SOUTHWEST FISHERIES CENTER

NATIONAL MARINE FISHERIES SERVICE

SOUTHWEST FISHERIES CENTER

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MAY 1986

DIRECTOR'S REPORT
To The
THIRTY-SEVENTH TUNA CONFERENCE
On
TUNA AND TUNA-RELATED ACTIVITIES
At The
SOUTHWEST FISHERIES CENTER
LA JOLLA, CALIFORNIA

For The Period
MAY 1, 1985 To APRIL 30, 1986

ADMINISTRATIVE REPORT LJ-86-09

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MAY 1, 1985 TO APRIL 30, 1986

MAY 18-21, 1986

SWFC ADMINISTRATIVE REPORT NO. LJ-86-09

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INTRODUCTION

Since 1970 most of the tuna research carried out nationally by the National Marine Fisheries Service, an agency in the U.S. Department of Commerce National Oceanic and Atmospheric Administration has been centered at the Southwest Fisheries Center, with one major exception. Research on Atlantic billfishes and bluefin tuna has been conducted at the NMFS Southeast Fisheries Center in Miami, Florida. This year, however, in response to the major changes--social, economic, and political--which have occurred within the tuna industry both in this country and abroad, there has been a realignment of tuna research responsibilities within the NMFS.

Early this year, Dr. Joseph W. Angelovic, Deputy Assistant Administrator for Science and Technology in the National Marine Fisheries Service decided in his capacity as NMFS National Tuna/Billfish Research Coordinator to divide responsibility for tuna and billfish research in NMFS. In a memo to the principals involved he wrote as follows: "The Southeast Center ...under Dr. Richard Berry...will be responsible for all NMFS research to support the International Commission for the Conservation of Atlantic Tunas, and the Southwest Center...under Dr. Izadore Barrett...will be responsible for all NMFS research for the Indian Ocean, Western and Central Pacific and any Federal efforts associated with the Eastern Tropical Pacific. This division of responsibilities follows the geography-related principles that underlie our fisheries objectives system."

Events have now combined--recognition of the new tuna responsibilities for the Center, the need to devote renewed and strengthened emphasis to our tuna studies, changes in the international tuna fleets and industry structure, and the change from the early days when the tuna-dolphin problem was a volatile issue--to make this an opportune time to make some alterations in our organizational structure at the Southwest Fisheries Center. Two new Divisions have been created at La Jolla from the former Oceanic Fisheries Resources Division--"Tunas and Other Oceanic Pelagics Division" and the "Marine Mammal" Division. Dr. Gary Sakagawa will be the Chief of the new tuna division and will also continue to serve as the Center's Coordinator for tuna under the NMFS Management by Objective system.

A retrospective look at the record and the accomplishments of tuna research at the Southwest Fisheries Center may be in order at this time of change and transition.

Historically, the SWFC's laboratory in Honolulu, Hawaii, led by Richard Shomura, has maintained a mix of programs and projects which emphasized the assessment and understanding of the abundant skipjack tuna resources of the Pacific and Indian Ocean. Because of its mid-ocean location and capability for holding large tropical pelagic fishes at the laboratory, fishery scientists there study the sensory and physiological reactions of tunas to their environment. Other tuna-related programs include assessment of the South Pacific albacore populations, analysis of

basic fishery statistics on tunas, billfishes and other important pelagic species of interest to U.S. commercial and recreational fishermen, principally the sport fishery for billfishes, monitoring tuna fishing activity, and preparing catch and effort statistics and economic data on market transactions.

Research results are important in the development of management plans by the Western Pacific Regional Fishery Management Council, the development of international policy on tuna and billfish management by the U.S. Departments of State and Commerce, and for the evaluation of fishing potentials and exploitation strategies by the U.S. tuna industry.

During the period covered by this report tuna research at the La Jolla Laboratory was conducted within the Oceanic Fisheries Resources Division, led by Dr. Gary Sakagawa. The staff provided basic fishery analysis and management information on tunas and billfishes to international fisheries bodies and commissions, and carried out studies on the status of dolphins involved in the eastern tropical Pacific tuna purse seine fishery. The Division staff also conducted research to determine the status of North Pacific albacore.

In addition, the staff of the Coastal Fisheries Resources Division, led by Dr. Reuben Lasker, conducted studies on the distribution, availability, and migration patterns of North Pacific albacore and associated influences in the eastern North Pacific. The SWFC's Pacific Fisheries Environmental Group at Monterey, California led by Andrew Bakun, also emphasized a multidisciplinary approach to research on the North Pacific albacore tuna.

Results of these studies are a basic source of information and advice for U.S. representatives to international tuna management organizations, fisheries scientists, administrators, and the U.S. tuna industry.

Among the achievements of the Southwest Fisheries Center over the past years in tuna and tuna-related research are the following:

- Maintaining tunas in captivity for extended periods. The Honolulu Laboratory was the first research laboratory to do so and even today, no other facility in the world captures and holds skipjack. This development has permitted Honolulu Laboratory and visiting scientists to conduct experiments on the behavior and physiology of tunas.

- Elucidating the migration of the albacore and skipjack tuna in the Pacific.

- Identifying the larvae and juveniles of yellowfin and skipjack tunas and determining their distribution.

- Providing an estimate of the potential yield of skipjack tuna resources in the Pacific Ocean. The Honolulu Laboratory studies have contributed to the dramatic development of skipjack tuna fishing activities in the central/western Pacific.

- Development of anchored fish aggregating systems in Hawaiian waters to enhance commercial and recreational fishing success for pelagic fishes such as tunas and billfishes.

- Determination of the spawning habits of albacore in the South Pacific, including a description of the spawning season and major spawning grounds.

- An order of magnitude decrease in incidental marine mammal mortality as a result of the NMFS program of innovative purse seine gear modifications and marine mammal releasing techniques developed with the cooperation of the U.S. tuna purse seine fleet.

- Determination of the impact of incidental mortality associated with the purse seine tuna fishery on the populations of dolphins in the eastern tropical Pacific Ocean.

- Development of a system for monitoring the incidental mortality of 21 stocks of marine mammals in the ETP on a regular basis.

- Determination of the status of albacore, yellowfin, skipjack and bigeye tuna stocks of the Atlantic Ocean as required by the Standing Committee on Research and Statistics of the International Commission for the Conservation of Atlantic Tunas to which the U.S. is signatory.

- With scientists of the Far Seas Fisheries Research Laboratory of Japan, determination of the condition of the North Pacific albacore stock and evaluation of the impact of the fisheries.

- Continued cooperative field studies with the American Fishermen's Research Foundation, a unique partnership between government and industry, which has yielded new knowledge about the North Pacific albacore resource and opened new fishing grounds in the western and south Pacific Ocean.

The U.S. has a long-range need to assure that American industry and consumers are provided a continuing supply of reasonably priced tuna while maintaining world stocks of tuna at optimal levels and ensuring U.S. access to those stocks. The U.S. is now the world's top tuna market, importing more tuna, raw and canned, than any other nation and consuming 50% of all the canned tuna in the world. Although the U.S. is a major component in the international tuna business, the domestic industry is faced with problems of expanding foreign fleets, influx of canned tuna imports, and high operating costs which have led to the closing of all but one major cannery in the continental United States and a dwindling fleet of tropical tuna seiners.

In the face of this new reality, what should be the role of tuna research at the SWFC? If we assume that the long range goal we have indicated is in the best interests of the U.S. then reasonable activities in the attainment of this goal would include the following:

- Monitor tuna fishery trends in the central and western Pacific Ocean and assess yield potentials, evaluating the impacts of changes in effort and fishing technology during this period of rapid development and change;

0 Conduct mission-related research to understand better the distribution and abundance of tunas in our area of interest, and to improve our ability to monitor and predict events affecting stock abundance within the fisheries.

In the weeks and months ahead, all of us involved with tuna research at La Jolla plan to work with the Director and staffs of the Southeast Center on transition issues and to meet annually with them to plan current and future tuna research, and to meet with SWFC constituents on research needs. We will also, during the coming year, develop a strategic plan for tuna research at the Southwest Fisheries Center and identify those areas in which we can undertake particular studies.

The report which follows is not intended as a comprehensive account of the Southwest Fisheries Center's research on tuna and tuna-related activities, but rather as an informal account of major, on-going events.

The information was compiled by Lillian Vlymen and Jean Michalski, Technical Writers/Editors, from material supplied by the Center's scientific staff at the Honolulu and La Jolla Laboratories, and the Pacific Fisheries Environmental Group at Monterey.

Izadore Barrett, Director
NMFS Southwest Fisheries Center

May, 1986
La Jolla, California

IN SUPPORT OF EXISTING INTERNATIONAL AGREEMENTS

INDO-PACIFIC TUNA

During the period 1980-1982, Indian Ocean catches of tunas and billfishes amounted to 272,000 metric tons. It is generally believed by tuna experts that there is a potential for greatly increased landings of various tunas by surface fisheries in the Indo-Pacific. Recently, French and Spanish tuna seiners have moved into the area of the Seychelles and informal reports have indicated high catch rates. Although there is little participation at present by U.S. fishermen in Indian Ocean fisheries, the area continues to be of interest as potentially productive.

At the SWFC laboratory in Honolulu, Hawaii, an important research activitity is the monitoring of tuna and billfish resources in the western Pacific and the Indian Ocean from examination of catch statistics collected from the various fisheries and the conduct of stock assessment studies based on these fishery statistics. A further major source of information for government researchers on the tuna fisheries of the Indian Ocean comes from tuna taken by Taiwanese, Korean, and Japanese longliners transshipped to Puerto Rico where the fish are routinely sampled for biological information by NMFS biological technician Eugene Holzapfel, now of the Southeast Fisheries Center.

Scientists from the Honolulu Laboratory also maintain an active involvement in fisheries research in the Indo-Pacific through regular participation in meetings and workshops sponsored by such international organizations as the Indo-Pacific Fishery Commission (IPFC) and the Indian Ocean Fishery Commission (IOFC).

Expert Consultation Workshop Held in Sri Lanka

Sponsored by FAO, Richard Shomura, Director of the Honolulu Laboratory chaired the workshop on, "Expert Consultation on the Stock Assessment of Tunas in the Indian Ocean," held in Colombo, Sri Lanka, from November 28 to December 2, 1985. Highlights of the workshop included:

- With the exception of the southern bluefin tuna, none of the tuna resources in the Indian Ocean is in an "overfished" condition.

- By terms of a tripartite agreement, the three countries presently fishing the southern bluefin tuna (Japan, Australia, and New Zealand) have agreed to control their catch of this species to maintain the level of protected biomass.

- The catch of skipjack and yellowfin tunas increased markedly in 1984 to approximately 100,000 tons for each species; the increase is due to the development of a purse seine fishery in the western Indian Ocean.

- Some coastal states expressed concern with the rapid development of industrial-type tuna fishing in the Indian Ocean; their concern was directed toward possible impact on the subsistence and small scale tuna fisheries of coastal states.

Efforts Continue to Establish Common Tuna and Billfish Fishery Data Base Among Coastal and Distant Water Tuna Fishing Nations

As the Director of the Center's Honolulu Laboratory, Richard Shomura is liaison for the United States to the Indo-Pacific Tuna Programme (IPTP) which is the FAO agency involved with matters related to tuna data in the Pacific and Indian Oceans. Through participation in IPTP, activities have been initiated to establish a common tuna and billfish fishery data base among the coastal and distant water fishing nations. The Honolulu Laboratory provided IPTP with historical tuna and billfish fishery data and recently provided total U.S. tuna catch data from the western Pacific.

