SOUTHWEST FISHERIES CENTER

NATIONAL MARINE FISHERIES SERVICE

SOUTHWEST FISHERIES CENTER

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MAY 1985

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

For The Period
MAY 1, 1984 To APRIL 30, 1985

ADMINISTRATIVE REPORT LJ-85-17

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SWFC ADMINISTRATIVE REPORT NO. LJ-85-17

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INTRODUCTION

Tuna research in the National Marine Fisheries Service (NMFS) has been conducted at the Southwest Fisheries Center's (SWFC) two laboratories in Honolulu, Hawaii and La Jolla, California since 1970, with one exception. Research on Atlantic billfishes and bluefin tuna is carried out at the NMFS Southeast Fisheries Center in Miami, Florida.

At the Honolulu and La Jolla Laboratories, fishery biologists are involved in studies of the population dynamics of most other species of tuna on a world-wide basis, often in cooperation with the research organizations of many fishing nations and with international fisheries organizations. Knowledge of these international fish and fisheries, based on national and international studies is growing steadily and is forming an increasingly valuable base for the rational management of tuna fisheries world-wide.

Under the leadership of Director Richard Shomura, tuna research at the Honolulu Laboratory includes studies on the behavior, energetics, physiology and sensory biology of tropical tunas, South Pacific albacore and other tuna populations of the central and western Pacific and recreational fisheries research, principally the sportfishery for billfishes. 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.

At the La Jolla Laboratory, the staff of the Oceanic Fisheries Resources Division under the leadership of Dr. Gary Sakagawa conducts studies on stock assessment and fishery evaluation of tunas and billfishes for fishery analysis and management advice on tunas and billfishes to U.S. Commissioners serving on international fisheries bodies, and conducts studies on the status of dolphin involved in the tuna purse seine fishery of the eastern tropical Pacific; the Division staff also conducts research to determine the status of North Pacific albacore by evaluation of domestic and foreign catch and effort data.

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

Results of these studies are a key source of information and advice for U.S. representatives to international tuna management organizations, the International Commission for the Conservation of Atlantic tunas, fisheries scientists, administrators, and the U.S. tuna industry.

In addition to existing biological and assessment studies on tuna, the Southwest Fisheries Center is pursuing lines of research which, if

successful, will provide new and better tools for future studies on assessment of tuna populations. At present two such studies are underway: the first is designed to provide information so that a size-specific mortality index can be applied to existing fishery models. Beginning in summer of 1985, a series of experiments will be conducted at the Honolulu Laboratory's Kewalo Research Facility to determine which biochemical factors measure the time period since last feeding and how time since last feeding affects performance. Measurement of this risk factor(s) in natural populations should permit determination of size-, sex-, or habitat-specific indices of natural mortality. Concurrent studies by workers at the Oceanic Fisheries Resources Division in La Jolla are investigating the effect of using such hypothetical risk factors in conventional fishery models.

The second new study is designed to measure the actual size distribution of the population which supports the U.S. West Coast albacore fishery. Experimental gillnets with known selectivity factors will be used to sample the albacore population. Mathematical transformation of the resulting data, based on the known selectivity factors, will provide estimates of the size structure of the population sampled.

Advances in fishery science require application of current technology both for the collection of data and the testing of fishery model assumptions. Included in this area may be such interesting and promising innovations as a highly-miniaturized fish tag which stores temperature, depth, and light level information for a period of up to two years. This kind of tag, when recovered and read, will provide periodic location information on the fish while it was at liberty. Another tag, currently used in the salmon fishery, could be adapted to identify itself actively when the fish is transferred to the hold of the ship.

Obtaining specific identifying information on a fish and position information from a built-in satellite navigator from every fish captured by the fleet would materially increase tag recovery rates and reliability. However, even when working with conventional data sets, the transfer of advanced mathematical and computer technology will permit cause and effect relationships to be extracted from existing and new data sets which previously resisted such efforts.

