involving catch rates versus population characteristics of tunas, and optimal foraging strategies in tropical pelagic species.

Dolphin Research

Within the **Fishery-Marine Mammal Interaction Division** (FMMID), led by Doug DeMaster, scientists with the **Fishery Independent Assessment Program,** conduct annual dolphin surveys in the eastern tropical Pacific (ETP) to determine trends in dolphin populations affected by the ETP tuna purse seine fishery, as mandated by the Marine Mammal Protection Act (MMPA). On July 10-11, 1990, a workshop was held at the SWFSC to reassess the dolphin monitoring program. Among the recommendations resulting from this meeting was that the standard Monitoring of Porpoise Stocks (MOPS) research vessel surveys should be interspersed with annual, single-year surveys targeted to derive minimum abundance estimates of specific stocks. In March 1991, NMFS approved a change in the original MOPS proposal, so that a California coastal marine mammal survey will be done this year, minimum population size surveys for common dolphins will be done in 1992 in the ETP, and the standard MOPS cruises will be carried out in 1993. The pattern will then be repeated in a second 3-year cycle (1994-1996). Last year's MOPS cruise, the fifth in a series of annual MOPS surveys, was completed and results are now being compiled.

In summer 1990, the **Southwest Region** established the **Eastern Tropical Pacific Gear Program** at the SWFSC in La Jolla, within the Fishery-Marine Mammal Interaction Division. This program, headed by John Young, is aimed at developing alternative tuna fishing methods that will reduce or eliminate the incidental mortality of dolphins.

The **Fishery-Dependent Assessment Program,** led by Steve Reilly, continued to examine dolphin encounter rates in relation to environmental features that may affect dolphin distributions. In November, a report was completed that describes a method for quantifying cetacean oceanic habitats. A second report has been completed that outlines how these data can be used to improve the trend analyses. In early 1991, this program was divided into two new programs: the **Dolphin Ecology Program** led by Reilly and dealing with eastern tropical Pacific ecosystem research, and the **Fishery-Dependent Analysis Program,** led by Elizabeth Edwards and dealing with analyses of tuna vessel observer data (TVOD). 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 rates.

The staff of **Biology Assessment Program,** led by Andrew Dizon, last year began a study of the genetics of ETP dolphins, extracting DNA from dolphin tissue samples collected from live animals during research cruises using special crossbow-fired collecting darts. The long-term goal is to genetically differentiate the major species and stocks of dolphins affected by the ETP tuna purse seine fishery. Work also continues on temporal patterns in life history parameters and studying correlation between stress in dolphins and patterns of calcification in their teeth.

Hawaiian Tuna Stocks

At the **SWFSC Honolulu Laboratory,** Chris Bogg's **Pelagic Ecosystem Program** is working with biological and fisheries data on Hawaiian yellowfin, bigeye, and skipjack tunas. This program has been working the past year on a new method for adjusting

longline efficiency for tuna and billfish, a paper on tuna swimming energetics, a summary of morphometric variation in yellowfin tuna, and an analysis of catch rates by small-vessel tuna fishermen in Hawaii in relation to developments in the large-scale longline fishery.

In Robert Skillman's **Pelagic Fisheries Management Plan Research Program,** information on basic biological parameters---age and growth, size/cohort composition, mortality rates, reproductive biology and recruitment---is gathered to improve the scientific basis for effective management of billfishes, wahoo, mahimahi, and oceanic sharks. Data are collected from the fisheries and from biological experiments.

Sam Pooley's **Fishery Management Research Program** provides fisheries data for biological and economic research on federally managed central and western Pacific fisheries. The primary sources for these data are Federal logbooks and wholesale market monitoring. However, additional information on vessel operations is also necessary; it is acquired through at-sea observations and by interviews at dockside. An additional objective is to provide summary reports of these data to the Western Pacific Regional Fishery Management Council for their evaluation. The program is also responsible for conducting economic and operational research on these fisheries to evaluate proposed fisheries regulations.

To understand the biology of tuna under specific environmental conditions, physiological studies are also being conducted by Richard Brill's **Ecological Physiology Program** using live tuna in tanks at the Kewalo Research Facility. Results of such studies are then tested by attaching ultrasonic transmitters to free-swimming tuna in the open ocean. The transmitters enable scientists to simultaneously measure the fish's horizontal and vertical movements and various physiological and environmental parameters. The results, when combined with historical information on the ocean environment, are useful in developing techniques for predicting catch rates of island-based tuna fisheries.

DR. IZADORE BARRETT, PH.D.
Science and Research Director
Southwest Region

May 1991
La Jolla, California

II. ECONOMIC OVERVIEWS

Statistics of the U.S. Canned Tuna Industry Compiled for the First Three Quarters of 1990

Statistics for the U.S. canned tuna industry for the first three quarters of 1990 were compiled by Al Jackson, Doug Prescott, and John Childers from the Southwest Fisheries Science Center, and Pat Donley and Mike Thabault of the Southwest Regional Office. The reports describing the statistics appear as articles in the August and November 1990, and February 1991 issues of the SWR/SWFSC Tuna Newsletter.

The total number of vessels in the U.S. tropical purse seine fleet was down one vessel from the same time last year, with 62 vessels active through the beginning of September 1990. Of that total, 29 U.S. vessels were active in the eastern Pacific, and 36 were active in the western Pacific (three of those vessels overlapped between the two areas). The total U.S. vessel capacity at sea was 68,520 short tons (st), with 26,745 st originating in the eastern Pacific, and 45,325 st originating in the western Pacific.

For the first quarter of 1990, receipts as received (not converted to round weights) of domestic and imported raw tuna by U.S. canners were down 19% from first quarter last year, at 100,500 st. Second quarter totals also showed a 19% decline, with 125,400 st received, while third quarter receipts showed a 32% decline from last year, at 86,500 st. Species composition data for all three quarters showed the largest component of the deliveries to be skipjack, comprising 41% of the total, followed by 35% yellowfin and 24% albacore.

As in the first three quarters of 1989, tuna delivered to U.S. canneries for the first three quarters of 1990 originated principally in the western Pacific. After the gradual increase of imported tuna by U.S. canners in the first two quarters of 1990, the third quarter showed a decline in imports (55% in second quarter to 51% in third), largely as a result of the U.S. canners' decision to buy only "dolphin-safe" tuna.

Of the imports in the first quarter, the top four nations, Taiwan, Ghana, South Korea, and Ecuador provided 59% of U.S. cannery imports, and the top 8 nations provided 82% of all imports. In the second quarter, imports by the top three nations, Taiwan, Japan, and south Korea, contributed 45% of the imports. By the third quarter, the top three nations were Taiwan, South Korea, and Ghana, contributing 57% of all imports to the total U.S. cannery imports. In the first two quarters, eight nations contributed almost 80% of total imports, while in the third quarter, 7 nations monopolized 84% of the total U.S. cannery imports.

Imports of canned tuna packed in water were down in the first three quarters of 1990. Compared to the 57% that imports contributed to the average total receipts from 1985-1989, total imports of tuna for the first quarter of 1990 were down to 54% of total receipts, and declined further to 51% by the third quarter ending September 1, 1990.

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

Data for purse seiners fishing in the area around the Seychelles were received from the Seychelles Fishing Authority and added to Center data bases by Biological Technicians Gary Rensink and Cheryl Brown. The data bases are available on PC diskettes and are in LOTUS spreadsheets; they cover the period 1983 to the present.

The number of vessels participating in this fishery reached a historical record high of 55 in February 1990 (20 French, 21 Spanish, 2 Mauritian, 8 Soviet, and 4 Japanese flag vessels). The previous record was 50 vessels in November 1989. By June, however, the number of seiners dropped to 44.