Presently, there is a reluctance of distant water tuna fishing nations to provide detailed catch and effort data. U.S. tuna purse seiners operating in the central and western Pacific are not required to provide such data since no treaty based agreement exists to cover the submission of data. Thus, the U.S., one of the distant water fishing nations active in the central and western Pacific, is not providing data for inclusion in such a data base. The lack of current, detailed catch and effort data precludes in-depth stock assessment analyses of Pacific tunas and billfishes.

During the past year the U.S. and 15 island nations have held meetings to discuss a broad based access agreement for tuna fishing in the South Pacific by U.S. flag vessels. Meetings have been held in Papua New Guinea, Fiji, New Zealand, and Hawaii. An important part of the discussions has been the collection and exchange of tuna statistics.

RESEARCH ON ATLANTIC TROPICAL TUNAS AT THE SWFC

Status of Atlantic Tuna Fisheries

Scientists from the Southwest Fisheries Center, headed by Dr. Gary Sakagawa, Chief of the Oceanic Fisheries Resources Division, prepared written and oral summary reports on the status of the Atlantic tuna fisheries for presentation to U.S. Commissioners and advisors to the U.S. Section of International Commission for the Conservation of Atlantic Tunas (ICCAT) on October 9 and 10, 1985. The meeting, which also included participants from other NMFS fisheries centers and regions, was held for the purpose of informing ICCAT Commissioners and advisors of the current conditions of Atlantic tuna stocks and fisheries, research conducted in support of ICCAT, and potential scientific issues which might arise at the November 1985 meeting of ICCAT.

Sakagawa reviewed the U.S. role in ICCAT, coordination and research planning efforts undertaken in the last year, and all ICCAT-related events for the year. Dr. Norman Bartoo described the condition of yellowfin, skipjack, bigeye, and albacore stocks in the Atlantic.

The summary points made at these briefings were as follows:

- The stocks of yellowfin tuna in the Atlantic Ocean are apparently increasing as a result of reduced fishing effort in the eastern Atlantic, although actual catches are lower. This improvement will likely continue if effort remains reduced. No additional management measures appear desirable at this time.

- The stocks of bigeye tuna appear to be stable with catches below expected maximum sustained yield (MSY) due to reduced effort in surface fisheries. No additional management measures are desirable at this time.

- Skipjack tuna stocks are still exploited below MSY with current catches down due to reduced surface fishing effort. The fishery appears capable, however, of absorbing additional fishing effort. No management measures were deemed desirable at this time.

- Albacore tuna stocks are exploited below MSY due to reduced surface and longline effort. Catches are down due to reduced effort. Recruitment into the fishery of the northern stock is highly variable. No management measures are desirable at this time.

SWFC Scientists Attend Ninth Regular Meeting of the ICCAT

A delegation from the SWFC attended the Ninth Regular Meeting of the ICCAT November 13-19, 1985 in Palma de Mallorca, Spain. Dr. Gary Sakagawa served as the head of the U.S. scientific delegation, which also included researchers from the SEFC. Carmen J. Blondin, U.S. Commissioner and Chairman of the Commission, opened the conference, which was preceded by a meeting of the Standing Committee on Research and Statistics (SCRS), November 1-12. Scientists from the SWFC presented three documents at the meeting. Two documents were prepared by Dr. David Au: "Interpretation of longline hook rates," reviewed the theory of random encounters with fish, reduction in efficiency from hook competition by non-target species, and the theory of prey clumping in making predators (or fishing gear) less successful. Au's conclusion was that prey clumping, interacting with fishermen who are randomly fishing with longline gear, could reduce gear efficiency and that the change in catch rates may underestimate the true changes in the size of stocks of target species.

The second document, "Significance of changes in catch and fishing effort in the eastern Atlantic yellowfin tuna fishery," addressed the question of the statistical significance of reduced catch and effort following departure of a part of the fishing fleet to Indian Ocean fishing grounds. This paper showed how the Monte Carlo randomization technique can establish confidence bounds about the equilibrium yield-effort relationship and how a simple statistical test determines the significance of departures of individual data points from the mean.

A third document, "Size and species compositions of Atlantic tuna imports landed in Puerto Rico, 1984," was prepared by Atilio Coan, Aaron Weinfield, and Eugene Holzapfel. The paper presents results of sampling 4,798 yellowfin, skipjack, bigeye, and albacore tunas from transshipments of foreign-caught Atlantic tunas landed in Puerto Rico and compares these

results to the results of sampling in previous years. In general, average sizes of fish in 1984 imports decreased for most species sampled, and percentages of yellowfin and bigeye tuna smaller than the minimum size (55 cm) were higher than in 1983 imports.

The Commission extended through 1986 the management measures currently in effect for bluefin tuna including a quota of 2,660 metric tons (mt) in the western Atlantic. In light of SCRS findings, based largely on results of a meeting of its Bluefin Tuna Working Group in September, the United States proposed extension of the current management measures for a 3- to 5-year period but agreed to the shorter period in order to achieve consensus and prevent a lapse in the ICCAT conservation regime. Working with an improved data base, the SCRS projected a 10 percent increase in stock biomass in the western Atlantic during 1986 if the catch level remains at 2,660 mt. Surplus production for 1985 and 1986 are projected at 3,850 mt and 4,400 mt, respectively.

While no other management measures concerning other stocks of tuna or tuna-like fish were considered by the Commission, the United States highlighted the SCRS findings on billfish which, over a number of years, have indicated declining trends in the blue and white marlin fisheries. In response to repeated statements by the SCRS of the need to monitor these fisheries, the United States proposed that the SCRS develop for presentation in 1986 a billfish assessment program with projected costs.

Carmen Blondin was reelected Chairman of the Commission following a strong show of support for his leadership during 1984 and 1985.

IN SUPPORT OF POSSIBLE FUTURE INTERNATIONAL AGREEMENTS

NORTH PACIFIC ALBACORE

Fishery Advisories and Extension Services Continued for North Pacific Albacore

Fishery advisories and extension services play important roles in the research program on North Pacific albacore. They are conducted as part of a system where fishery and environmental data required for research studies are obtained from fishermen and other segments of the industry in return for fishery advisory information which fishermen and others in the industry use to optimize planning and operating to promote a viable U.S. albacore fishing industry. A fishery advisory and extension program is essential if the U.S. is to realize its goal to increase its catch of North Pacific albacore and for NMFS to obtain the data bases essential to provide management advice to assure optimum productivity of the resources.

Currently, the SWFC fishery advisory operations consist of a seasonal forecast of where and when albacore are expected to be available for harvesting by U.S. fishermen and biweekly narrative bulletins containing current fishing activities. A summary of fishery data from the previous year's fishing is also provided near the start of a new fishing season. In addition, reports of cooperative research conducted with the albacore fishing industry through the American Fishermen's Research Foundation (AFRF) are distributed to interested fishermen. Numerous presentations dealing with recent reseach findings and general information about albacore are given each year to commercial and recreational fishermen and the interested public.

The albacore fishing industry is providing considerable information and assistance in response to the fishery advisory information supplied by the SWFC. Fishermen keep voluntary logbooks, conduct tagging experiments, and recover and report tagged albacore. They also collect specimens for research and collect oceanographic and marine weather data. In addition, AFRF provides vessel time for research studies and support for tagging, biological, and fishery-oceanography studies.

A number of future needs for fishery advisory information have been identified by constituents at a workshop sponsored by the Southwest Fisheries Center December 11-12, 1985. The development of the plan came at a time when it was apparent that any new NMFS initiatives would be severely affected by budgetary constraints. The plan which was developed therefore is necessarily limited to those activities wherein the industry provides a major share of the costs and to those where NMFS activities can be affected by reprogramming and redirecting existing staff and resources.

Major elements of the agreed upon plan include:

- Concentration of additional effort on cooperative SWFC/industry tagging studies.

- Cooperative work by the SW Region and industry to transfer state of the art technology for at-sea processing of albacore for the fresh/frozen market to the fishermen.

- Future development of a Southwest Fisheries Center/Southwest Region/industry cooperative program for the expansion of the U.S. albacore fishery into the South Pacific to take advantage of the increased U.S. tuna canning capability which has been developed in American Samoa.

- Development of a NMFS/industry workshop to assess the potential for increasing the efficiency of the albacore fleet through cooperative research and technology transfers and to develop a mechanism for coordinating NMFS/NOS/industry resources to determine potential benefits of fisheries environmental advisories.

It should be noted here that the above element is dependent on the availability of information which is currently being developed as part of the NMFS operational plan for albacore (issued as NOAA Technical Memorandum NMFS-SWFC-52, May, 1985). Preliminary results of this work are expected to be available in early 1987.

Ninth North Pacific Albacore Workshop

The North Pacific Albacore Workshop was established in 1974 by an informal agreement between the Southwest Fisheries Center (SWFC) of the United States and the Far Seas Fisheries Research Laboratory of Japan for a cooperative research program on the North Pacific albacore. In 1982, the Pacific Biological Station, Canada, joined the informal agreement as an additional participant in the Workshop. The objective of the Workshop has been to assess the status of the albacore stock in the North Pacific and to understand better the biology of albacore.

The Ninth North Pacific Albacore Workshop was held at the Southwest Fisheries Center in La Jolla, California, May 15-17, 1985, with 18 scientists from the U.S., Canada, and Japan participating. The meeting was chaired by Norman Bartoo with Earl Weber, Michael Laurs, and Pierre Kleiber as rapporteurs. Seventeen working documents and several oral accounts were presented. Some of the highlights of this Workshop are recounted below.

Review of current fisheries

Data continue to be collected for most of the major gear types that are used in harvesting North Pacific albacore. For some fisheries, however, the participants noted that data are becoming more difficult to gather. For other fisheries, no formal arrangements exists for data collection or exchange. Within the Japanese Ome-Ami (drift gillnet) fishery, catch and length frequency information are obtained only through informal means, such as from interviews with fishermen. Korea and Taiwan operate longline fisheries in the North Pacific, although their fisheries data are several years out of date. Korean baitboats also operate in the North Pacific, but no data from these operations have been made available. Participants decided to contact those agencies responsible for the collection of that information and request data for recent years. It appears, for example, that there is no formal system for determining Canadian landings in the United States and vice versa.

Canadian fishery--Canadian **troll** catches decreased from an estimated 233 mt in 1983 to 47 mt in 1984. The decline was attributed to poor availability of albacore in the near-shore areas. There is increased interest in albacore among Canadian fishermen because of stricter quotas on salmon and shorter halibut seasons. Many vessels in the salmon fleet are poorly suited for offshore albacore trips of long duration due to their small size and lack of adequate hold space and refrigeration. An estimated 35 percent of Canadian catches during these two years were landed in the United States.

Japanese fishery--**Pole and line** catches have declined in recent years. Since a record catch of 83,336 mt in 1976, catches have shown a highly variable but decreasing trend reaching 21,098 mt in 1983, the lowest catch since 1968. The 1984 catch is estimated to be 26,000 mt. The low catches in recent years are primarily due to poor development of fronts in the vicinity of 35 degrees north. In addition, there has been a decrease in recent years of large vessels that normally catch substantial amounts of albacore in the offshore areas. Under Japanese law, 5 of these vessels must be decommissioned before one purse seiner can be built. Low catches tend to be exaggerated because, during a poor season for albacore, many of these baitboats leave the albacore fishery early to fish for skipjack.