The U.S. tuna fishery--supply, harvest, processing, and marketing--is conducted within the world-wide multi-national arena of foreign affairs. Internationally, the U.S. must be prepared to reach agreement on conservation measures, negotiate fishing access to foreign waters for U.S. boats, and bargain for long-term annual benefits. In order to do this effectively, the U.S. negotiators must be informed about the status of the world's tuna stocks and the world's tuna fisheries, a role which is central to the mission of the Southwest Fisheries Center. The collection and analysis of such information on tuna resources and the fishery is essential to the effort to conserve the resource for the benefit of all Americans, now and in future years.

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 presentation of major, on-going activities. 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 Environmental Group at Monterey.

Izadore Barrett, Director
NMFS Southwest Fisheries Center

May, 1985
La Jolla, California

IN SUPPORT OF EXISTING INTERNATIONAL AGREEMENTS

INDO-PACIFIC TUNA

Indo-Pacific Tuna Program Meeting Held in Tokyo

Honolulu Laboratory Director Richard S. Shomura attended a consultative meeting of tuna experts sponsored by the Indo-Pacific Tuna Program (IPTP) in Tokyo, Japan, on March 13-14, 1984. The objectives of the meeting were to determine (1) the types of tuna data needed to support management and development decisions and (2) the availability of tuna data to the IPTP program.

Although there was some discussion on the specific types of data needed to support management and development decisions, the meeting primarily focused on the availability of tuna statistics to the IPTP program. The discussions suggested that IPTP would not be successful in obtaining sufficiently detailed catch and effort statistics for stock assessment analyses, and that the difficulty in obtaining these statistics was associated with negotiating tuna access agreements. It appeared that, at best, IPTP would be able to gather summarized catch and effort data for statistical areas such as those established by FAO. There was unanimous agreement that the only way detailed catch and effort data could be collected was through formal international agreements.

Tuna Stock Assessment Workshop Held in Jakarta

Richard Shomura chaired a tuna stock assessment workshop sponsored by FAO at Jakarta, Indonesia, on August 20-22, 1984. Scientists from the various Indo-Pacific Fishery Commission (IPFC) and Indian Ocean Fishery Commission (IOFC) countries, as well as scientists from several international organizations, participated in the workshop.

The workshop participants reviewed (1) the status of tuna fisheries and related activities in the western Pacific and Indian Oceans, including the purse seine fishery in the western Pacific, tuna fishing access agreements between distant water fishing nations and the south Pacific island governments, the growing tuna industry of Thailand, and increased tuna fishing activities in the Indian Ocean; and (2) the status of tuna stocks, including the South Pacific skipjack tuna, southern bluefin tuna, yellowfin tuna in the central and western Pacific, North Pacific albacore, and South Pacific albacore. The review of the South Pacific albacore stock was based on a paper "Assessment of the South Pacific albacore stock based on changes in catch rates of Taiwan longliners and estimates of total annual yield from 1964 through 1982" (Admin. Rep. H-84-11) by Dr. Jerry A. Wetherall and Marian Y.Y.Yong.

RESEARCH ON ATLANTIC TROPICAL TUNAS AT THE SOUTHWEST FISHERIES CENTER

Research on Atlantic albacore and tropical tunas in support of the United States commitment to the International Commission for the Conservation of Atlantic Tunas (ICCAT) is carried out at the La Jolla Laboratory of the Southwest Fisheries Center. The Center also administers a tuna port sampling program in Puerto Rico, maintains a comprehensive Atlantic tunas data base, facilitates the exchange of data between U.S. and foreign researchers and coordinates general scientific matters involving ICCAT-related research conducted by U.S. scientists.

During the past year, Southwest Fisheries Center scientists Drs. Izadore Barrett, Pierre Kleiber, Norman Bartoo, and Gary Sakagawa participated in the Fifteenth Regular Meeting of the Standing Committee on Research and Statistics (SCRS) of the International Commission for the Conservation of Atlantic Tunas (ICCAT), held October 28 to November 7, 1984, in Las Palmas, Canary Islands, Spain. Immediately following the SCRS meeting, the Commission held its fourth Special Meeting from November 7-13. Sakagawa, head of the U.S. Scientific Delegation, attended the Commission meeting as a technical advisor to the United States Commissioners.