Catch rates during the first half of 1990, averaging 11 tons/day, compared to 22 tons/day for the same period in 1989. Cumulative catches for the first two quarters (through June 1990) totaled 65,800 tons, a decrease of 47% from the same period in 1989. Yellowfin and skipjack tuna were equally represented in the catch during the first two quarters of 1990.

The number of vessels participating in the purse seine fishery in the western Indian Ocean during the third quarter of 1990 reached a high of 45 in September (14 French, 21 Spanish, 2 Mauritian, 1 Panamanian, 4 Soviet, and 3 Japanese), much lower than earlier in the year, and lower than the 49 vessels recorded for the same period in 1989.

Average catch rates for the third quarter of 1990 were double those of the previous two quarters, and an improvement over the same period last year, while cumulative catches through September 1990 showed a decrease of 31% compared to catches for the same period in 1989. The species composition of catches for the third quarter of 1990 was 45% yellowfin and 55% skipjack tuna, compared to 22% yellowfin and 78% skipjack tuna during the same period in 1989. Yellowfin tuna accounted for 83% of the catch for the month of July 1990.

IV. PACIFIC OCEAN FISHERIES

Pacific Albacore

Summary of 1988-89 U.S. Pacific Albacore Fisheries Data

Data from the 1988-89 South Pacific and 1989 North Pacific U.S. albacore fisheries were summarized by Atilio Coan, Gary Rensink, Christina Perrin, and Forrest Miller (IATTC) in SWFSC Administrative Report LJ-90-21; the report is entitled "Summary of the 1989 North and South Pacific albacore fisheries data."

In 1989 there was a 67% decline from 1988 in total U.S. albacore catch for the North Pacific albacore fishery (down 89% from the 15,000 ton average for 1969-88), but a 7% increase in total catch in the South Pacific. Catch-per-effort (CPE) since 1988, however, decreased for both the North and the South, with a 45% CPE decline in the North Pacific, and an 8% CPE decline for the South.

High catches for the 1989 North Pacific albacore fishery were centered nearshore, off California, Oregon, Washington, and British Columbia. The majority of albacore caught by jigboats consisted of 61-70 cm fish. Baitboat-caught albacore were mostly from two length modal groups, 61-70 cm and 73-85 cm, as compared to a single mode of 59-66 cm in 1988. Fewer large (85 cm) fish were caught compared to 1988. High catches in the South Pacific were centered in an area 35° to 39° South and 138° to 161° East.

Sampling coverage of logbooks for the U.S. North Pacific fishery was 42% in 1989, compared to 32% coverage in 1988, while length frequency data coverage in 1989 was 4%, up from 3% for 1988. In the South Pacific fishery, logbook coverage increased from 21% in 1988 to 42% in 1989, and length frequency data coverage increased from 1% to 3% in 1989.

Albacore Troll Fishery - High Seas Drift Net Interaction

High-seas gillnet fisheries of Japan, Taiwan, and Korea operating in the North Pacific, target on squid using small mesh nets and on tuna and marlin using large mesh nets. These fisheries take albacore and operate in areas where albacore concentrate during the trolling season.

In cooperation with the Western Fishboat Owners Association, SWFSC observers accompanied five U.S. troll vessels during the 1990 fishing season. The observers, placed onboard in response to complaints by U.S. albacore fishermen concerning decreased catches and substantial numbers of gillnet-damaged fish, documented daily catches and recorded gillnet inflicted damage on albacore in the catch over a wide fishing area of the North Pacific Ocean. An analysis of the resulting data provides minimum estimates of albacore encounter rates with the gillnet fisheries.

Between the end of May and the beginning of October, six cruises were completed, totaling 377 observed sea days in the Midway, offshore, and coastal fishing areas. A total of 19,526 albacore or 78% of all albacore caught, was examined and measured (both fork length and maximum girth), and 8,720 of these were also weighed. Overall, 87.2% of the catch examined showed no evidence of net related damage. Recent gillnet damage occurred in 7.2% of the catch while 5.2% had healed scars from earlier net encounters.

Larger fish averaging 20-25 pounds were taken in June and the first 2 weeks of July by vessels departing from Honolulu, Hawaii, and fishing west of 140°W. Observers reported injuries from recent encounters with drift gillnets in up to 18% of the catches west of 140°W. Old and healed scars appeared on less than 1% of the catches in the Midway area and on 5.5% of the catch in the offshore area.

By the end of July, all vessels were fishing east of 140°W where they encountered smaller fish weighing 12-20 pounds. The incidence of gillnet injuries in that area was lower (4.1%), while the incidence of old injuries remained at about 5%. In August, large fish (20-25 pounds) were caught off Vancouver Island, British Columbia, and fishing remained moderately good North of 50°N until seasonal storms out of the Gulf of Alaska forced many vessels to return home by the end of September. Gillnet damage rates in this northern area were about 5%, and no different from rates in the areas South of 50°N.

Preliminary analysis of fish with and without gillnet marks indicated no weight loss due to injuries from encounters with the high-seas gillnets.

Blood and tissue samples were collected from subgroups of uninjured and injured fish, including fish that had recovered from previous injuries. Analyses of the samples to determine if disease or other abnormalities occurred in the injured fish, are underway and will be reported when completed.

Albacore Drop-out Experiment

In ongoing attempts to understand the impacts of gillnets on albacore, SWFSC scientists completed an albacore gillnet drop-out experiment using the facilities of ARCTEC, Inc., an Escondido, California based firm, in February 1991. One tank of commercial-type, 175-mm stretch mesh drift gillnet was "fished" in the 350- x 50-foot wave and towing basin at ARCTEC. This large wave basin is 13.5 feet deep and holds 1.3 million gallons of water. Through the use of a sophisticated, computer-controlled wave generation package, it is capable of simulating full size wind driven seas corresponding up to 23 knots of wind.

Dead albacore were placed in the net by SWFSC divers, and then the net was subjected to full scale wave spectra typical of wind driven seas during spring in the transition zone of the North Pacific Ocean. This included seas corresponding to wind speeds between 8 and 23 knots, with varying wave periods. In addition, the net was subjected to regular periodic swells of varying heights. A total of fourteen 30-minute runs was made with albacore gilled in the net. Data on the rate of loss of fish from the net were collected. Loss rates ranged from 0 to 70% and showed an increasing trend with increasing wave energy levels. The results are currently being analyzed.

Japanese Albacore Data Confirms Population Decline Deduced From U.S. Data

Pierre Kleiber worked with Hideki Nakano from the Japanese National Research Institute of Far Seas Fisheries to analyze catch-and-effort data from the Japanese North Pacific albacore pole-and-line fleet. The object was to see if they would find the same diverging trend between two methods of calculating catch-per-effort as reported by Pierre Kleiber and Christina Perrin (1991) for the U.S. jig fleet during the 1980s. Kleiber and Perrin found that the divergent trends resulted from the fact that U.S. fishermen were improving their ability to find albacore concentrations during the 1980's. This caused upward biases in the trends of both catch-per-effort time series. Because one of the catch-per-effort measurements had a slightly downward trend, the actual population trend must have been an even steeper decline. Because the Japanese and U.S. fleets depend at least to some extent on the same biological population of albacore, it was felt that the Japanese data could confirm the results from the U.S. data.

The two types of catch-per-effort are pooled and semi-stratified given by

$$cpe_{\text{pooled}} = \frac{\sum c_i}{\sum e_i}$$

$$cpe_{\text{semi-strat}} = \frac{1}{N}\sum\left[\frac{c_i}{e_i}\right]$$

where c_i and e_i are the catch and effort in the i-th stratum, and N is the number of strata. The pooled catch-per-effort appears to trend upwards while the semi-stratified catch-per-effort remains relatively constant, and approximates the results from the U.S. data.