Ome-Ami--Catches in the Ome-Ami (**drift gillnet fishery**) have also fallen in recent years from about 17,000 mt in 1981 and in 1982 to approximately 9,000 mt in 1983. Declines were thought to be due to poor frontal development, as was the case with the pole and line fishery, and poor weather conditions which hampered fishing operations. Some variability is expected in the catches of this fleet because of the relative ease with which fishermen are able to change nets and fish for squid, which command a price similar to that of albacore.

Longline--The 1983 **longline** catch of approximately 15,000 mt is about the same as catches in recent years. This fishery shows the least variability in yearly catches among the Japanese fleets.

United States fishery--The **jig fleet** caught approximately 9,500 mt in 1984. This amount, when combined with an unusual catch of about 3,500 mt by coastal purse seiners, represents the highest catch in recent years and is more consistent with the long-term mean. The increase was attributed to good fishing weather and well-developed fronts close to shore. An additional factor was increased enthusiasm among fishermen brought on by improved marketing due to more buying stations along the coast and increased attempts to market fresh albacore. However, fishing was spotty along the Pacific Northwest, despite well-developed fronts, and in the mid-Pacific region. There was also some reduction of effort in the offshore region because of early uncertainty as to whether Hawaiian canneries would buy albacore.

In 1984, two **gillnet** vessels fished for albacore, and there seems to be interest among other fishermen. To date, however, yearly catches are thought to be less than 200 mt. In December 1984, gillnet fishermen in the shark and swordfish fisheries reported catching substantial numbers of large albacore (up to 27 kg) near the northern Channel Islands, California.

The **recreational** fishery experienced the best season since 1962, with an estimated catch of 1,278 mt. This high recreational catch was due to good fishing off California and Mexico; fishing off the Pacific Northwest was poor.

An **experimental longline fishery**, which began in 1981, continues to work toward gear development and fishery exploration. The purpose of the experiment is to expand the U.S. fishery in time and space and to provide fresh frozen albacore for the restaurant trade, which requires a steady supply, as well as to provide canners with a more continuous source. Approximately 17 mt were caught during two trips by an experimental vessel between November 1984 and February 1985.

Condition of the stock--Based on current and past analyses plus available statistics, the North Pacific albacore, if viewed as a single stock, appears to be moderately exploited at levels which appear to be sustainable.

The participants noted some problems in fully satisfying the assumption needed for various analyses including the likelihood of increased catches from new, expanding fisheries as well as the lag-time required to obtain catch data from a few of the fisheries. These stocks should be watched carefully and particular attention paid to catch-per-effort indices in established fisheries which are the most basic indicators of stock abundance, if viewed over a long time period. Producing a reliable assessment of the North Pacific albacore resource remains a difficult task. The expansion of present assessments to various multi-stock hypotheses compounds the assessment problems but must be addressed because increased accuracy is required. Further, some indicators of the condition of the stocks, such as recruitment, have not yet been adequately addressed.

Tagging--In 1983 and 1984, 1061 albacore were tagged and released in the mid-north Pacific; 984 fish were tagged and released in the eastern North Pacific. This is part of a continuing cooperative albacore tagging program conducted jointly by the SWFC and the American Fisheries Research Foundation (AFRF). Tagging is again planned in 1985 and will be conducted by jigboats operating in the mid-Pacific from the dateline eastward.

Records indicate that 21,287 albacore have been tagged and released; 1,216 tagged fish have been recovered since 1971. Between 1971 and 1980 most tagging was conducted within a few hundred miles off the coast of North America. In recent years, the emphasis has been in central North Pacific waters. Returns have allowed some preliminary analyses which suggest that albacore follow well-defined migration routes and return to the same areas of release after several years at liberty.

The Fisheries Agency of Japan conducted an albacore tagging program between 1971 and 1981 during which approximately 4,000 albacore were tagged and released, with about 200 recoveries. This activity was terminated in 1982; however, prefectural agencies and the Japan Marine Fishery Resource Research Center continue to tag some incidentally caught albacore.

Acoustic tracking experiments planned in recent years were not carried out due to severe weather conditions and limited availability of tracking

vessels. An aggressive tracking program is planned for the 1985 albacore season near the northeastern coastline.

Age--Recent validation of daily increment formation on the sagittae of North Pacific albacore indicates that the count of daily rings will give an accurate estimate of an albacore's age, and allow the estimation of growth models for use in stock assessment and harvest policy analysis. In previous work, the relationship between size and age in albacore has been inferred from scales, vertebral centra, and dorsal fin rays. In these cases, age assignments have been largely unsubstantiated and there has been no consensus on absolute age-size relationships.

The relationship between albacore fork length and age was analyzed using counts of daily growth increments from the otoliths of 90 North Pacific albacore. In addition to fitting the usual deterministic von Bertalanffy growth model, several stochastic growth models were evaluated to estimate the variance of length-at-age. It appears that reliable estimates of the variance of length-at-age cannot be computed for all ages. Additional observations and a wider length range of samples can improve the current estimates of the variance of length-at-age.

Stock structure--The hypothesis that the North Pacific albacore population is not homogeneous but consists of subpopulations exhibiting different and possibly overlapping biological characteristics was originally made on the basis of migration patterns. Further evidence of heterogeneity was provided by analysis of tag returns which suggests that the hypothesized northern and southern subpopulations could have different growth rates.

Oceanography--It has been repeatedly shown that albacore are associated with frontal features in the ocean. Albacore aggregate at small-scale local features and migrate and are distributed along large-scale ocean fronts. The relationship between albacore migration and distribution patterns and the variations in large-scale ocean characteristics (fields of sea surface gradients) has been shown for the North Pacific.

Temperature gradients calculated for the 20 year means of sea surface temperature (SST) for each of the 12 months were resolved at one-degree squares of latitude and longitude. From values plotted in contoured fields of the North Pacific, it was observed that:

- The largest temperature gradients are associated with the subarctic front which occurs off the east coast of Japan at the confluence of the Oyashio and Kuroshio Currents and extends eastward in a zonal band centered about 41 degrees north.

- A second maximum occurs seasonally in the western and central North Pacific at about 28 degrees north, the latitude of the subtropical front.

- The primary maximum in SST gradient is not directly associated with the wind patterns and shows only small changes with season.

- The eastward extension of the primary zonal maximum exhibits seasonal development. It extends furthest east in June and July, when albacore are migrating into the U.S. West Coast fishery.

- A strong annual buildup in the thermal gradient occurs off the U.S. coast during July and August and weakens in October. This pattern follows the annual development of the albacore troll fishery in this region.

It is apparent that the gross patterns in SST gradients do not explain some of the large-scale distributions of albacore during all seasons. The range of temperatures associated with the gradient extremes affects the distribution. In some seasons the temperatures at the fronts are outside the limits considered appropriate for albacore. Past studies have also shown that some fronts may have stronger salinity gradients than temperature gradients and show stronger subsurface gradients than surface gradients.

Pacific Albacore Simulation Model

A simulation model for the North Pacific albacore population has been under development at the Southwest Fisheries Center since 1980. Its intended use is to test hypotheses concerning the interactions between the albacore population, the fisheries, and environment. It forms the framework for organizing information on population dynamics, migration, life history information, economic information, and environmental parameters and processes. The model deals with recruitment, growth, and death of albacore in nine areas in the North Pacific. The modelled fish move among the areas according to size-specific migration coefficients. Fish are harvested by the three major Pacific fleets according to fleet-specific and size-specific capabilities and an imposed seasonal and geographic pattern of effort for each of the fleets.

The model was used to investigate the degree of interaction among the major fleets and how the activity of one fleet affects the catch of the other fleets. Using corrected catchabilities as a basis for comparison, a series of model runs were made in which the effort level of one of the fleets was either doubled or halved, and the effect on catch in each of the fleets was noted. As expected, the most dramatic effect was always on the catch of the fleet with the altered effort level. Significant interaction among fleets occurred with the doubling and halving of the pole-and-line effort which resulted in a 20 percent reduction and a 15 percent increase respectively in the longline catch. All other interactions were less than 5 percent.

Summary of the 1985 North Pacific Albacore Fishery

An estimated 17,484,820 pounds of albacore were landed in ports throughout California, Hawaii, and Oregon in 1985, a decrease of 44% from the 1984 catch. Even though albacore fishing was less successful in 1985, excellent offshore catches were reported early in the season throughout May and June 1985 in areas 300-400 nautical miles northeast of Midway Island. Fishing inshore started early in 1985 with significant catches off southern California throughout June. Fish caught early in the season were taken

west of Erben Bank by the larger jigboats leaving for areas north of Hawaii and the western Pacific.

Favorable environmental conditions offshore from April to June may have contributed to the success of the larger jigboats fishing northeast of Midway Island early in the season. Strong coastal upwelling inshore in September may have helped to provide the excellent catch rates for vessels fishing in areas from Point Conception to Cape Blanco.

About 61% of the total albacore catch was sampled for information on catch and effort and 3% was sampled for information on length-frequency. The average size of albacore caught in 1985 was 69.0 cm (15.0 lbs), which was larger than the average size in 1984 of 66.1 cm (13.1 lbs). Estimated annual catch per unit of effort for a standard 45-foot vessel in 1985 was 82.0 fish per day, which was slightly higher than the 81.0 fish per day in 1984.

The information on the 1985 North Pacific albacore fishery was compiled by fishery biologist Anthony P. Majors of the La Jolla Laboratory and Forrest R. Miller, Meteorologist with the Inter-American Tropical Tuna Commission in Administrative Report LJ-86-10, "Summary of the 1985 North Pacific Albacore Fishery Data." More than 400 copies of these reports will be sent out to participating fishermen. Another 500 reports will be sent to state fisheries agencies to be distributed at the waterfront by samplers during the 1985 albacore fishing season. Copies will be made available to anyone interested upon request to the Director, Southwest Fisheries Center.

South Pacific Albacore Research Survey Conducted

Under the leadership of Richard Shomura of the Honolulu Laboratory, Michael Laurs, oceanographer at the La Jolla Laboratory, and Jerry Wetherall, fishery biologist at the Honolulu Laboratory, conducted oceanographic and biological research in the South Pacific aboard the NOAA Ship Townsend Cromwell during February, 1986. The research was conducted to develop improved models of South Pacific albacore biology, ecology, and population dynamics. Data were also collected on the physical and biological characteristics of the ocean environment associated with high concentrations of albacore and the distribution and availability of albacore in surface waters of the Subtropical Convergence Zone (SCZ) of the South Pacific were investigated to assess the potential for development of a U.S. surface fishery in the region.

The cruise operations were part of a multi-ship investigation which, in addition to the Cromwell, involved the New Zealand research vessel Kaharoa and two U.S. commercial fishing vessels, the Day Star and the Bald Eagle (these latter two funded in part by Saltonstall-Kennedy funds). The survey was part of an international cooperative effort investigating South Pacific albacore involving the U.S., New Zealand, France and the South Pacific island nations.

The oceanographic research and albacore tagging operations were conducted aboard the Cromwell and the Kaharoa. The Kaharoa worked between Chatham Islands and the main islands of New Zealand, and the Cromwell worked in the area east of the Chatham Islands and in the central South

Pacific. The fishing vessels conducted exploratory fishing, made oceanographic observations, and conducted albacore tagging operations.

A full suite of oceanographic measurements and observations was made on board the Cromwell, including continuous monitoring of surface temperature and salinity, vertical profiles to abut 1,000 meters of conductivity-temperature-depth, collection of water samples from various depths for salinity and chlorophyll measurements, and vertical temperature profiles to 750 meters of ocean temperature. The Cromwell trolled during daylight and made Isaacs-Kidd midwater trawl hauls at night.