During the SCRS meeting, Center scientists served as rapporteurs, convener of the subcommittee on statistics, and technical experts on tropical tunas and albacore for discussions on the current condition of tuna stocks fished in the Atlantic Ocean.

A list of documents presented to SCRS by the staff of the Oceanic Fisheries Resources Division at the La Jolla Laboratory follows:

Garces, A.G. and E. Weber. Yield-per-recruit analysis of North Atlantic albacore (Thunnus alalunga). SCRS/84/62

Au, D.W.K. Species composition in the Japanese longline fishery off the southern and eastern United States. SCRS/84/75

Foster, T.C. and E.P. Holzapfel. Size and species composition of Atlantic tunas from imports landed in Puerto Rico during 1983. SCRS/84/77

Coan, A.L. and N. Bartoo. Collection of Task I, II and biological data for United States Atlantic Ocean fisheries. SCRS/84/88

Overview of the Atlantic Ocean Tuna Fishery

The tuna fishery of the Atlantic Ocean is undergoing marked changes which are being shaped by events in the Atlantic as well as in other parts of the world. During the past three to five years economic forces, such as the slowing of demand for canned tuna, the rise in fuel prices, the increase in the costs of capital investment and greater competition among vessels, together with the discovery of new productive fishing areas, such as the western Pacific and Indian Oceans, have contributed to altering the world tuna fisheries. The effects of these events on the Atlantic fisheries have heretofore been subtle. This year, however, the effect is quite obvious, so that special note should be taken of the situation.

Most significant for tropical tunas was the relocation of virtually the entire French-Ivory Coast-Senegal fleets (FIS) and part of the Spanish purse seine fleets from the eastern tropical Atlantic to the Indian Ocean to participate in a more profitable fishery there; flag changes to Ghanaian flag in the Tema-based baitboat fleet and the exploitation of large-size fish for economic reasons; and the changes in the pattern of unloading of catches at different ports as vessels adjust to changing market conditions.

The impact of all these events on the stocks in the eastern tropical Atlantic in general will be beneficial as they will allow the stocks an opportunity to rebuild. However, with the reduced fishing and perhaps also with changes in fishing patterns of the remaining vessels, the amount and type of data obtained from the fisheries may not be sufficient for stock assessment purposes or may not be comparable to data collected in previous years.

With respect to temperate tunas, a large part of the longline fleet that fished in the south Atlantic moved to the North Atlantic and Indian Ocean in 1983 in search of better returns. This shift in effort caused the exploitation of the south Atlantic albacore to decline sharply, which will benefit this population. Changes in the pattern of market demand are also affecting bluefin fisheries as medium and large fish are being sought more actively in some areas, in preference to the smaller fish that have been taken habitually.

The SCRS concluded that the stock of yellowfin tuna in the eastern Atlantic was fished near its maximum potential as of 1983. In 1984, nearly 50% of the effective fishing effort transferred to the Indian Ocean and catches from the eastern Atlantic stock have been much lower than the maximum. This should allow the stock to increase.

Bigeye tuna stocks were determined to be nearly fully exploited with existing fishing gears (predominantly longlines) and patterns of fishing. A reduction in fishing effort by surface gears in 1984 is expected, although significant reduction in bigeye tuna catches is not expected.

The stocks of skipjack in the Atlantic were determined to be only moderately exploited with potential for additional catches. Atlantic albacore stocks are nearly fully exploited by current fisheries in the

Atlantic. Some additional catches are possible from the south Atlantic if the surface fishery expands.

The 1983 U.S. Atlantic Tuna Fisheries[1]

In 1983, the United States catch of Atlantic tunas and tuna-like species totaled approximately 11,000 MT. This total is approximately 27 percent lower than the 1982 catch of 15,000 MT.