To check for evidence that the pole-and-line boats were increasingly concentrating on areas rich in albacore, a "favoritism index"

was calculated. This index is the proportion of the effort in any year that is expended in strata with a catch-per-effort above some threshold value, *cpe**. The favoritism index in year *y* is given by

$$favoritism\_index_y = \frac{\sum_{i \in T_y} e_i}{\sum_{i=1}^{N_y} e_i}$$

$$T_y = \{i \mid (c_i/e_i) \geq cpe_y^*\}$$

where T_y is the set of stratum indices for which *cpe* is greater than cpe^*_y, and cpe^*_y is a threshold for the top 20th percentile (ranked by catch-per-effort) of the strata in each year *y*. The increase in favoritism is not as dramatic for the Japanese fleet as for the U.S. fleet, but the trend is the same; this indicates rising positive biases in both cpe_{pooled} and $cpe_{semi\text{-}strat}$ time series.

If a parallel rise in both pooled and semi-stratified catch-per-effort had been found instead of a divergence, as seen in the U.S. data, it would have cast doubt on the notion that Japanese and U.S. surface albacore fisheries in the North Pacific are harvesting the same biological population. But this study's results are similar to the results from the U.S. data, and are therefore consistent with the notion of a shared resource. Furthermore, the results of this study carry the same implication as the U.S. data, namely that the resource was in decline during the 1980s.

South Pacific Albacore Longline CPUE Declines

At the 1990 SPAR III workshop in Noumea, New Caledonia, Jerry Wetherall described the procedures he and Marian Yong are using at the Honolulu Laboratory to periodically monitor the South Pacific albacore stock. Wetherall and Yong are using Korean and Taiwanese longline logbook catch-per-unit-effort (CPUE) data collected by Gordon Yamasaki and his Southwest Region (SWR) staff in Pago Pago. Under an assumption of constant longline catchability with respect to albacore, the CPUE statistics provide measures of the relative abundance of larger, older albacore and a way to track changes in abundance over time. Further, allowing for delays in response time, the data should indicate how longline fishing success and the abundance of older albacore are affected by expanding surface fisheries, which take mainly smaller, younger fish.

In earlier work, Wetherall and Yong showed how the spatial distribution of longline effort and albacore CPUE vary seasonally and indicated that N-S variation in albacore CPUE is more pronounced than E-W variation. Accordingly, they presented historical time series of annual and monthly CPUE statistics for several 5 degree bands of latitude.

Attention was focused on the 1988-89 data to see whether there was any evidence that longline CPUE had been affected by the dramatic increase in surface catch by drift gillnet and troll vessels. One of the key strata examined was the 35-40°S band, which corresponds roughly to the southern Subtropical Convergence Zone (STCZ). Most of the surface fishing occurs in this zone during December-April. Furthermore, from March to June, the STCZ is visited by many longliners. During this interval, the longline fleets compete directly with the troll and gillnet fleets for immature albacore. Changes in the STCZ longline CPUE data may provide a direct measure of surface fishery-longline fishery interactions.

The longline CPUE statistics indicated a decline in albacore stock density from the mid-1960s to the mid-1970s, during the period of fleet expansion. Then there appears to have been a slight but short-lived increase in abundance or availability of albacore to longliners, followed by a period of decline lasting until the mid-1980s. The CPUEs rose again, peaking in 1986 or 1987, then declined in most strata during the period of rapid surface fishery expansion.

Overall, the data showed that the Korean albacore CPUEs for April and May 1989 were the lowest on record. The level of logged effort in the STCZ has also declined, however, so that the reliability of the STCZ indices has suffered. Taiwanese albacore CPUEs for April and May of 1989 and 1990 (provisional

results) also were much reduced from the 1986 peak levels. In the STCZ stratum, Taiwanese and Korean longline albacore CPUEs declined in the first two quarters of 1988-89. Such a decline could have arisen from several factors, including a reduction in overall stock size due to expanded surface fisheries, reduced availability of albacore in the STCZ, or other factors.

In all strata, the CPUE data clearly suggested a decline in abundance of the older albacore as the longline fishery developed in the absence of a significant surface fishery. However, considerable systematic interannual variation in longline CPUE was evident. Such variation will make it difficult to detect changes due to increased surface fishing.

Launching of Albacore Reproduction Biology Project

In September, Fishery Biologists Norman Bartoo and Darlene Ramon, working in collaboration with foreign scientists, launched a project to examine the spawning biology of Pacific albacore and its relation to recruitment.

Equipped with an integrated image capturing system, composed of an Olympus SZH dissecting microscope, a Cohu solid state camera, and a Macintosh IIcs computer with a Data Translation Quickcapture board installed to capture and process images, they began measuring oocyte diameter and recording data for later analysis.

Albacore gonads from both the North and South Pacific will be provided for the study by several sources, including the South Pacific Commission, the Honolulu Laboratory, and the National Research Institute of Far Seas Fisheries in Japan. In addition, 74 albacore, ranging in size from 78 to 92 cm, were collected by SWFSC observers aboard U.S. troll vessels in the North Pacific between August 7 and September 24, 1990.

To test the possible effects of preservation methods on laboratory analysis, the right gonads from these fish were preserved in formalin, while the left gonads were frozen. Results indicate that either preservation method is satisfactory for analyzing levels of maturity in the fish. Results also showed, however, that the size of ova in pairs of ovaries was different--a difference that might be related either to the preservation method, or to actual physical asymmetry in ova sizes associated with differences in weights between the right and left ovaries. A detailed study of this finding is planned.

As part of the larger program, Ramon has begun examining albacore gonads taken in New Zealand's Exclusive Economic Zone (EEZ) by South Pacific Albacore Research (SPAR) program observers, to determine spawning periodicity.

The sampling design, prepared by Program Leader Norman Bartoo, calls for collection of mature albacore gonads from various areas throughout the year, as well as special collections by observers. Other laboratories cooperating in the collection of samples include: the Institute of Oceanography; National Taiwan University; the National Research Institute of Far Seas Fisheries, Japan; and SPAR participants in the South Pacific.

Work on Albacore Catch Forecasting Continues

At the Pacific Fisheries Environmental Group in Monterey, California, scientists continue to work on environmental influences on albacore catches. Models at differing spatial resolutions have been developed, and their ability to forecast albacore catch-per-unit-effort (CPUE) is being evaluated. Computer animations are being developed that display the observed CPUE by area against environmental factors and the model CPUE against environmental factors. The animations also model observed CPUE and model CPUE against transformations of the environmental variables that appear to improve the predictions. A book describing these and other results is in preparation.

Hawaii Fisheries

1990-91 Developments in the Hawaii Longline Fishery

During 1990, the longline fishery continued to expand at a very rapid rate in Hawaii, through a combination of investments in new vessels and vessel conversions and transfers of vessels from other areas. While many vessels target on swordfish for much of the year, other vessels shift from swordfish to tuna during the year. This fishery is mainly a night fishery, and "night light sticks" are used to attract fish to the baited hooks. By May 1990, 46 vessels had already made 128 trips, landing over 1.3 million pounds of fish, which amounted to almost 3 times the total landings for 1989. During this period each vessel would set an estimated 10-30 miles of longlines and 900 hooks nightly. The fishermen followed migrating swordfish from about 100 miles north of French Frigate Shoals (FFS) to inshore areas adjacent to the atoll.