Oceanic sampling showed that the survey area was entirely within SCZ waters. This area is analogous to the Transition Zone in the North Pacific where the U.S. albacore fishery operates. Nearly all catches were associated with SST fronts or "edges." Findings from the research and fishing vessels indicated that the distribution of albacore in the south Pacific is associated with the SCZ and that the southern limit to the distribution appears to coincide with the southern boundary of the SCZ.

A total of 724 albacore was tagged and released on the troll vessels and on the Cromwell. Most of the tagging was done by the fishermen (702 of the 724 fish). About one-third of the fish tagged on the Day Star and all the fish tagged on the Cromwell were also injected with oxytetracycline for an aging study.

The fishing vessels used standard U.S. commercial troll fishing methods for the exploratory fishing. By the end of the survey, the Day Star caught an estimated 55 and 1/2 tons of albacore. The Bald Eagle caught about 52 tons of albacore over a 39-day period. The captain of the Day Star rated the fishing as good to excellent 35% of the time.

Based on the survey, prospects for establishing a U.S. albacore fishery in the South Pacific appear to be favorable. The relatively high catch rates and total catches, along with relatively good weather conditions, suggest that it is economically feasible for U.S. vessels to operate in the South Pacific. Fishery scientists also believe that the South Pacific albacore population is in good condition and can support a surface fishery. Nonetheless, substantially more fishery exploration and knowledge of the migration patterns and biology of the population are required before a viable U.S. albacore fishery in the South Pacific can be successfully developed.

Size Structure of the North Pacific Albacore Population Investigated

To provide an unbiased estimate of the size structure of the local north Pacific albacore population, fishery biologists David Holts and Earl Weber conducted a research cruise in September 1985 aboard a commercial albacore gillnet vessel.

The albacore in the North Pacific are harvested by several fisheries which use a variety of gears. Each type of gear catches a size range of fish particular to that type of gear. To date, the only measure of the size structure for this population is that derived from the commercial troll and baitboat fisheries. The catches from these fisheries produce different

length frequencies and cannot provide an unbiased sample of the underlying population from which the fish were taken.

In this experiment, the research gillnets, which were designed to sample specific lengths of albacore, were used to sample albacore at eight offshore and seven coastal stations. All sets were conducted at night close to the U.S. commercial troll fishery. These sets produced a total of 780 albacore. During day-time hours, commercial trolling operations were conducted and catch rates and fish sizes recorded. Trolling operations produced 3,300 albacore in 28 active trolling days. The selectivity for albacore at each mesh type was recorded for all net-caught fish as was the depth at which they were taken. Length frequency data were collected for a total of 1,118 albacore which measured 52 cm to 105 cm. The size frequency was bimodal with peaks at 64 cm and 74 cm and there was little apparent difference in size composition between gillnet- and troll-caught albacore. Fish caught in the offshore fishing area were taken higher in the net than those caught along the coast.

Total Catch in the sampling net was:

Pacific albacore	Thunnus alalunga	780
Bigeye tuna	Thunnus obesus	1
Bullet mackerel	Auxis rochei	2
Swordfish	Xiphias gladius	2
Blue shark	Prionace glauca	726
Bigeye thresher	Alopias superciliosus	2
Bonito shark	Isurus oxyrinchus	2
Pacific pomfret	Brama japonica	2
Louvar	Luvarus imperialis	14
Ocean sunfish*	Mola mola	14
Squid	Ommastrephidae	5
Common dolphin	Delphinus delphis	1

*Released alive.

Satellite Remote Sensing Used to Help Fishermen Find Albacore

The Southwest Fisheries Center is a leader in research on the applications of satellite remote sensing in fisheries. Among the accomplishments of scientists at the Center is the finding that the distribution and availability of albacore tuna off the west coast of the U.S. are related to oceanic fronts seen in ocean temperature and color measurements made by satellite. Commercially fishable aggregations of albacore are found in warm, blue oceanic water masses. These oceanic boundary features, which result primarily from coastal upwelling, are clearly observable in satellite imagery collected along the U.S. Pacific coast. To help albacore fishermen locate potentially productive fishing grounds, ocean color boundary charts are distributed to West Coast fishermen via radio facsimile and by mail by the NOAA National Ocean Service in cooperation with the Southwest Fisheries Center. These charts are derived from measurements made by the Coastal Zone Scanner on board the NIMBUS 7 satellite.

Satellite remote sensing has been an especially important tool during the recent El Niño for monitoring anomalous ocean conditions along the U.S. Pacific coast. Scientists at the Center also use satellite measurements to assist in the design of fisheries research field studies and to guide research operations on fishery research vessels at sea.

IN SUPPORT OF

DOMESTIC REQUIREMENTS

TUNA ECONOMICS

1985 U.S. Tuna Trade Summarized

Dr. Samuel Herrick, Industry Economist at the Southwest Fisheries Center in La Jolla, California, and Steve Koplin, Fishery Reporting Specialist at the Southwest Region at Terminal Island, California, have written a Southwest Region Administrative Report entitled "U.S. tuna trade summary, 1985." The report reviews harvesting and processing for the U.S. tropical tuna fisheries during 1985.

For the U.S. tuna industry, 1985 appeared to be a year of relative calm following three years of turmoil during which four canneries in California and Hawaii were closed and the U.S. tuna harvesting capacity was significantly reduced. Although 1985 was not as tumultuous as 1984, recent trends continued into 1985, including the further attrition of the U.S. tuna fleet, decreased cannery deliveries of domestically-caught tuna, a decline in U.S. cannery production, and increased imports of canned tuna.

Substantial growth in foreign fleet harvesting capacity in recent years has led to greatly increased supplies of raw tuna available through the international market. As a result, ex-vessel prices fell sharply to levels below the costs of harvesting tuna for many of the vessels in the U.S. fleet. The opportunity to reduce production costs by purchasing tuna through the international market, particularly at a time when revenues were being severely squeezed by intense competition from canned imports, moved U.S. processors to revise their raw tuna procurement strategies. Historically, processors relied on close integration with the U.S. fleet in order to secure dependable supplies of low cost tuna and these supplies were then supplemented with imports to meet processing requirements. With reliable supplies of low cost tuna available from numerous sources outside the U.S., however, long-term supply arrangements with the U.S. fleet are no longer critical, and processors have reduced their involvement with U.S. vessels. Lacking cannery support and confronted by ex-vessel prices below the vessel's breakeven production level, many vessels were compelled to leave the fishery. By the close of 1985, the U.S. tropical tuna fleet had experienced a 15% loss in number and a 12% reduction in carrying capacity. Nine vessels transferred flag, four had sunk and six changed to alternative fisheries. For the first time in recent years, no new vessels had entered the fishery.

In the wake of a disintegrating relationship with processors, a number of owners of independent vessels joined together in a multi-million dollar antitrust suit against the major U.S. canneries. Owners of the vessels contend that since the 1960s the major canneries have conspired to gain monopoly control of unprocessed tuna in the United States by engaging in unlawful vertical integration, price fixing, and imposing sanctions against vessels that attempted to deal independently. The plaintiffs are seeking close to a billion dollars in economic and punitive damages.

With the reduction in domestic processing capacity that occurred in 1984, U.S. cannery receipts[1] of imported and domestically-caught albacore (white meat) and tropical (light meat) tunas (skipjack, yellowfin,

blackfin, bluefin, and bigeye tuna) fell sharply in 1985. The total volume was 468,956 short tons (tons), a decrease of 11% in total volume from 1984 and 15% below the 1980-1984 average volume of annual cannery receipts. Cannery deliveries by domestic vessels amounted to 213,808 tons in 1985, 16% below deliveries for 1984 and 14% below the 1980-84 (five-year) average. Raw tuna imports made up the 255,145 ton balance in total cannery supplies for 1985, a 5% decrease in imports. Direct exports[2] of domestically-caught tuna totaled 34,797 tons in 1985, up 7% from 1984 and 324% greater than the five-year average. When exports of domestically-caught raw tuna are combined with deliveries of domestically-caught tuna to U.S. canneries, total U.S. deliveries amounted to 248,605 tons for 1985, 13% less than the corresponding amount for 1984 and 4% less than the five-year average.

The western Pacific Ocean[3] was the predominant production area for the U.S. fleet in 1985, providing 129,431 tons or 52% of the domestically-caught cannery receipts and direct exports for the year. Total domestically-caught deliveries from this area decreased 31% from 1984, however, and as a share of total domestically-caught deliveries by oceanic area decreased 21% from 1984. The western Pacific was also the area from which most of the raw tuna imports originated in 1985, 74,356 tons, or 29% of total imports by oceanic area.

The decrease in western Pacific fishing activity by the U.S. fleet during 1985 can be largely attributed to prevailing economic conditions. The lowest ex-vessel prices in five years, particularly for skipjack tuna, and exceptionally good fishing for yellowfin tuna--the light meat species that commands the highest ex-vessel price in both domestic and foreign markets--led to a resurgence of U.S. fishing in the eastern Pacific Ocean during 1985 where a record catch of yellowfin tuna (218,920 tons) was reported from the Inter-American Tropical Tuna Commission's yellowfin regulatory area. The U.S. fleet accounted for almost 39% of the eastern Pacific yellowfin tuna catch in 1985 which represented the largest contribution to domestically-caught light meat tuna cannery receipts by oceanic area for the year.

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[1]Cannery receipts include only tuna destined for U.S. canneries. Cannery receipts exclude U.S.-caught tuna landed at foreign sites, U.S.-caught tuna landed at U.S. sites that is destined for foreign canneries, U.S.-caught tuna destined for the fresh-fish market, tuna imported as flakes, imported tuna not fit for human consumption, and imported "sushi" grade tuna.

[2]Direct exports include tuna landed directly in or transshipped to a foreign country; excludes tuna exported from the U.S. east coast.

[3]The eastern and western Pacific for this report are distinguished at 150 degrees west longitude.

The loss of canning capacity in Hawaii and the west coast and overwhelming imports of foreign packed tuna contributed to a decrease in overall U.S. canned tuna production (27.9 million standard cases[4]) of 11% from 1984. When canned imports were combined with U.S. production, the total addition to U.S. canned supplies in 1985 was 38.9 million standard cases which was a 2% decline from that in 1984. Canned imports set a new record in 1985, reaching 11.0 million standard cases, a 32% increase from 1984, and an increase of 237% since 1980. Tuna packed in water, which is subject to a much lower import duty than tuna packed in oil, dominated imports of tuna.

To promote fairer competition between U.S. and foreign processors, two pieces of legislation aimed at eliminating the tariff disparity between imports of canned tuna in water and canned tuna in oil were introduced into the U.S. House of Representatives during 1985. In a related matter, the U.S. Trade Representative called on the International Trade Commission (ITC) to conduct an investigation of the competitive conditions within the U.S. tuna industry. The ITC had recently completed an investigation of canned tuna imports in response to a petition from the U.S. tuna industry seeking tariff relief from imports of canned tuna packed in water. The industry's outlook with regard to these actions was perhaps best revealed through a significant increase in canned tuna imports bearing nationally advertised labels during 1985.

The U.S. consumer continued to benefit from competition between foreign and domestically produced canned tuna. The retail composite canned tuna price, which decreased 3% during 1984, fell an additional 2% through mid-1985. The downward price trend contributed to corresponding growth in overall apparent consumption which increased at a projected annual rate of 0.7% in 1985, following a 2% increase for all of 1984. Sales of water-packed products--except water-packed products in the health/diet category--had increased 8% by mid-year. Since water-packed products account for more than 60% of total sales, this increase helped offset reduced sales of tuna in oil and of health/diet canned tuna products.