In 1983, tropical tuna catches totaled approximately 1,000 MT, down sharply from 2,000 MT in 1983. Bluefin tuna catches approached 1,400 MT in 1982, approximately double the 1981 catch. Catches of swordfish dropped in 1983 to 2,100 MT from 3,100 MT in 1982.

Both the United States tropical tuna and bluefin tuna fleets operated under regulations in 1982. The tropical tuna fleet was subjected to a minimum size limit for yellowfin and bigeye tunas. The bluefin tuna fishery was subjected to a minimum size limit and catch limitation.

In addition to fishery data and statistics collection, research was conducted on problems associated with stocks of yellowfin, skipjack, and bluefin tunas and stocks of swordfish and billfishes. Results of research and statistics collected were reported.

SWFC Scientists Participate in ICCAT's Working Group on JuvenileTropical Tunas

Drs. Norm Bartoo and Pierre Kleiber participated in an intersessional SCRS meeting in Brest, France, July 9-20. The Working Group on Juvenile Tunas met to review the current minimum size regulations on yellowfin and bigeye tunas, assess the effectiveness of the regulations, recommend continuance or elimination of the minimum size regulation on bigeye, and evaluate other management measures that could be taken to raise the yield-per-recruit of yellowfin, bigeye, and skipjack tunas in the eastern tropical Atlantic.

The Working Group considered alternative management measures such as time-area-gear closures which could reduce the catch of small fish. The Working Group concluded that because of the mixing of small yellowfin and bigeye with skipjack (which do not need minimum size regulations) and larger yellowfin and bigeye, there are no combinations of time-area-gear which would result in a net increase in catch of the three species in aggregate. It is possible to realize small gains in the catches of

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[1]This information was prepared by members of the staff of the NMFS Southwest Fisheries Center, La Jolla, California, and the Southeast Fisheries Center, Miami, Florida.

yellowfin or bigeye individually, but these will be done at the expense of a decrease in total landings and will likely affect one gear more than others.

The conclusion of the participants is that the current minimum size regulations appear to be ineffective in raising the yield-per-recruit of yellowfin or bigeye tunas. The effectiveness of the regulations in discouraging increased catches of small fish could not be determined. Based on strictly biological considerations the Working Group recommended that the minimum size regulation on bigeye not be extended and also recommended the removal of the yellowfin tuna minimum size regulation.

RESULTS OF SAMPLING 1984 ATLANTIC TUNA CATCH

Foreign-caught Atlantic tunas transshipped to Puerto Rico are sampled routinely for biological information by biological technician Eugene Holzapfel. Data on fork length, weight and species composition of catches are collected. Results of Holzapfel's sampling during the period January 1, 1984 to December 1, 1984, are as follows:

Species	# of samples	# of fish sampled	Tonnage sampled (MT)
Yellowfin			
Purse seine*	15	988	504.7
Baitboat	26	1861	156.4
Longline	0	0	0
Unknown	8	585	313.65
Skipjack			
Purse seine*	10	357	4981.5
Baitboat	21	1072	2753.7
Unknown	5	233	1837.5
Bigeye			
Purse seine*	12	495	506.4
Baitboat	13	441	88.5
Unknown	5	192	37.9
Albacore			
Longline	4	200	831.4
Baitboat	1	50	5.4
Blackfin			
Baitboat	2	73	26.0
Little Tunny			
Baitboat	1	50	408.0

*Also includes 6 yellowfin, 3 skipjack and 5 bigeye tuna length frequency samples from transshipments of catches by French seiners fishing in the Indian Ocean.