Because of movement of the fishery into certain areas in the Northwestern Hawaiian Islands (NWHI), the SWFSC and Southwest Region became concerned about potential interactions with endangered Hawaiian monk seals as early as April 1990. In May, the Southwest Region issued a press release warning about possible fishery-monk seal interactions and requesting cooperation from the public and fishermen in reporting any interactions. Also in May, a field party from the Honolulu Laboratory surveyed monk seals and turtles at French Frigate Shoals for any evidence of interactions with the fishery, but results of the survey were generally inconclusive. Special Agents from the Southwest Enforcement Branch then interviewed captains and crews of vessels returning from the NWHI in late May, but they found no substantiated evidence of harm to the seals.

To gather more information, the SWFSC's Honolulu Laboratory began deploying NMFS observers on a voluntary basis aboard cooperating vessels in July 1990 to document any longline gear-protected species interactions, and also to collect data on fish catch and effort and biological information vital to swordfish stock assessment. Regulations went into effect on November 27, 1990, which authorized the Southwest Regional Director to require longline vessels to carry observers if the vessels were to fish within 50 miles of the NWHI.

In January 1991, the U.S. Fish and Wildlife Service reported observing monk seals with hook injuries, and a follow-up visit to French Frigate Shoals by Honolulu Laboratory personnel confirmed the reports. They observed seals that had been impaled with longline hooks and others that had injuries not consistent with natural causes.

On March 1, 1991, the Western Pacific Regional Fishery Management Council (WPRFMC) took action to protect the seals, requesting an emergency action to close longline fishing in an area within 50 miles of the NWHI between Nihoa and Kure Atoll, with a 100-mile-wide corridor connecting islands that are more than 100 miles apart. This is to facilitate enforcement by closing a continuous corridor around the NWHI, with no gaps. Longline fishing vessels would be permitted to transit the area but not fish in it.

In addition, at the Council's request, NMFS has now implemented a moratorium on the issuance of new permits, which will be in effect for 90 days beginning April 23, 1991, and may be extended for another 90 days with the agreement of the WPRFMC. The WPRFMC has begun developing a long-term management program, including limited entry, for the longline fishery. The SWFSC Honolulu Laboratory will provide significant data collection and analysis assistance to the WPRFMC in developing the program, which will have to consider the needs of inshore troll and handline fisheries for billfish and tuna as well as offshore longline fisheries.

WPRFMC Meetings

A meeting of the WPRFMC was held June 18-20, 1990, to focus on two major management issues. First, the WPRFMC discussed the definitions of overfishing for each of the four fishery management plan fisheries (i.e., pelagic fishes, bottomfishes and groundfishes, crustaceans, and corals); second, it considered

an effort limitation in the lobster and longline fisheries. The same material was previewed by the WPRFMC's Scientific Statistical Committee on June 14-15.

At the May meeting of the WPRFMC's Pelagic, Bottomfish and Seamount Groundfish Fishery Plan Monitoring Teams, Biological Technician Russell Ito reported on Hawaii's longline fishery. Based on the market monitoring program of the Honolulu Laboratory's Fishery Management Research Program, landings increased by 94% in 1989, while the troll and handline pelagic fisheries declined by 33%. Total longline landings equaled 5.9 million lb for tuna, and 3.6 million lb for pelagic management unit species (mahimahi, *Coryphaena hippurus*; ono (wahoo), *Acanthocybium solandri*; billfishes; and sharks). Troll and handline landings totaled 1.8 million lb for tuna and 1.6 million lb for pelagic management unit species; troll landings of yellowfin tuna, *Thunnus albacares*, were particularly poor in 1989. The total value of the pelagic fishery in 1989 was $31.2 million.

At the same May meeting, Fishery Biologist Kurt Kawamoto of the Honolulu Laboratory reported that the bottomfish fleet in the Northwestern Hawaiian Islands continued to decline, with only eight vessels active in 1989. Landings of bottomfish management unit species in 1989 totaled 303,000 lb ($756,000), down 52% from 1988, and 70% from 1987. Landings of bottomfish in the MHI in 1989 equaled 1.2 million lb ($3.9 million), down 25% from 1988. The report added that foreign imports of snappers, groupers, and jacks now constitute 26% of Hawaii's market.

South Pacific Tuna Fisheries

Sampling of Tunas Under the South Pacific Tuna Treaty

U.S. purse seiners have fished under the South Pacific Regional Tuna Treaty since June 1988, with landings totaling 137,400 metric tons (t) from January through December of that year, 145,100 t in 1989, and 72,000 t through July of 1990. Landings consisted of 60 to 80% skipjack tuna, with the remainder consisting of yellowfin and bigeye tunas. So far this year, the percentage of skipjack has been closer to 60% of the landings, as yellowfin tuna catches improve. Since the price paid for both yellowfin and bigeye tunas is the same, they are landed mixed as yellowfin tuna at U.S. canneries, where species composition samples were taken. These mixed landings consisted of 6% to 9% bigeye tuna, with the remainder consisting of yellowfin.

Catches were also measured for size composition as they were unloaded to canneries in American Samoa. In general, fish in school fish sets tended to be larger than those caught in log sets. The majority of the yellowfin tuna measured between 40 and 77 cm long; bigeye tuna 40-65 cm long, and skipjack tuna 46-66 cm long. Through July 1990, more small fish were being caught than in 1988 or 1989. Over the entire season, it appears that modes of fish sizes increase by approximately 2 cm between quarters 1, 2, and 3, but smallest fish are found in quarter 4. This may indicate recruitment to the fishery in quarter 4 of each year.

Tuna Behavior and Physiology Studies

Kewalo Research Facility Hosts International Cooperative Tuna Studies

Considered the ocean's most impressive athletes, tuna can use energy and recover from the effects of exhaustive exercise about 10 times faster than any other fish species. This remarkable aspect of tuna biology was the focus of the month-long cooperative research effort conducted last summer on skipjack tuna (*Katsuwonus pelamis*).

Eight scientists, from the University of British Columbia, Simon Fraser University, Massey University, and the University of California, San Diego, visited the Honolulu Kewalo Research Facility to participate in the multidisciplinary study which examined specific aspects of the physiology and biochemistry of tunas. Those participating in

the cooperative research were divided into two groups: a physiology group, headed by Anthony Farrell (Department of Biology, Simon Fraser University, Vancouver, British Columbia); and a biochemistry group, headed by Peter Hochachka (Department of Zoology, University of British Columbia, Vancouver, British Columbia).

The physiology group examined the importance of blood circulation in the heart muscle using an unusual technique developed by Farrell that allows scientists to control a fish's arterial and venous blood pressures while simultaneously monitoring its heart response. Farrell's group also tried to determine the normal cardiac output of tuna and describe the mechanisms that control the heart muscle contractions. In an attempt to explain the unusual physiological behavior of tuna hearts, Glen Tibbits of the Department of Kinesiology, Simon Fraser University examined the role that free intracellular calcium plays at the biochemical level to promote heart contractions.

Meanwhile, to gain insight into how tuna replenish their energy so quickly after exhaustive exercise, Hochachka's group measured levels of glycogen and its metabolite, lactate, in tuna white muscle. After sustained exercise, glycogen metabolizes to lactate, depleting stores of glycogen in the muscles and building up excess lactate. The group investigated the apparent ability of tuna to refuel their glycogen supply very rapidly compared to other fish species.

Hochachka's group also examined the relative abilities of tuna skeletal muscle, cardiac muscle, and liver to aid these fish in recovery after severe exercise. One study in particular focused on isolated groups of cells from tuna liver, the organ believed to play a major role in resynthesizing glycogen after exhaustive exercise.

Tuna used in the studies were supplied by Sadami Tsue, captain of the fishing vessel *Corsair*, which docks at Kewalo Basin. Tsue has been supplying the Honolulu Laboratory's Kewalo Research Facility with fish for scientific study for the past 17 years.