U.S. consumers are also developing a taste for fresh and frozen tuna products. Fresh albacore tuna has become increasingly popular in the restaurant and retail trade. There is also a growing domestic market for high quality fresh tuna which has stimulated development of fresh fish tuna fisheries on the U.S. east and west coasts, the Gulf of Mexico, and in Hawaii.

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[4]A standard case can consists of: Chunk light 48 (6.5 oz) = 19.5 pounds; solid white 48 (7 oz) = 21 pounds prior to 1985, solid white 48 (6.5 oz) = 19.5 pounds beginning in 1985. Grated/flake 48 (6 oz) = 18 pounds. Because of the change in size of a standard white meat case from 1984 to 1985, output in units of weight is used to calculate the relative change in volume and value of canned white meat production from 1984 to 1985.

A Budget Simulation Model for West Coast Albacore Trollers Completed

At the La Jolla Laboratory industry economists Sam Herrick and Kevin Carlson completed a budget simulation model for West Coast albacore trollers which they described in NOAA Technical Memorandum NMFS-SWFC 57 published in February 1986.

In this paper Herrick and Carlson note that private and public fisheries administrators require information about cost and earnings of fishing vessels when evaluating alternative investment opportunities, gauging the economic impacts on a fishery of proposed policy changes, and assessing the effectiveness of existing fisheries policies. Data on the gross revenues of individual vessels are routinely collected by the Pacific coast states' fisheries agencies. On the other hand corresponding cost data, needed to derive estimates of the net earnings of vessels, are not regularly collected. Data on vessel costs which are assembled for these purposes, are generally collected through periodic cost and earnings surveys, and the results from these surveys are used to provide point-in-time estimates of net returns for particular classes of vessels or an entire fleet.

To extend the usefulness of cost and earnings survey data beyond the survey period, vessel budget (or fiscal) simulation models (budget simulators) can be constructed, which typically specify vessel costs and revenues as functions of variables, the values of which are collected on an ongoing basis (e .g., vessel characteristics that are recorded during the annual registration process). As new values of the explanatory variables become available they can be incorporated into the model together with expenditure-specific price indices--to adjust for relative changes in unit costs--to predict vessel costs and earnings outside the survey period. In this way vessel budget simulators provide a means of generating predictions of net returns for years in which cost and earnings surveys are not conducted.

The paper written by Herrick and Carlson describes the development and application of a budget simulation model that can be used to monitor and predict the financial and economic performance of specific vessels or classes making up the North Pacific albacore fleet. The model is capable of generating budgetary information for West Coast albacore trollers when the values of key variables describing vessel characteristics, fishing activities, and costs of inputs (e.g. fuel) are specified. This, according to Herrick and Carlson, makes the model a particularly useful analytical tool for evaluating events that affect the fleet's operating environment.

Summer Faculty Fellow Completes Study on Economic Issues of Skipjack

Dr. Linda L. Hudgins of the University of Notre Dame completed a 2-month stay at the Honolulu Laboratory as a summer faculty fellow. During her stay, Hudgins completed a paper on "Economic issues of the size distribution of fish caught: Hawaii skipjack tuna catches 1964-82." Before 1973-74 the catch of large skipjack tuna made up 64% of the landings in Hawaii, while in the following years its share fell to 36%. Hudgins

investigated a number of biological and economical possibilities for this decline, and concluded that fuel price increases may have contributed to a loss of $1.3 million in landings due to reduced search time. About $1 million per year is lost due to the absolute decline in catches, and approximately $300,000 is lost due to declining size distribution, both attributable to fishing activity elsewhere in the Pacific. If larger numbers of smaller fish had not replaced the large fish, however, the loss attributed to changing size composition would have been $1.2 million. Hudgins concluded that it appears that the stock is being truncated before it ever reaches Hawaii waters, and that for the skipjack tuna industry in Hawaii to expand, it will have to make changes in technology or expand its markets.

PACIFIC COOPERATIVE MARINE GAMEFISH TAGGING

Under the auspices of the Cooperative Marine Gamefish Tagging Program, recreational fishermen have tagged billfish to help fishery scientists determine the migration patterns and geographic limits of the populations of gamefish in the Pacific Ocean. The tagging program, which began in the Pacific in 1963, is currently supported by the NMFS in cooperation with the International Gamefish Association. James Squire, fishery biologist at the NMFS Laboratory in La Jolla, California, coordinates the Pacific program, as he has since its inception.

1985 Billfish Tag and Release Highlighted

Billfish anglers tagged and released 682 billfish of all species in the Pacific Ocean during 1985. Tagging was down by 166 billfish in 1985, compared with the total tagged in 1984. The major area of tagging was about the southern tip of Baja California, Mexico, where anglers tagged and released 363 billfish, 262 striped marlin, 75 Pacific sailfish and 26 blue marlin.

Although environmental conditions were less than optimum and catch rates were down off southern California, billfish anglers tagged and released a near record 216 striped marlin and one short-billed spearfish. The record numbr of marlin tagged and released off southern California was 225 marlin, tagged during the El Niño of 1983. The increased effort in tagging and releasing marlin off southern California since 1983 is a direct result of the support being given the program by the National Coalition for Marine Conservation - Pacific Region.

Squire is now distributing to cooperating anglers a newly-designed billfish tag developed by Michael Hall of South Australia who has made a detailed study of fish tags used throughout the world. In developing the new tag, Hall conducted considerable testing of tagging materials and incorporated new innovations in tag design. Hall's new tag is similar in many respects to the "Floy tag" used since 1971 but features a vinyl sleeve molded on a stainless steel wire. It can be used with the many hundreds of tag applicators presently in use by anglers taking part in the cooperative

program. The tag is printed with tag number and return information and produces a smaller, less traumatic wound in the billfish. Squire believes that its use should result in a greater tag return owing to fewer lost tags.

Southern California Sportfishermen Tag Striped Marlin

In 1985, as noted above, 216 striped marlin and 1 short-billed spearfish were reported tagged off southern California by sportfishermen. The majority of the striped marlin were tagged in the area from Santa Barbara Island north and west to the Santa Barbara Channel Islands. Until the El Niño in 1983, most catches and tagged fish were made off Catalina Island and in the area from Catalina Island to the mainland and south to off San Diego. However, during the warm water years of 1983 and 1984, striped marlin were most abundant in the area south of the Santa Barbara Islands.

In 1984, one of the warmest years on record for southern California waters, striped marlin were tagged and released as far north as off Morro Bay, California. In 1985, even though sea surface temperatures were much cooler, approaching the "normal" or average temperatures for southern California, the best area of catch remained in the northwestern waters of southern California.

The objective of the tagging program is to enlist the support of recreational fishermen to tag billfish and to help fishery scientists determine the migration and distribution of these fishes. Marine gamefish anglers have tagged and released billfish in many areas of the Pacific. The NMFS program has been responsible for an extensive tagging effort off Australia to map the migration of black marlin and for tagging billfish and mako sharks off New Zealand in cooperation with the New Zealand Ministry of Agriculture and Fisheries.

The longest migration recorded thus far was that of a black marlin tagged and released off Cabo San Lucas, Baja California, Mexico in early 1983. This marlin was recovered about 18 months later off Norfolk Island, northwest of New Zealand. This fish traveled a straight line distance of more than 5,700 miles between the points of tagging and recovery and represents a world record for billfish travel between tagging and recovery points. Another noteworthy example is a striped marlin which traveled from Cape San Lucas to an area west of Hawaii in 3 months, a straight line distance of 3,120 nautical miles.

Certain migration patterns, based on results from the tagging program, have been evident. Marlin which are found throughout the year in varying abundance near the entrance to the Gulf of California migrate southward and westward in the late spring and summer. Some fish round Cape San Lucas and move northward along the west coast of Baja California. Most fish marked in the fall off southern California show a southward migration toward Cape San Lucas. Some fish, however, have been recaptured near Hawaii. Tagged fish have been recovered more than 4 years after their release.

MARINE MAMMAL RESEARCH AT THE SWFC

Marine Mammal Protection Act of 1972

Since the passage of the Marine Mammal Protection Act (MMPA) in 1972, the United States has been committed to long-term management and research programs to conserve and protect these animals. In implementation of the MMPA, the Southwest Fisheries Center staff conducts a program of research which is directed toward understanding the abundance and biology of dolphins associated with the purse seine fishery for tunas in the eastern tropical Pacific. In 1985, the research effort concentrated on questions concerning changing abundance of the dolphin stocks, stock structure and distribution, biological profiles of the animals killed, and the rate at which these animals are replaced through new births.

In its 1984 reauthorization of the MMPA, Congress called for an expanded stock monitoring program. In response, the Center made detailed plans to conduct a program using research ships to collect data for monitoring trends in population size. Scientists at the Center developed a draft design which addressed two questions: the number of research vessels required to survey the area inhabited by the stocks of dolphins associated with the fishery and the number of years required to detect trends in abundance. A committee of experts composed of scientists from the U.S. Marine Mammal Commission, the Inter-American Tropical Tuna Commission (IATTC), the Porpoise Rescue Foundation, the Environmental Defense Fund, and North Carolina State University, reviewed the design. They concluded that a 6-year program of annual surveys using two survey vessels and operating between August and December would be required to detect a significant decrease in dolphin abundance over a 5-year period. Scientists at the Center drafted plans for a survey using two research vessels and one helicopter in six annual surveys. The first cruises are scheduled to depart in July 1986.

In support of the research vessel surveys, tests were conducted aboard the NOAA Ship David Starr Jordan to investigate the use of a computer-assisted sighting technique (CAST) to improve accuracy of measuring the distance between a marine mammal school and the ship's trackline and the angle of the line of sighting from the trackline. The accurate measurement of distance and angle is the key to using the line-transect method to monitor abundance of dolphins. CAST enables significant improvements in estimates of distance and angle and, therefore, significant improvements in indexing of abundance.

In a parallel approach to detecting trends in abundance, Center scientists are examining the possible use of dolphin sighting information collected aboard commercial tuna purse seiners in the eastern tropical Pacific. These data have been collected systematically by scientific observers since the early 1970's. A meeting of experts on tuna/dolphin interaction provided advice on how to use tuna vessel observer data to monitor trends. The group suggested research projects which might yield information required for monitoring abundance trends. Suggested projects are under review or have been started, some in cooperation with IATTC.

Preliminary work on seasonal patterns of dolphin distribution was completed. The analysis concentrated on the four species targeted by the fishery: spotted, spinner, common and striped dolphins. Sighting information was combined with oceanographic information. Factors examined included geographic areas (four large sub-areas based on thermocline topography and current structure), seasons (calendar quarters) and inter-annual periods (whether or not another related event such as El Nino was present). Because areas and inter-annual periods were defined from environmental considerations, they provide indirect tests of the association of encounter rates with these environmental features. Analyses suggest that there are pronounced changes in dolphin school density and school size by season and sub-area within the ETP. Further, there appear to be differences between El Nino and non-El Nino periods in the distribution of encounter rates and school sizes. These patterns are complex, and may be complicated further by changes in tuna vessel fishing patterns and strategies for searching for tuna.

Biological research on the dolphins of the ETP continues on stock-structure, age-determination, growth, reproduction, and bioenergetics. Data for biological studies of population condition and replacement rates of ETP dolphins continue to be compiled and analyzed by Center scientists. Biological profiles are taken on incidental mortalities by tuna vessel observers, and biological samples (whole carcasses or tissue samples) are collected at sea, preserved, and returned to the laboratory for analysis (age, sexual condition, possible stock membership, pathologies, etc.). Information and samples collected are entered into data bases maintained by the office of the Southwest Regional Director. The goal is to develop indices for monitoring conditions of the exploited populations and to improve estimates of replacement rates should changes in allowable take become necessary.