During the period of January 1 to December 31, 1984, thirty size composition samples were collected for the SWFC by the Inter-American Tropical Tuna Commission. These data were collected from eight Venezuelan and U.S. purse seiners that fished in the Caribbean Sea and transshipped or landed their catches in Puerto Rico. A summary of these data follows:

Species	Trips sampled	# of samples	# of fish sampled
Yellowfin	10	14	700
Skipjack	9	13	625
Bigeye	1	2	91
Bluefin	1	1	15

Report Summarizes Results of the 1983 Puerto Rico Tuna Sampling Program

Tod Foster, formerly employed at the SWFC as a fishery biologist, and biological technician Eugene Holzapfel recently completed an Administrative Report (LJ-84-25) titled, "Size and species compositions of Atlantic tunas from imports landed in Puerto Rico during 1983." This report summarizes the results of the sampling of more than 9,700 yellowfin, skipjack, bigeye, albacore, bullet, and blackfin tunas for size and species composition in 1983. When compared with samples taken in 1982, the results show that the average length of fish in the imported catches went up 5 cm for yellowfin and albacore, decreased 4 cm for bigeye tuna, and remained the same for skipjack tuna. The percentage of fish in import catches that were less than the minimum size limit (55 cm) for both yellowfin and bigeye tunas was 55%, a decrease of 13% and 1% respectively over percentages in samples collected from the 1982 catches.

IN SUPPORT OF POSSIBLE FUTURE INTERNATIONAL AGREEMENTS

NORTH PACIFIC ALBACORE

Strategic Plan for NMFS Albacore Fishery Program

The North Pacific Albacore fishery research and management program was selected by the Directors of the Southwest Fisheries Center and the Southwest Region as the subject of an intensive review and expanded planning effort after the NMFS Tuna Research Workshop held at San Clemente, California in December 1980. Planning for an expanded albacore program has proceeded in several steps. The first phase was completed in June 1983, when members of the U.S. albacore industry and other invited constituents participated in a workshop at the Southwest Fisheries Center to set forth their desirable goals and objectives for the fishery. The second phase of the planning effort, strategic planning, involved NMFS management determining what NMFS could do to meet those objectives. An Administrative Report (LJ-84-09), "The Strategic Plan for the National Marine Fisheries Service's North Pacific Albacore Fishery Program" summarizes the NMFS strategic plan that was developed by the NMFS management.

The third planning phase focused on developing operational plans and budgets for the various sectors of the research and management program. A report of the planning effort prepared by Dr. Richard Parrish, of the Center's Pacific Environmental Group at Monterey, assisted by staff from the Southwest Region and Center, has been completed, and will shortly be issued as a Technical Memorandum of the Southwest Fisheries Center. As developed, the operational plan wil focus the work of NMFS on three areas: 1) assessment of the size and productivity of albacore stocks in the North Pacific through population dynamics research (collection of fishery statistics, sampling of the fishery, continuation of the albacore log program, aging of albacore, tag and recapture studies, assessment of stocks, etc.); 2) development of information for fisheries advisories which will include exploratory fishing, tagging and tracking studies, and analysis of catch rates in relation to environmental features; and 3) development of markets for the domestic albacore catch through improvement of technology for maintaining the quality of fresh and frozen albacore and the development of alternative albacore products and markets.

The Albacore Operational Plan also included elements which were contributed by the staffs of the Southwest Fisheries Center's Oceanic Fisheries Resources Division, Coastal Fisheries Resources Division, Honolulu Laboratory, the Pacific Environmental Group, and the NMFS Southwest Region. Other inputs to the plan came from industry groups concerned with the North Pacific albacore resources, other NMFS organizational units, and ideas and proposals contained in Saltonstall-Kennedy Grant proposals on albacore.

A meeting with constituents to discuss progress to date and to gather information to update the strategic plan is planned in late October or November, 1985.

The activities and results reported in the following section devolve from specific elements identified in the NMFS Strategic Plan for albacore.

Status of North Pacific Albacore Model

The Albacore Model has been developed at the La Jolla Laboratory by Dr. Pierre Kleiber and associates in order to investigate a variety of theoretical questions concerning the albacore population in the North Pacific and the fisheries that depend on this population. By keeping track of recruitment, growth, migration and death, the model simulates changes in the numbers of albacore of various sizes and at various locations in the North Pacific. The model also simulates the numbers of albacore caught at different sizes by the Japanese baitboat fishery, the Japanese longline fishery and the American jig fishery.