The Kewalo Research Facility, the only laboratory in the world where tuna are maintained in shoreside tanks and made available for live research, has had an active tuna research program for almost 30 years, and regularly hosts visiting scientists from around the world.

Manuscripts Completed on the Cardiac Physiology of Tunas

Two recently completed manuscripts based on the multidisciplinary tuna physiology and biochemistry studies, conducted in the summer of 1990 at the Kewalo Research Facility, have been completed. They are "Cardiac physiology in tunas: I. Perfused heart preparations in yellowfin and skipjack tunas" and "Cardiac physiology in tunas: III. Coronary pressure-flow relationships in skipjack tuna." Coauthors of the manuscripts are A. P. Farrell, C. E. Franklin, J. Johansen, P. S. Davie, and R. W. Brill.

The manuscripts describe, for the first time, some of the unique aspects of cardiac function in tunas and explain how tunas are able to produce cardiac output more than an order of magnitude higher than other fishes. One of the surprising discoveries of these studies is that tuna hearts, unlike hearts of most other fish, appear incapable of increasing cardiac output by increasing stroke volume (i.e., the amount of blood pumped per heart beat). These results explain why the adaptations that tunas have evolved to permit exceptionally high cardiac outputs make them relatively intolerant to reductions in ambient oxygen.

Pacific Billfish Programs

Gardiner Foundation Billfish Tagging Awards for 1989

Since 1970, the Gardiner Foundation of Oakland, California, has provided cash and award plaques to encourage captains to tag billfish, thereby assisting the SWFSC program in determining the migration patterns and rates of migration of billfish in the northeastern Pacific Ocean.

In recognition for the most billfish tagged by Mexican charterboat captains fishing the southern tip of Baja California, the Gardiner Foundation announced the 1989 winners. According to the SWFSC billfish tagging program records, Captain Gilberto Castro Collins recorded 57 billfish tagged and released, earning himself the first place award. Cash awards and a plaque were given to each of the six leading captains, whose names and numbers of billfish tagged are: Captain Victor Garcilia (54), Captain Antonio Vargas (50), Captain Jesus Ariza (43), Captain Martin Verdugo (39), and Captain Tomas Yepiz (34). About 35 charterboat captains participated, and the winners are all from the east Cape area of Baja California.

Thirty-Fourth Annual Hawaiian International Billfish Tournament

Jim Squire participated in briefing events for the 34th Annual Hawaiian International Billfish Tournament in Kailua-Kona, Hawaii, last August. The briefing, which was for participants of the 59 fishing teams from throughout the world, included a review of the results of billfish tagging off Baja California, Mexico. At a reception preceding the tournament, Squire presented the 1989 Hawaiian Billfish Tagging Award to Captain Bobby Brown of the charter boat *No Problem*. The award is given by the Pacific Ocean Research Foundation (formerly the Pacific Gamefish Research Foundation) to the captain who tags and releases the most billfish in the area during the year. Captain Brown started tagging marlin off Kona in 1976, and in 1989 tagged and released 62 billfish.

V. DOLPHIN RESEARCH AT THE SOUTHWEST FISHERIES SCIENCE CENTER

Introduction

In its initial response to the 1972 Marine Mammal Protection Act (MMPA), the Southwest Fisheries Science Center broadened an existing research project on dolphin and initiated new projects designed to reduce dolphin mortality and estimate dolphin abundance. Currently the Southwest Fisheries Science Center has a large research program devoted to the life history and population dynamics of dolphins, providing up-to-date information to fishery managers so that a rational management plan can be devised. Using two NOAA research vessels, the Center completed its fifth planned survey of an intensive 6-year program censusing dolphin populations in the eastern tropical Pacific (ETP), and collecting information necessary to estimate the density, size, and species composition of dolphin schools. Since dolphins range over a large ocean area and occur at relatively low densities, a long-term study, coupled with other abundance indices, was needed to get an accurate view of the trends.

NMFS is required by the MMPA to report to Congress in 1992 concerning our results on the status and trends of ETP dolphins. The report will be based upon these five surveys, and will be integrated with environmental data and 14 years of data collected by observers on tuna vessels, to improve the reliability of the analysis.

U.S. Tuna Canners and 'Dolphin-Safe' Tuna

Major U.S. canneries announced last year that they would stop buying tuna caught in association with dolphin, or any fish products taken in high seas drift nets. By mid-summer 1990, cans with "dolphin-safe" labels appeared in the market--labels based on reports from U.S. federal and international observers placed on the tuna vessels. With foreign nations currently maintaining 33 to 50% observer coverage, and the U.S. maintaining 100% coverage on its tuna vessels, NMFS and IATTC responded to the request by the U.S. canners to provide certificates or other documentation from observer records to determine if the tuna caught during a trip was intentionally taken in association with dolphin.

The Southwest Fisheries Science Center continues to work to ensure that viable populations of dolphins and other protected species are maintained. The Southwest Fisheries Science Center is dedicated to presenting for scrutiny, unbiased research results on this issue, so that steps can be taken if needed to ensure continuing healthy populations of marine mammals.

Data Show Decline in Fishery-Related Dolphin Mortality in 1990

In 1990, NMFS observers were on-board U.S. tuna purse seiners in the eastern tropical Pacific for 92 fishing trips, with a total of 1,845 sets on dolphins. Forty-four of those trips were observed entirely under the direction of the NMFS while the remainder (48 trips) were observed in cooperation with the Inter-American Tropical Tuna Commission. The data collected on these trips were verified by Biological Technicians Randy Rasmussen and Mike Trianni, and are maintained by the Multispecies Data Collection and Evaluation Program of the Southwest Fisheries Science Center's Pelagic Fisheries Resources Division.

The estimated number of dolphins killed in the U.S. tuna purse seine fishery in 1990 was 5,083, down 60% from the estimated 1989 kill of 12,643. The 1990 dolphin kill was well below the allowable annual quota of 20,500,

and was the lowest recorded for the U.S. fleet since this information was first tracked in 1972. The major reasons for the low 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 by the remaining fleet on non-dolphin-associated tuna, both consequences of the U.S. tuna canners' decision in April 1990 to purchase only "dolphin safe" tuna.

The observed dolphin kill-per-set rate in 1990 was 2.8 dolphins, down 22% from the 1989 rate of 3.6 dolphins, and was the lowest rate achieved by the U.S. fleet since 1979 when the kill-per-set rate was 2.7 dolphins. The dolphin kill-per-ton rate in 1990 was 0.14 dolphin, down 26% from the 1989 rate of 0.19 dolphin, and is the lowest rate on record.

Dolphin Survey Design Workshop Held

On July 10-11, 1990, a workshop was held at the Southwest Fisheries Science Center to discuss the survey design of the eastern tropical Pacific (ETP) dolphin monitoring program for 1992 and beyond. Participants reviewed a number of manuscripts prepared by the Fishery-Marine Mammal Interactions Division (FMMID) staff, and discussed a variety of topics, including: the relative abundance estimates from data collected during the 1986-89 monitoring of porpoise stocks (MOPS) cruises; a comparison of NMFS tuna vessel data with MOPS research vessel data; the use of the tuna-vessel observer program simulator (TOPS) model to determine the ability of research and tuna vessels to reflect decreases in dolphin density; and the statistical power analysis of dolphin surveys in the ETP. Based on this review, panel members made recommendations about future survey designs.

Reviewers concluded that research vessel observer data (RVOD) are most useful for estimates of absolute abundance because the time period covered is relatively short and the survey effort is predetermined. In contrast, tuna vessel observer data (TVOD) are better sources of trend estimates because these data from commercial vessels have much greater spatial coverage, allow for fine-scale post-stratification, and extend over a much longer period of time.