The division of stocks of the eastern and offshore whitebelly spinner dolphin and of the offshore northern and southern spotted dolphin is considered provisional. Work using both morphological and genetic measures of stock identification continues. Analysis of mitochondrial DNA (mtDNA) is being used to examine how the populations of spinner dolphin are related. Analysis of mtDNA clones (lineages) indicate that sufficient interbreeding between the eastern and whitebelly stocks has occurred (or is occurring) so that the distribution of the lineages does not appear to be correlated with the eastern or whitebelly morphotype. However, it appears that strong selection has occurred (or is occurring) to maintain morphological discreteness in the presence of gene flow which has intermixed the lineages. This implies that these physical traits may have an adaptive or survival benefit to its possessor.

The Center's staff continued investigating age-related reproductive parameters in an effort to provide population indices to indicate trends of population condition. To reach the goal of improved estimation of replacement rates and development of density-dependent condition indices of exploited dolphin population, researchers continue to investigate age distribution, age at sexual maturity, lifetime reproductive potential, sex ratio, proportion of mature females and estimates of natural mortality--all necessary to determine population growth rates.

Readings of dolphin teeth for age determination and growth were completed for samples of female spinner dolphins collected from 1973 to 1982. This marked the successful end of the second phase of efforts to analyze growth rates, age structure, sexual maturity, and age-specific reproduction rates in the northern and southern whitebelly spinner and eastern spinner dolphins. Since examination of the data resulted in the discovery of large biases in the samples due to sampling conditions, the preparation and reading of large samples of teeth for age distribution and growth has been discontinued this year.

During the year, about 1,400 gonad (sex glands) specimens from dolphins killed incidentally during fishing operations were collected and processed. Reproductive information from these samples will be used to study seasonality in reproductive behavior, responses of populations to levels of fishing effort and other vital rates.

Work has also been conducted on the origin of the association between yellowfin tuna and spotted dolphins. Results of experiments using comparative bioenergetic models for the two groups suggests that the origin of the association may be explainable on the basis of optimal sustained cruising speed for each species. Persistence of the association could be explained on the basis of feeding dynamics. Although the association could have arisen fortuitously on the basis of cruising speed, energetics models predict that persisting in the association could be a problem for tuna. Estimated forage requirements for dolphins are 5 to 15 times greater than requirements for tuna which are, therefore, associating with an especially voracious competitor. Tuna, however, are much smaller than dolphins and have correspondingly smaller stomachs. Given equal probability of successfully capturing an item of prey, tuna will have full stomachs earlier than will dolphins. Thus, tuna will complete their feeding bout while food is still relatively dense. Dolphins on the other hand must continue feeding on prey that are more dilute. Studies of dolphin acoustics suggest that these animals may have superior ability to locate prey. If so, tuna would benefit from associating with dolphins by encountering prey more often and at no added energetic cost. The persistence hypothesis is supported by the observation that stomach contents of tuna and dolphins caught simultaneously are similar.

Workshop Held at NMFS Southwest Fisheries Center to Plan Analysis of Tuna Vessel Observer Data for Monitoring Dolphin Populations

Information on dolphins in the eastern tropical Pacific has been collected systematically by scientific observers aboard commercial tuna purse seiners since the early 1970's. These data have been used to monitor the mortality of dolphins which occurs incidentally in the tuna purse seine fishing operations and to study dolphin life history, stock structure, and movements and distribution. Using a variety of approaches and techniques, scientists at the Center are examining the possibility of monitoring and detecting trends in abundance of these dolphin stocks from these observer data.

To determine how and to what extent these tuna vessel observer data can best be used to monitor trends in population abundance and to identify

the specific elements of a research plan to accomplish this, a meeting was held on November 13, 1985 at the Southwest Fisheries Center. Experts on the tuna/dolphin interaction were asked to provide advice and counsel to the NMFS. Taking part in this meeting were technical representatives of the U.S. tuna industry, the U.S. Marine Mammal Commission, the Inter-American Tropical Tuna Commission, and members of the staff of the Southwest Fisheries Center's Oceanic Fisheries Resources Division.

After reaching agreement on the objectives, members of the Workshop group suggested 42 research or development projects which might be expected to yield the kinds of information required for the abundance study in the areas of: stratification and search processes, line transect methods, school size estimation, stock identification, method development and comparisons, observers' effects on estimates, and economics of the fishery. In the ensuing months the staff of the Oceanic Fisheries Resources Division has incorporated the recommendations of the participants at this meeting in a research plan which can test the use of the tuna vessel observer data for monitoring purposes.

As this was being written, approval was received from Washington that the planned dolphin monitoring cruises could begin in July, 1986. Two vessels, the NOAA Ships McArthur and David Starr Jordan will leave San Diego on July 28, 1986 with their primary objective to collect information to estimate the density, size and species composition of dolphin schools in the eastern tropical Pacific Ocean. The McArthur will initially proceed to Honolulu and gradually work a cruise track to Panama City, Panama. The Jordan will proceed southeast to Mexico and as far south as Lima, Peru. Both ships will return to San Diego about December 10, 1986.

1985 Tuna/Dolphin Observer Data Base Summarized

Observers are placed aboard U.S. tuna vessels by the National Marine Fisheries Service in a program to monitor purse seine operations to ensure that fishermen abide by federal regulations as set forth in the Marine Mammal Protection Act of 1972 and subsequent modifications and to collect specimens of dolphin and attendant field data. At the Southwest Fisheries Center biological technicians Randy Rasmussen and Rick Lindsay completed the editing of data which had been collected in 1985 by NMFS technicians (observers) aboard U.S. tuna purse seiners in the eastern tropical Pacific Ocean. The data summarized by Rasmussen and Lindsay have now been added to the data base used for the investigation of the distribution, abundance, mortality and life history of the dolphin populations involved in the tuna purse seine fishery.

Biological technician Al Jackson calculated that 23 observer cruises were conducted in 1985. This is an increase over the 11 cruises fielded in 1984 and provides a sample size of approximately 21% of the fishing trips made by U.S. purse seiners to the ETP during the year. The 23 observers collectively spent 1,484 days at sea during 1985. The average length of cruise was 65 days. While at sea the observers logged 7,147 hours of marine mammal watch effort along transects having a combined length of 86,442 nautical miles.

Complete sighting records, including estimates of sizes of dolphin schools and confirmed species identifications, were collected for 18 different species (or stocks of species) of cetaceans. Information for 8 less specific classifications of cetaceans was also collected. The most frequently encountered animal was the offshore spotted dolphin with 1,351 confirmed sightings. The offshore spotted dolphin is most actively pursued by the purse seine fleet in the ETP because it is most often found in association with tuna.

Detection rates of target dolphin stocks, expressed as the number of schools sighted per 1,000 nautical miles of watch effort, ranged from a high of 11.0 schools/1000 miles for offshore spotted dolphin to a low of 0.3 schools/1000 miles for striped dolphin. These figures are for all sea surface conditions. There is, however, a distinct decrease in the detection rates as the sea surface condition (as measured by the Beaufort wind force scale) deteriorates. The detection rate for all target dolphin stocks for calm sea conditions (Beaufort 0 and 1) was 24.3 schools/1000 miles, and the encounter rate during periods of rougher seas (Beaufort 4 and 5) was only 12.7 schools/1000 miles. (The amount of watch effort logged during Beaufort 0-1 was 17,520 and for Beaufort 4-5 was 16,690 miles.)

A total of 1,015 purse seine sets was observed in 1985. Of these, 972 were sets made on tuna associated with dolphin schools (dolphin sets), 24 were sets made on free-schooling tuna (school fish sets) and 17 were sets made on tuna associated with floating debris (log sets). An additional two sets were made with no intent to catch fish.

A total of 18,646 tons of yellowfin tuna, 285 tons of skipjack tuna and 5 tons of other tuna were loaded aboard the vessels. The average catch from a dolphin set was 18.4 tons, the average from school fish was 30.0 tons, and the average from log sets was 20.6 tons. The overall average set catch was 18.7 tons.

The observers counted a total of 4,887 dolphins killed in the vessels' nets. The overall observed dolphin kill per set was 5.03 and kill per ton of tuna loaded was 0.27 animals. Observers examined 982 dolphin specimens in the field and returned some of the specimens to the laboratory for detailed examination.

Responsibility for Estimations of Dolphin Mortality Transferred to SW Region

A computerized data base system, developed at the Southwest Fisheries Center and originally used there to estimate dolphin mortality incidental to tuna fishing in the eastern tropical Pacific was transferred from the UCSD VAX computer system to a La Jolla Standard microcomputer and turned over to the San Diego field office of the NMFS Southwest Region. The staff of the field office will now have responsibility for making estimates of dolphin mortality. The conversion was coordinated by computer programmer analyst Ken Wallace although the actual conversion was done by contract programmers.

The system simplifies and speeds up entering of information pertaining to vessel departures and arrivals and radio-reported dolphin kills observed by technicians at sea. The information turned over to the SW Region's staff includes the current 1985 database.

Interactions between Seabirds, Tunas and Dolphins Described

Dr. David Au and Robert Pitman have completed a manuscript describing the interactions of seabirds with tuna and dolphins, based on data they collected between 1976 and 1980. In the paper, they point out that seabirds are commonly associated only with spotted and spinner dolphins, that only these two dolphin species are commonly associated with yellowfin tuna, and that this multispecies association is common only on the purse seine fishing grounds of the eastern tropical Pacific. In the dolphin-associated bird flocks there are multispecies assemblages in which three species of boobies and frigatebirds are common. In contrast, bird flocks found in waters beyond the purse seine fishing grounds contain few species, are dominated by sooty terns, are associated with small, skipjack-like tuna, and are seldom associated with dolphins. Au and Pitman discuss the implications of these differences with respect to possible area-wide differences in prey and in the strategies for exploitation of that prey.

Use of mtDNA to Discriminate between Spinner Dolphin Stocks

At the La Jolla Laboratory, Drs. Andrew Dizon and John Graves have been using analysis of mitochondrial DNA (mtDNA) to examine relatedness of populations of spinner dolphins in the eastern tropical Pacific Ocean (ETP). These dolphins are one of the species which are killed incidentally during the process of purse seining for yellowfin tuna.

Analysis of mtDNA clones (lineages) among closely related populations allows the tracing of the movements of females. The female's movements can be traced because all the mitochondria comes from the mother; sperm does not transfer any mitochondria to the egg during the fertilization process. For example, if a female from one population stock strays and breeds with a male from a second, the offspring will bear the mtDNA clone-type of the female. Since this mtDNA clone-type is probably neutral (not subject to selection), it will remain in the second population and be passed on to subsequent generations. In contrast, nuclear genes expressing morphological traits are subject to selection and, as in the example, may prevent the morphological characteristics of the female from spreading in the second population.

On examining a pair of population stocks, four "scenarios" are possible:

1) Large mtDNA differentiation and large morphological variation would indicate two discrete stocks with little or no gene flow and little adaptation to local environment.

2) Little mtDNA differentiation and little morphological differentiation would indicate considerable gene flow.

3) Large mtDNA differentiation and little morphological differentiation would indicate two distinct stocks with little or no gene flow and which are subject to very similar environmental selection pressures.