The primary recommendations for future work include: a continued use of TVOD for deriving trend estimates; development of calibration systems that will relate TVOD to RVOD, and vice versa; and interspersal of MOPS-type surveys covering the full fishery area, with single-year surveys targeted to derive minimum abundance and/or absolute abundance estimates of specific stocks determined to be in jeopardy or to be incompletely surveyed by the existing MOPS design.

Latest in Alternative Fishing Methods

In September 1990, the National Academy of Sciences (NAS) was scheduled to complete a study that evaluates alternatives to fishing tuna associated with dolphin. They have requested, and received, an extension from NMFS until April 1991, but this extension has now been delayed until June 1991, with a recommendation to expand the scope of the final report. It is expected to recommend new fishing techniques as well as improvements in existing methods of purse seining. NMFS has requested that the NAS panel give special attention to methods that do not directly involve dolphin.

NMFS has also begun a cooperative program with the IATTC and the tuna industry to start three projects in anticipation of recommendations expected to come out in the NAS report. One involves using subsurface fish aggregating devices (FADS)--a kind of floating artificial reef--that will be deployed in areas frequented by large yellowfin tuna, but outside the jurisdiction of ETP nations. U.S. and foreign vessels will cooperate in the research by donating ship time. The second project involves the design of a prototype laser scanning device which can be attached to the ship's helicopter and used to locate subsurface schools of tuna not associated with dolphin. A third involves the design of a current meter which can be deployed by the vessel before making a set on dolphin to determine the status of currents under the net. A review of observer data indicates that subsurface currents

are a major cause for the purse seine to malfunction and cause harm to dolphins.

Comparing Tuna Vessel Data With Research Vessel Data

Fishery Biologist Paul Wade completed a comparison analysis between NMFS U.S. tuna vessel (TV) and research vessel (RV) data on dolphins in the ETP using school size estimates, encounter rates, the detection probability density function, and abundance estimates. The comparison included only tuna vessel data collected at the same time of year as was the research vessel data (July 28 to December 10, 1989). Wade found that, in the tuna vessel observer data (TVOD), dolphin schools that are likely to carry the most tuna (i.e., large schools of spotted and/or spinner dolphins) are selectively recorded by crewmen on a regular basis. He attributes this either to a failure to see other types of schools, or a failure to communicate sightings of other types of schools to the TV observer. Such selective recording results in low TV encounter rates for striped and common dolphins, and in few data for these species. This bias also results in fewer recordings of the very small spotted and spinner dolphin schools (less than 50 animals), and more recordings of the very large schools (greater than 1000 animals) of these species, relative to research vessels. Again, this conclusion may only apply to the U.S. fleet; data from the international fleet will be analyzed in the near future.

This under-reporting of small schools of spotted and spinner dolphins apparently keeps TV encounter rates for these species in the same range as RV encounter rates, despite the fact that tuna vessels effectively search a strip more than 50% wider than research vessels. The lack of small spotted and spinner dolphin schools and the high percentage of very large schools in the TVOD causes the mean school sizes from tuna vessels to be more than 2.5 times greater than the mean school sizes from research vessels for these two species. Given the similar encounter rates for spotted dolphins and the lower school density calculated from TV data, differences in published abundance estimates between the two platforms for spotted dolphin are probably driven mostly by the large difference in mean school size. The similarity in abundance estimates between the two platforms for spinner dolphins may be a result of the offsetting differences of a higher TV mean school size versus a wider TV effective strip, as encounter rates are significantly different.

TOPS Model Used to Evaluate Two Sampling Methods for Detecting Dolphin Population Trends

The TOPS computer simulation model, developed by Elizabeth Edwards and Pierre Kleiber, was used by Fishery Biologist Debbie Palka to evaluate sampling and analysis methods of tuna and research vessels. The aim of the model, designed to detect a population decreasing by a constant rate of 10% per year, was to determine the vessels' abilities to track a constantly decreasing dolphin population over a period of 6 years, when the spatial distribution of the dolphin schools are density dependent.

While the tuna vessel procedure overestimated the abundance, and the research vessel procedure underestimated it, both were able to follow closely the 10% linear decrease.

The estimated abundance of individual dolphins, calculated from the research vessel's procedure, was not changed by increasing the amount of time spent at each sighting (up to one hour) or by excluding schools with less than 15 animals from the analytical method. The research vessel's procedure was improved by decreasing the amount of time spent at each sighting and by including small schools in the analysis method. Only in the case where small schools were included in the analysis was the estimated school abundance statistically indistinguishable from the actual school abundance; in all other cases, the estimated school abundance was lower than the actual abundance.

Statistical Power and Detectable Trends

Two additional ways of analyzing the statistical power of estimated trends in abundance of ETP dolphins were evaluated by Elizabeth Edwards and Cheryl Glick. First, they calculated the statistical power for cases where weighted linear regression across 5-year series detected no significant trend ($P>0.10$). Then, for these same cases, they calculated the amount of change that would have had to exist for detection at $\alpha=\beta=0.10$, given observed variability of the data. Due to the relatively large and variable coefficients of variation associated with individual estimates of abundance, power tended to be low in general, but highly variable overall. Power was highest for the group with lowest coefficients of variation.

Given reported CVs and abundance estimates, and assuming $\alpha=\beta=0.10$, calculations of the trend that would be detectable showed generally that the large size of the CVs obscured all but very strong trends. Detectable trends ranged from a minimum of 16%/year for northern offshore spotted dolphins to a maximum of 40% for central common dolphins.

The results imply that despite the apparently greater density of sightings data in TVOD, trend estimates derived from these data are generally not very precise. Since it is not practically possible to increase or otherwise control effort by the tuna fleet, the only way to improve both the power of the TVOD estimates and the detectability of trends in abundance is to reduce the variability in annual estimates of abundance, both within and between years. Another avenue would be to reduce variability in estimates derived only from TVOD by some sort of improved stratification of the data. Edwards and Glick have shown that the precision and accuracy of their analysis using TVOD is not appreciably worse than the results to date from the MOPS cruises. MOPS estimates are also characterized by a large variance within years, and large changes in abundance estimates between years. In this sense, TVOD and RVOD may be roughly equivalent in terms of usefulness for management, except that the TVOD time series is much larger than the RVOD time series.

Comparison Made of U.S. Eastern Tropical Pacific Tuna Purse Seine Day and Night Set Mortality Rates

Mathematical Statistician Al Coan, Computer Programmer Analyst Ken Wallace, and Fishery Biologist Alan Jackson completed a paper that describes differences in dolphin mortality rates in day and night sets for U.S. purse seiners fishing in the eastern tropical Pacific (ETP). This paper is an expansion of an earlier one on the same subject. Analyses with geographic stratification of sets (Figure 1) are included in this expanded study.

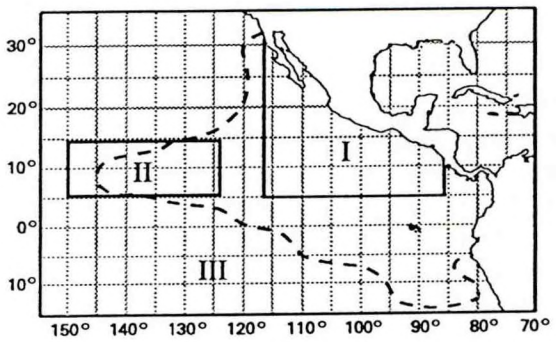

Figure 1. Area of the eastern tropical Pacific where yellowfin tuna are caught in sets associated with dolphins, and three subareas used to stratify dolphin mortality rates of the U.S. purse seiners participating in the fishery.

During the period 1979 to 1988, 21,000 dolphin sets and an associated dolphin mortality of 84,000 animals were observed by scientific observers aboard U.S. purse seiners fishing in the ETP. Approximately 67% of the sets and 49% of the dolphins killed occurred in area I, 16% of the sets and 19% of the animals killed occurred in area II, and 17% of the sets and 32% of the animals killed occurred in area III.

Night sets, while accounting for only 10% of the dolphin sets and 30% of the dolphin

mortality, consistently killed dolphins at a higher rate than day sets in all areas of the ETP. Only in area II did mortality rates for night sets ever fall below day set rates. The average number of dolphins killed per set (kill/set) and per ton of yellowfin tuna caught (kill/ton) in night sets, was approximately 3 to 4 times that in day sets for all areas of the ETP. Mortality rates were the highest in area III. Night sets also had consistently lower percentages of sets with no dolphins killed (zero-kill sets) and higher percentages of sets with more than 15 dolphins killed (high-kill sets) compared to day sets. A Wilcoxon paired-sampled test was used to test if these differences between day and night sets were statistically significant. Results indicate that mortality rates, as well as percentages of high-kill sets, are significantly higher (5% probability level) in night sets than in day sets; and the percentages of zero-kill sets are significantly lower in night sets than in day sets. Stratification of the data by area did not change these results.

High-intensity floodlights have been used during night sets by U.S. purse seiners since 1982 and became mandatory equipment for all vessels in 1986. The use of these floodlights during the period 1982 to 1988 decreased mortality rates as much as 77% over sets using other types of light (i.e. low-intensity lights). However, even with the use of floodlights, mortality rates were not lowered to parity with day set mortality rates.

Changes in mortality rates as a result of prohibiting night sets were also examined. Night sets on dolphins usually start in daylight or twilight hours, when dolphin schools can be readily seen. These are classified as "night" sets because the backdown procedure used to release dolphins from the net was completed in darkness. In order to assess the change in mortality rates from eliminating "night" sets, analyses were conducted using data collected from the fishery between 1979 and 1988. Initially, all sets that started 15 minutes prior to sundown and during twilight hours were eliminated (this process would also eliminate day sets that started 15 minutes before sundown and finished backdown before darkness). Mortalities and mortality rates for the remaining sets were recalculated and compared to mortalities and mortality rates before elimination of any sets. The analysis was repeated by progressively eliminating additional sets beginning 30, 45, 60, 75, and 90 minutes before sundown. Results indicated that overall mortality rates, calculated from the remaining sets would decrease 6 to 20%. Dolphin mortalities decreased as much as 30% and yellowfin tuna losses from the eliminated sets were as high as 38,000 tons.

Completion of Fifth Annual Survey to Monitor Trends in Dolphin Abundance

On December 6, the NOAA research vessels, *David Starr Jordan* and *McArthur*, returned to San Diego after participating in the fifth of six planned surveys counting dolphins and assessing their habitat in the eastern tropical Pacific Ocean (ETP).

The primary objective of the cruise was to collect information to estimate the density, size, and species composition of dolphin schools in the ETP in order to determine the trends in population sizes. Other objectives included the collection of information to investigate the physical and biological environment of dolphins, and also to collect data to contribute to ongoing U.S. and international interactions in the ETP.

Marine mammal observers involved in the surveys maintained a visual watch using two 25-power binoculars with a maximum ship-to-horizon sighting distance of approximately 6 nautical miles. Generally, all schools encountered within 3 nautical miles were approached to confirm identification and obtain school size estimates.

Preliminary calculations from the *Jordan* indicate that 594 schools of marine mammals were sighted. Of the total schools, 16% were seen on Leg 1, 32% on Leg 2, 28% on Leg 3, and 24% on Leg 4. Thirty-five percent of all schools sighted (208 schools) contained target species.

Preliminary calculations from the *McArthur* indicate that 518 schools of marine

mammals were sighted. Of the total schools, 20% were seen on Leg 1, 30% on Leg 2, 32% on Leg 3, and 18% on Leg 4. Thirty percent of all schools sighted (156 schools) contained target dolphins.

After data entry and editing, the survey data will be analyzed, using line-transect analysis, and compared to surveys in previous years. The results of the MOPS surveys are being compiled for the purpose of presenting a report to Congress prior to the reauthorization hearings for the Marine Mammal Protection Act, which begin in the spring of 1992. A series of workshops will be held in 1991 and early 1992 to review reports on trends in abundance and stock structure. In addition, those data will be used to assist NMFS and the IATTC in negotiating an international agreement to reduce porpoise mortality over the next 5 years.

Photography Used to Calibrate Observer Estimates

Typically it is very difficult to estimate the size of dolphin schools from a ship, especially when some schools include several thousand individuals. To resolve the potential for systematic errors in observer estimations, the Photogrammetric Remote Sensing Group (PRSG) at the SWFSC operated aboard the Jordan using a Hughs 500D helicopter to photograph dolphin schools and to calibrate observers' school size estimates.

Two high-resolution aerial reconnaissance cameras were mounted below the helicopter fuselage, and large-format 5-inch photographs were taken of dolphin schools. From these photographs, an estimate of the actual number of dolphins in a school can be counted, and individual observer estimates can be calibrated against the more precise photo estimates.

During the 1990 survey, the helicopter flew a total of 110.4 hours (13.4 of those hours consisted of pinniped, bird, and training flights). A total of 43 days was spent photographing cetaceans, averaging 2.3 hours per day. Sixty-eight schools of small cetaceans and 6 large and small whales were photographed from the helicopter during this time.

Second Year of Tissue Sample Collection

At present the four species of dolphins that are targeted by the purse-seine fishery for tropical tunas are divided into 13 stocks. These stock divisions are based on differences in various morphometric and life history parameters, and gaps or breaks in distribution. The current stock specific quotas on the U.S. fleet are based on these determinations.

Our long-term goal is to use tissue samples to study the stock structure of the species/stocks primarily impacted by the ETP tuna purse-seine fishery: spotted, spinner, striped, and common. We intend to employ a polymerase chain reaction (PCR) process coupled with sequencing for resolving intraspecific genetic differences between population centers, if such differences exist.

During the 1990 MOPS cruise, both vessels collected cetacean tissue samples for genetic analysis using a low-powered crossbow. Tissue samples were collected from seven different species of marine mammals. Mitochondrial DNA analysis will be conducted on these samples to determine if there are any discernable stock differences within the species.

Bioacoustics as a Tool for Differentiating ETP Dolphin Stocks

Dolphin populations subjected to incidental mortality due to purse-seine fishing by the international fleet are managed using a quota system which is set at the stock, rather than at the species level, when possible. In this spectrum, three forms of spinner dolphins are recognized: the coastal form, the eastern form, and the whitebelly form. Each of these forms is morphologically distinct; they are managed independently of one another as separate stocks. Common and spotted dolphins in the ETP also occur in more than one stock. In the past, differentiation of stocks has been accomplished mainly by examining

genetic, morphological and geographical variation within the species. During the Monitoring of Porpoise Stocks (MOPS) cruises, an ancillary project using bioacoustics has shown promise for differentiating these ETP dolphin stocks.

Fishery Biologists Aleta Hohn and Scott Benson completed a report describing the bioacoustics project in the ETP. The MOPS cruises, designed to cover the geographic range of dolphin species taken incidentally during tuna purse-seine fishing, provided a platform for recording underwater vocalizations (e.g., whistles) from dolphins in the ETP. During MOPS 1989, six sonobuoys were deployed to evaluate the relative success of various methods of collecting these underwater "calls." Data recorded included: the type of sonobuoy; depth of hydrophone; the date, time and location of deployment and recording; environmental conditions; and characteristics of the school. In addition, comments about the behavior and characteristics of the school or sub-school were made. A preliminary analysis of the recorded whistles was conducted in real time on a UNISCAN II digital sonograph set at 20-kHz bandwidth at Hubbs Marine Research Center in San Diego, California.