4) Little mtDNA differentiation and large morphological differentiation indicates a situation where gene flow has resulted in the mixing, between stocks, of opposite mtDN A clone-types and strong selection pressures have resulted in the elimination or suppression of the opposite morphotypes.

For the ETP spinners, Dizon and Graves are interested in whether scenario 1 or 4 is likely since they know that considerable morphological variation exists between the easterns and the whitebellies. In more detail, they are asking about the nature of the "overlap" of the two populations--is it a common area of two isolated stocks with little or no gene flow between stocks, is it a bi-directional zone of hybridization between the two stocks, or is it uni-directional where genes from one stock are accumulating in the gene pool of the other but not vice versa?

For the ETP spinners, Dizon and Graves have some tentative answers. The molecular phylogeny based on clones of mtDNA (Dizon and Graves liken this to the inheritance of surnames but passed on by the female rather than the male) is best explained by scenario 4. That is, sufficient interbreeding between the stocks, in the sampled region, has occurred (or is occurring) so that the distribution of the mtDNA clones does not appear to be correlated with morphotype. It is likely that selection has occurred (or is occurring) to maintain morphological discreteness in the presence of gene flow.

These findings have important implications for tuna management. The distribution of mtDNA clones in the sampled population indicates a fair degree of gene flow and it is undeniable that two morphotypes are being maintained in that sampled population. Dizon and Graves believe that this implies that these physical traits confer an adaptive or survival benefit to its possessor. It is likely that the morphological traits of the eastern morphotype have survival value in the regions where the eastern stocks are predominantly distributed and vice versa. It may not, therefore, be prudent to manage the spinner dolphin in the eastern tropical Pacific as one stock and risk the elimination of the more heavily fished eastern morphotype.

Current work is aimed at completing analysis of an additional group of about 70 spinner samples from the ETP and 12 from the Timor Sea just north of Australia. The larger sample size will allow Dizon and Graves to examine the distributions of lineages in animals killed in the same set. Presumably animals from the same set should be much more highly related than those between sets and between sets separated by large distances such as the Timor Sea animals. One question that may be answered is whether school groups (presumably those killed in a set are all from the same schools) are "tribal" and composed of animals showing common maternal ancestry.

TUNA BEHAVIOR AND PHYSIOLOGY STUDIES

Natural Mortality in Tropical Tunas -- Improving the Estimates

A cooperative effort among Elizabeth Vetter and Earl Weber of the La Jolla Laboratory and Christofer Boggs of the Honolulu Laboratory is underway to develop methods for improving estimates of natural mortality (M) used in tuna stock assessments, by incorporating independent information about physiological condition of the fished stock into these mortality estimates.

In the past, analysts have tended to consider the stock as a whole and assumed a constant value of natural mortality for all ages in the fishable stock. This value of M has been estimated from the overall change in numbers with age (size) between recruitment and the oldest age caught. This and other assumptions, such as no migration between stocks or areas, and unbiased or identifiably biased sampling, are rarely valid. In addition, more recent stock assessment techniques consider the stock as a collection of ages or cohorts, and require age-specific parameters for the analyses.

As these catch-at-age analyses become more common, it becomes more important to consider the possibility that natural mortality changes significantly with age after recruitment. In particular, it is important to determine what effect age-specific mortality may have on predictions generated by stock assessments that previously assumed natural mortality to be constant. It is also necessary to devise ways other than simply following numbers through time to estimate what the age-specific values for natural mortality may be.

Vetter, Boggs and Weber are using a combination of mathematical modeling and the results of physiological experiments to study this problem in tropical tunas. The physiological studies provide independent data for "tuning" the mortality parameters used in tuna assessment models to more adequately reflect patterns in natural populations.

Weber is using computer simulations to quantify the sensitivity of catch-at-age models to variations (errors in estimation) in either constant (scalar) or age-specific (vector) natural mortality. The results from these studies will determine the level of precision needed from field samples to make any measurable improvement in predictions of assessment.

Reasoning that energy stores are the most parsimonious expression of survival capacity in tuna, which are characterized by an unusually high-energy life style, Boggs conducted studies on the age-specific response to simulated foraging bouts and predation in starved versus well-fed yellowfin and skipjack tuna.

Vetter has developed a conceptual model for the process of natural mortality and identified internal versus external controls on the magnitude of this process in size-structured populations. From this framework it

becomes possible to identify which aspects of the process can be studied with physiological indexes, and which are not amenable to this approach.

Weber's simulation results indicate that errors in estimation of natural mortality can be important to predictions generated by size-structured fishery models. Boggs's laboratory experiments have confirmed the hypothesis that measurable reductions in burst performance capacity occur in tuna after ecologically realistic periods of starvation (3-5 days). Vetter's theoretical models demonstrate that physiological measures can be useful indices of internally-generated (donor-controlled) risk (e.g., ability to avoid predation or capture food) but that the physiological approach is not appropriate for studying factors under recipient control (e.g., predator abundance).

Two Yellowfin Tuna Successfully Tracked

Two yellowfin tuna, Thunnus albacares, tagged with ultrasonic depth sensitive transmitters were successfully tracked for 12 and 38 hours on the research vessel Kaahele'ale. This tracking project is a joint effort with Dr. Kim Holland of the Hawaii Institute of Marine Biology and is jointly supported by the Honolulu Laboratory, University of Hawaii Sea Grant Program, and the state of Hawaii. The first fish was caught immediately adjacent to fish aggregating device (FAD) "S" located off the Waianae coast of Oahu. It remained in the immediate vicinity of the FAD for approximately 5 hours and then slowly moved offshore. Unfortunately, the track had to be abandoned after 12 hours due to mechanical problems with the boat's engine.

The fish was 74 cm (fork length) and was the largest tuna tracked by project scientists to date. Although its horizontal movements were similar to those of other yellowfin tuna tracked in this area, it remained at significantly greater depths than did the smaller yellowfin tuna. These data seem to support the heat production-heat loss models for yellowfin tuna which predict that larger fish must remain in cooler water to avoid overheating.

A second, smaller yellowfin tuna (56 cm fork length) was tracked for 38 hours. This fish was caught near the 50 fathom isobath, which is several miles inshore of the local FADs around Oahu. Similar to other previously tracked yellowfin tuna, this fish patrolled along the isobath during the day but moved offshore during the night, and returned to the isobath again at dawn. In contrast to the larger fish tracked just 2 weeks earlier, this yellowfin tuna completely ignored the four FADs that were easily within its range. In addition to providing replicate data on diurnal movements, this fish also provided high quality data on sustained swimming speeds. During one phase of the track, the fish swam a very straight course for over 5 hours at approximately 3-4 body lengths per second.

In related work Dr. Kim Holland, Randolph K. C. Chang, Fishery Biologist, and Lt. (jg) Jeffrey A. Koch, NOAA Corps, successfully tracked two female mahimahi. Like small yellowfin tuna and skipjack tuna, mahimahi are often associated with FADs. The first fish (102-cm fork length) was caught at 0800 March 5 immediately adjacent to FAD "W" located off windward

Oahu. The second mahimahi was also captured near FAD "W." Unfortunately, this fish died after only several hours of tracking. These are the first two mahimahi ever tracked. Like tuna, mahimahi appear to have good navigational abilities and appear to know the location of FADs. Unlike tuna, the first mahimahi moved inshore at night (all yellowfin tuna tracked near Oahu moved offshore at night) and swam at deeper depths during the night than during the day (yellowfin tuna exhibited the opposite behavior).

Analysis of Cardio-Respiratory Reactions of Tunas Completed

Fishery biologist Peter G. Bushnell at the Honolulu Laboratory completed analysis of data on experiments of cardio-respiratory reactions of skipjack and yellowfin tunas exposed to brief periods of low ambient oxygen. The objective of these experiments is to provide quantitative information on the effect of varied ambient oxygen levels on the distribution, abundance, gear vulnerability and natural mortality of skipjack tuna and yellowfin tuna.

During the experiments, oxygen, carbon dioxide, and pH of arterial blood, heart rate, cardiac output, ventilation volume, blood pressure, and mouth gape were measured simultaneously. The skipjack tuna showed significantly lowered heart rates, increased mouth gape and increased ventilation volume when the oxygen level of the water was reduced by one-third from full oxygen saturation. Similar reactions have been obeserved in yellowfin tuna that were tested under the same conditions. Skipjack tuna, however, were found to be much more sensitive than yellowfin tuna to reduced water flow over the gills, although the physiological reactions were similar to those observed under reduced water oxygen levels.

The data clearly showed that both tuna species were more sensitive to changes in oxygen levels than other fish species studied, such as the trout and lingcod. A comparison of these with data on swimming depth behavior of yellowfin tuna showed that the oxygen level at which yellowfin tuna first begin to show cardio-respiratory reactions in the experiments is the lowest oxygen level that yellowfin tuna are found in the ocean around Hawaii. Whether this oxygen level (which is far above the lethal level) is the limiting factor in the depth distribution of yellowfin tuna is still unclear.

Analysis of Tuna Tissue Completed

Robert E. Bourke, Research Assistant at the Honolulu Laboratory, has completed RNA-DNA analysis of tissue samples taken from small yellowfin tuna that were infested with a parasite (a larval cestode) found in the dorsal aorta and compared the samples with samples taken from tuna that were not infested. The biochemical analysis allows determination of the instantaneous growth rates of fishes. The objective of this work was to determine if the parasite had any significant effects on the growth rates and natural mortality of yellowfin tuna.

The data indicate that there is no difference in the growth of infested and non-infested yellowfin tuna. Also, there were no differences in length/weight ratios, condition factors, and relative heart and other

internal organ weights between the parasitized and non-parasitized fish. These results are surprising because of the importance of the blood vessel (dorsal aorta) which was occluded completely by the parasite.

During January and February 1986, Bourke found no fish infested with the parasite from a sample of over 50 small yellowfin tuna he examined. Over the past 2 years the infestation rate in small yellowfin tuna caught near Hawaii has been approximately 50%. The reasons for the apparent sudden disappearance of the parasite during this period are unknown.

FURTHER RESEARCH ON TUNA AND TUNA-RELATED ACTIVITIES

THE DYNAMICS OF TUNA MOVEMENTS

In 1984, an international group of research scientists and administrators, sponsored by the Inter-American Tropical Tuna Commission, met to consider how research efforts could be focused to meet the specific needs of tuna management to the year 2000. In the summary of their report, (Considerations for Tuna Research to the Year 2000), the participants noted, "The rapid expansion of tuna fisheries into previously underexploited oceanic regions, the extension of national jurisdiction of fisheries by most coastal states and the increase in effort in historic fisheries have placed new demands on the management of tuna resources."

Among the key issues identified by the participants was that of the movement and distribution of tunas. As a result of this recommendation a series of three technical workshops was held during the past year at the Southwest Fisheries Center to conceptualize the problems of tuna movements and distribution and to define specific research projects and experimental designs for the study of tuna movement dynamics.

Supported jointly by the Inter-American Tropical Tuna Commission and the National Marine Fisheries Service the first workshop addressed the results and uncertainties in conventional mark and recapture studies of tunas; the second, the relation between oceanography and tuna movements; and the third, new technologies that might be used to measure tuna movements.

A report, "The Dynamics of Tuna Movements: An Evaluation of Past and Future Research," has been completed and will be submitted to FAO of the United Nations, Marine Resources Service, which has agreed to publish the report in an established fisheries series.

Recommendations obtained in the report include:

- Establish international arrangements to share data on tuna movement and to provide links with international oceanographic programs.

- Increase the number and kinds of observations of movements of tuna in the vertical plane.