Although the situations and conditions varied greatly, successful recordings were obtained from each of the six sonobuoys deployed during the MOPS 1989 survey. The quality of some of the recordings was good enough for evaluation of whistle parameters, although too few groups were recorded to begin a comparison of whistle patterns to discriminate stocks. The best recordings were from the smaller aggregations of animals located at least 3.2 km from the ship, as noise from the propeller interfered with closer recordings, and recordings of large numbers of animals made it difficult to distinguish individual sounds.

From the results to date, the optimal protocol for recording distinct whistles from individual dolphins seems to be to deploy a sonobuoy 0.8-1.6 km in front of a school of 25-30 animals when the school is 3.2-8 km from the ship, preferably off the stern. Sea state must be less than a low Beaufort 4 and the depth of the thermocline must be greater than the depth to which the hydrophone will descend. The minimum depth of the hydrophone is 18.3 m.

For each of the three species recorded during MOPS 1989, the geographic distributions of the schools of each species were too close and the number of successful recordings from each were too small to accurately differentiate stocks. The plan is to continue making recordings during future MOPS cruises in order to obtain the necessary sample sizes required to make judgements on stock distinctions. The report by Hohn and Benson is published as Administrative Report LJ-90-23.

Optimal Strategy by Dolphins for Detection Avoidance

It is well known that certain species of dolphins attempt to avoid detection, when a vessel approaches, by fleeing. The species *Lagenodelphis hosei* is so successful at this endeavor that knowledge of its occurrence and distribution range is incomplete.

Because of the implication of this behavior to dolphin census using ship sighting surveys, Carlos Salvadó, Pierre Kleiber, and Andy Dizon at the La Jolla Laboratory constructed a sighting model that asks: If a vessel approaches at speed V_B, in what direction must a dolphin go at speed V_D in order to maximize its distance to the vessel at the point of closest approach? The answer to this question is that the angle between the velocity of the vessel and that of the dolphin must equal $\arccos(V_D/V_B)$. This model is being tested using data from eastern tropical Pacific dolphin surveys.

VI. OTHER TUNA-RELATED RESEARCH AT SWFSC

Brill Presents Lecture at International Conference

Fishery Biologist Richard Brill attended the 29th Annual Conference of the Canadian Society of Zoologists held at Simon Fraser University, Vancouver, British Columbia, on May 2-5, 1990. During the Conference's Cardiac Scope in Lower Vertebrates Symposium, Brill presented an invited lecture entitled "Metabolic and cardiac scope of high energy demand teleosts--the tunas." His talk described features of the cardiovascular system of tunas that account for their ability to have maximum levels of oxygen uptake far above those of most other fishes. A manuscript based on the talk will be published as part of the symposium proceedings in the *Canadian Journal of Zoology*.

Fishermen Honor Laurs

Oceanographer Dr. Michael Laurs was honored on November 6 in Reno, Nevada, by members of the U.S. albacore fishing industry for his 20 years of contributions to world-wide albacore research.

Presenting an engraved plaque at the annual meetings of the Western Fishboat Association and Fishermen's Research Foundation, spokesman Bill Perkins commended Laurs "for his many contributions to albacore tuna research and to the U.S. albacore fishing industry, including his effectiveness in communicating scientific findings to the industry and his high caliber of professionalism."

Perkins went on to commend Laurs' leadership as scientific adviser to the American Fishermen's Research Foundation where he has served since 1971, and where his scientific contributions and leadership have led to joint government-industry albacore research studies that form an excellent model for government-industry cooperation.

Largely as the result of Laurs' pioneering research efforts in the application of satellite remote sensing to the U.S. albacore fishery, U.S. albacore fishermen now routinely utilize satellite measurements of the ocean to locate potentially productive albacore fishing areas and to assist them in avoiding stormy weather and sea conditions.

Dr. Laurs is currently the leader of the Fisheries and Environment Program at the SWFSC. For the past decade, he and his staff at the Center have prepared and published the popular annual albacore tuna forecast, which is widely used by commercial and sportfishermen along the west coast. Much of this information will now be included in the widely-read *Tuna Newsletter*.

Theoretical Models of Longline Fishing Development

In order to show that the relationship between catch rate and population density of passive fisheries is fundamentally different from that of active fisheries, Fishery Biologist David Au and Operations Research Analyst Carlos Salvadó at the La Jolla Laboratory have developed computer models of longline fishing, a passive fishery type. These models were developed along two lines of thought:

1. Schools of fish are treated as points moving in a space, and whose foraging speed is proportional to P^a, where P is the fish population in an arbitrary neighborhood of the longline, and $0<a<1$. The direction of movement of each school is randomly selected at each time interval.

2. The diffusing population of fish $P(\underline{r},t)$ is treated as a continuous distribution of fish with the position vector $\underline{r}$ at time t. In this case, the foraging velocity of the fish is not only proportional to a power of the local population density, but also to the gradient of a chemical

signal (i.e., smell) above an arbitrary threshold emanating from the location of the longline. The chemical signal disperses by diffusion and the advective velocity of the ocean current. This model is particularly amenable to a treatment using differential equations, which have been formulated and are being solved analytically.

The completed computer program models the random movement of fish in the vicinity of a hook. Parameters of the model that can be adjusted to examine different situations are:

1. The number of fish in the exploited population which affects the foraging speed of the fish.

2. The effective radius of capture of the hook which is dependent on the smell emanating from the bait on the hook.

3. The maximum time interval between changes of movement of the fish in random directions.

This model will form the basis of studies involving catch rate versus population characteristics of tunas, optimal foraging strategies, including foraging for sparse and ephemeral food patches, and the efficacy of frenzied feeding, in tropical pelagic species.

Tag Analysis and Assessment off Fishery Interactions

One approach to assessing fishery interaction is the construction of a mechanistic model incorporating fish movement, harvest, and other features of population dynamics (recruitment, growth, and natural mortality). The parameters of this model can then be estimated from tag-recapture data using a modified version of the model that deals specifically with tagged fish. The original model can then be run with hypothetical effort regimes to investigate how different fleets affect one another.

Pierre Kleiber and Carlos Salvadó at the La Jolla Laboratory have constructed such a model for skipjack tuna and tuna fleets in the eastern tropical Atlantic. In collaboration with Alain Fonteneau of ORSTOM and Rick Deriso of IATTC, Kleiber and Salvadó are making use of tag-recapture data from the International Skipjack Year Program that was conducted by the International Commission for the Conservation of Atlantic Tunas to test the model. The areas in which tags were released and recovered are the coastal fishing regions of western Africa.

The picture that is emerging from their analyses is that advective movement is small relative to diffusion in the skipjack tuna stock in the eastern tropical Atlantic. Estimated maximum advective velocity is 20 to 40 nautical miles per month, whereas the diffusivity estimate is approximately 50,000 square nautical miles per month, corresponding to an average displacement in one month of 250 nautical miles. Natural mortality is high, at 5 to 10% per month, but a significant part of this percentage is suspected to be due to offshore diffusion, which cannot be accounted for separately from mortality in the model. At the prevailing average effort levels, the estimated catchability implies an average fishing mortality of less than 1% per month, which corresponds well with the findings of low exploitation rate in previous analyses of International Skipjack Year Program data.

The next step will be to formulate the model for predicting catch rates of any fish rather than recovery of only tagged fish. When this is done, the model will be available to test the interaction of different fleets operating either in the same zone, or in different zones.

VII. SWFSC PUBLICATIONS ON TUNA AND TUNA-RELATED SUBJECTS

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