- Develop and use technology for tracing the actual path followed by tunas over extended periods and for measuring movements independent of the fishery.

- Conduct intensive ocean studies on the dynamics of tuna movements which combine old technologies with the new approaches, i.e. development and use of an archival tag.

NMFS Contributes to 36th Annual Tuna Conference

The Tuna Conference, an annual event since 1950, is held for the purpose of providing an opportunity for fishery biologists to meet and

exchange current research information on tuna and tuna-like species. The 36th annual Tuna Conference, hosted by the Inter-American Tropical Tuna Commission (IATTC) and chaired by Kurt Schaefer, Associate Scientist with the IATTC, was held at the University of California Conference Center in Lake Arrowhead, California from May 21 to May 24, 1985. There were 73 participants, including a sizeable contingent from the NMFS, with representatives from Australia, the Azores, Canada, Indonesia, Japan, Mexico, and the Seychelles.

The presentations were organized into four sessions: distribution, abundance, movements, and other aspects with NMFS scientists well represented. For example, contributing to the session on distribution were NMFS scientists Paul Sund of the Pacific Fisheries Environmental Group (PFEG) who discussed "Tuna distribution in relation to the environment"; Dr. Richard Brill of the Honolulu Laboratory who presented a talk, "Physiological factors affecting tuna distribution and movements"; Dr. Steve Reilly of the Oceanic Fisheries Resources Division (OFRD) at La Jolla who presented, "Spatial temporal patterns in ETP dolphin distribution from tuna vessel observer data"; and Dr. David Au of OFRD who spoke on "Avifauna of eastern Pacific tunas.

In the session on abundance, Dr. Tim Smith of OFRD talked about "A heuristic data analysis device for examining spatial-temporal patterns." Smith discussed the potential for using micro-computers for graphically displaying fine scale aspects of tuna purse seiner searching strategies.

In the session on movements, Dr. Michael Laurs of the Coastal Fisheries Resources Division (CFRD)gave an overview on albacore movements through the Pacific Ocean in a talk entitled, "Large-scale and small-scale movements of albacore." Dr. Pierre Kleiber of OFRD and Dr. Sam Bledsoe, University of Washington, presented a talk on "Behavior of albacore population dynamics and movement model." Dr. John Hunter, CFRD, gave an overview of the workshops he recently chaired on tuna movements and distribution in a talk entitled, "Future directions for research on the dynamics of tuna movement."

Dr. Christofer Boggs, Honolulu Laboratory, was the convener for the session on other aspects of tuna research. In that session Boggs presented, "A physiological index for natural mortality"; Dr. Elizbeth Vetter, OFRD, presented, "Running hot and cold in the ETP": some simple hypotheses about origin and persistence of the tuna-dolphin association;" Dr. Richard Brill, Honolulu Laboratory, presented "Description of a newly rediscovered parasite from the dorsal aorta of yellowfin tuna"; Paul Sund, PFEG presented, "A wind fishability index for albacore"; and Dr. Jay Barlow and Stephanie Sexton of OFRD, presented, "Geographic variation in spotted dolphin reproduction parameters."

At the business meeting which closed the 36th Annual Tuna Conference, Dr. Richard Brill of the Center's Honolulu Laboratory was appointed Chair of the 37th Annual Tuna Conference.

PUBLICATIONS

SWFC PUBLICATIONS ON TUNA AND TUNA-RELATED SUBJECTS

MAY 1, 1985 TO APRIL 30, 1986

PUBLISHED

Ankenbrandt, Lisa. 1985. Food habits of bait-caught skipjack tuna, Katsuwonus pelamis, from the southwestern Atlantic Ocean. Fish. Bull., U.S. 83(3):379-393.

Stomach contents of skipjack tuna captured in 1981-82 by live pole-and-line vessels off the southern coast of Brazil were analyzed for the presence of larval and juvenile skipjack tuna. The percentage frequency of occurrence, percent number, and percent volume were evaluated. Of the 1,041 stomachs that were examined for food, 436 were empty. The mean volume of food in all stomachs analyzed was 36.9 mL, of which 18.9 mL was bait and 18.0 mL was prey.

The gonostomatid Maurolicus muelleri and the euphausiid Euphausia similis were the principal foods. Other important foods were the chub mackerel, Scomber japonicus; the frigate tuna, Auxis thazard; gempylids; trichiurids; and carangids. In the study area, adult skipjack tuna were not found to feed on their young.

Kruskall-Wallis nonparametric one-way analysis of variance was used to test for differences in the mean volumetric ratios of food items in relation to skipjack size. The percentage of E. similis in the diet was found to decrease, while the proportion of M. muelleri was found to increase with increasing skipjack size. Seasonal variations in the diet were also examined and discussed.

Apparently the anatomy of their gill raker apparatus allows skipjack to ingest a wide variety of prey types above a minimum size. These variations in the food can be attributed to the number and size of the prey species in an area.

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Jones, D.R., R.W. Brill, and D.C. Mense. 1986. The influence of blood gas properties on gas tensions and pH of ventral and dorsal aortic blood in free-swimming tuna, Euthynnus affinis. J. Exp. Biol. 120:201-213.

Laurs, R.M., R. Nishimoto, and J.A. Wetherall. 1985. Frequency of increment formation on sagittae of North Pacific albacore (Thunnus alalunga). Can. J. Fish. Aquat. Sci. 42:1552-1555.

An examination of sagittae from 116 albacore (Thunnus alalunga) caught in the North Pacific, injected with tetracycline, tagged, released and subsequently recaptured in sport and commercial fisheries showed that detectable increments are formed on these otoliths at an average rate of 0.954 per day. We take this as a confirmation of daily increment

formation in North Pacific albacore sagittae. The slight departure of observed mean increment counts from the expected rate of one per day may be due to an occasional interruption of otolith growth, or to a systematic bias in detecting daily increments or interpreting otolith microstructure. The estimated rate of detectable increment formation applies explicitly to albacore of fork lengths between 50 and 100 cm. If the same rate holds for fish smaller than 50 cm, as is likely, most albacore taken in sport or commercial catches can be aged accurately by applying our methods and expanding the increment count by 5%.

Mackett, David J. 1985. Strategic planning for research and management of the albacore tuna fishery. Systems Research 2(3):201-210.

The National Marine Fisheries Service (NMFS) employed the principles of interactive management, supported by consensus building techniques for facilitating meetings, to produce a strategic plan for research on and management of an important fishery. A technically oriented task force aided by a planner was assigned the task of facilitating the production of the plan; an important first step was the production of a probable future scenario of the fishery. Interested citizens, informed by the scenario, were invited to state their goals for the fishery and to list what they considered desirable future trends and events. An options field for the research and management strategy consisting of 17 design categories was produced by the task force and knowledgeable members of NMFS management. The pros and cons for including each option in the NMFS strategy were discussed in a meeting of NMFS Headquarters, Regional and Laboratory management. A set of options was chosen by consensus to represent the NMFS strategic plan for its research and management of the North Pacific albacore fishery.

Perry, S.F., C. Daxboeck, B. Emmett, P.W. Hochachka, and R.W. Brill. 1985. Effects of exhausting exercise on acid-base regulation in skipjack tuna (Katsuwonus pelamis) blood. Physiol. Zool. 58:421-429.

The effects of exhausting exercise on acid-base balance of skipjack tuna blood were investigated. Following exercise, tuna displayed a mixed respiratory/metabolic acidosis with blood pH being reduced by ~ 0.4 units. The respiratory component (51% of the initial acidosis) was compensated following 20 min of recovery, while the blood metabolic acid load (H^+_m; ~ 8mM) was cleared after only 50 min. At that time, there was a great discrepancy between blood lactate load and H^+_m load because blood lactate levels were still increasing. The significance of these results is discussed with reference to the tuna's habitat, behavior, and physiology.

_____. 1985. Effects of temperature change on acid-base regulation in skipjack tuna (Katsuwonus pelamis) blood. Comp. Biochem. Physiol. 81A:49-53.

Wahlen, Bruce E., and Tim D. Smith. 1985. Observer effect on incidental dolphin mortality in the eastern tropical Pacific tuna fishery. Fish. Bull., U.S. 83(4):521-530.

Scientific observers placed aboard a sample of purse seine vessels collect data that are used to estimate the total number of dolphins killed incidentally in the eastern tropical Pacific tuna fishery. If the presence of these observers, who are not crew members, affects incidental kill levels, then the kill estimates will be biased. To test for the existence of such an observer effect, the author compared dolphin kill data that had been recorded by observers who differed in levels of obtrusiveness according to their purposes for data collection. Some observers were placed on board primarily to collect data for estimating the total number of dolphins killed annually. Other observers collected data both for that purpose and for monitoring compliance with dolphin-release regulations. Results confirm that the presence of an observer does affect dolphin kill. The primary effect is an increase in the proportion of sets with no dolphins killed, and a decrease in the proportion of sets with one to nine dolphins killed. While the magnitude of the effect of observers cannot be estimated from their data, estimates of total dolphin mortality based on data collected by the scientific observers are biased downward.

TECHNICAL MEMORANDA

Parrish, Richard H. 1985. Operational plan for NMFS albacore program. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFC-52, 31 p.

Sund, Paul N. 1985. Albacore fishing and windspeed. U.S. Dep. Commer., NOAA, Tech. Memo., NOAA-TM-NMFS-SWFC-53, 18 p.

Note: Copies of these and other NOAA Technical Mamoranda are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22167. Paper copies vary in price. Microfiche copies cost $4.50.

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Barrett, I. 1985. Director's report to the Thirty-sixth Tuna Conference on Tuna and Tuna-related Activities. Southwest Fish. Cent. La Jolla Lab., Natl.Mar. Fish. Ser., NOAA, Admin. Rep. LJ-85-17, 53 p.

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Harada, T., R.S. Shomura, T.K. Kazama, O. Murata and S. Miyashita. 1986. The transport of eggs and larvae of skipjack tuna from Hawaii to Japan. Southwest Fish. Cent., Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Admin. Rep. H-86-2, 3 p.

Holt, R. 1985. Estimates of abundance of dolphin stocks taken incidentally in the eastern tropical Pacific yellowfin tuna fishery. Southwest Fish. Cent., La Jolla Lab., Natl. Mar. Fish. Serv., NOAA, Admin. Rep. LJ-85-16.

Holts, D. and N. Bartoo. 1985. Report of the Ninth North Pacific Albacore Workshop. Southwest Fish. Cent., La Jolla Lab., Natl. Mar. Fish. Serv., NOAA, Admin. Rep. LJ-85-25.

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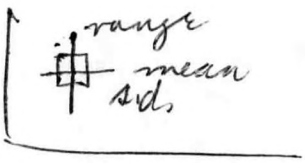
size comp

seasonal/geographic variation
size at maturity
batch fecundity
spawning frequency

mean diam's



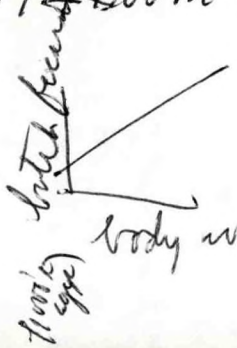
> .55 – .60 oocytes diam's are ready to spawn

size at maturity (Richards (1959) function but for) proportion of fish with each .20 mm oocytes

size at 50% maturity

Batch fecundity based on ovaries in a hydrated state

.7 ± .02 mm. diameter



7.5 – 150 eggs/gram depending on area where collected

proportion of fish
hydrated eggs can be used to
estimate spawning frequency

% of hydrated