The model now operates on a Stride 440 microcomputer. It displays animated histograms on the computer screen showing both the state of the population in different regions of the North Pacific and the rates of migration between the regions.

Using this model investigations are conducted on how sensitive the albacore population might be to various kinds of environmental fluctuations. Presently, Kleiber and associates are also addressing the question of fishery interaction, that is, "How much does the activity of one fishery affect fishing success in other fisheries?" The model is also used to document sources of error in simpler analytical models that are standardly used for assessing the status of fish populations.

Summary of the 1984 North Pacific Albacore Fishery

The 1984 albacore catch by U.S. vessels fishing in the North Pacific is estimated at about 15,500 short tons. This total is slightly above the ten-year average of about 15,000 tons and nearly double the catch landed in 1982 which was about 7,650 tons. Several factors contributed to the increased catch in 1984 including oceanographic conditions, relatively good weather overall, and a stable market for fish-buying by processors. Another factor contributing to the high 1984 albacore landings were catches made by the southern California purse seine fleet which are estimated to have been about 3,600 tons. This is one of the highest purse seine catches on record and resulted from unusually high surface availability of albacore in the Cortes Bank - 60 Mile Bank area for about a five week period during July and August.

Sports fishing for albacore in waters off southern California was one of the best on record. According to California Department of Fish and Game the number of albacore caught by sports fishermen aboard California partyboats was 181,836, the highest in 37 years.

Albacore arrived in waters south of Point Conception a little over one month earlier than usual and good catches were made until mid-August. After that time jig catches dropped to virtually nil; however, some baitboats continued to make good catches throughout much of the season. The drop off in catches after mid-August in waters off southern California was related to warm upper layer ocean temperatures residual from the recent EL Niño. The fishery shifted to waters north of Point Conception to about Eureka where much of the seasonal catch was taken. The fishery operated in

this area where favorable ocean conditions and moderately good weather conditions prevailed through October. Only spotty catches were made off the Pacific Northwest, except for the area centered about 1000 miles off southern Oregon where a large fleet of boats made high catches for a number of weeks during August and part of September. Fishing in the central North Pacific was termed "average" by fishermen who operated there.

Areas fished included the traditional fishing grounds off the U.S. west coast, areas north of Hawaii, and areas in the western Pacific. The average length of albacore measured was 66.1 centimeters (13.1 lbs). Approximately 84% of the fish measured were taken from jigboats. Estimated catch-per-unit-effort (CPUE) for the standard 45-foot (14-meter) jigboat in 1984 was 82.0 fish per day. Highest CPUEs for the year (127 fish per day) were reported during the first half of July in inshore areas off San Diego. Total sampled effort (days fished) for the season was 10,321 days. Approximately 77% of the effort (7,956 days fished) was spent inshore (areas east of 140°W longitude) yielding 77% of the catch.

Much of the above information was summarized 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-85-14, "Summary of the 1984 North Pacific Albacore Fishery Data." More than 400 copies of these reports were sent out to participating fishermen. Another 500 of these summary reports were 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.

U.S. Exploratory Longline Fishery Development for Albacore

The American Fishermen's Research Foundation (AFRF) in cooperation with the SWFC continued to conduct exploratory longline fishing operations for albacore tuna during winter 1984-85. Fishing results from the exploratory fishing operations indicate that the U. S. albacore fishery can be extended to operate during winter months using longline fishing methods in an area where the fleet has not traditionally fished.

The F/V Resolute, on fuel subsidy from Saltonstall-Kennedy (S-K) funds awarded to AFRF, conducted fishing trips during November-December 1984 and January-February 1985. The vessel made sets from approximately 600 to 1,400 miles west and west-southwest of Point Arguello, California. The albacore catch for 21 longline sets made in November-December ranged from 3 to 139 per set and averaged 73 per set. The mean catch rate per 100 hooks was 7.2 for albacore and 7.5 when bigeye tuna, yellowfin tuna and skipjack were included. The mean catch rate of 7.5 tuna per 100 hooks is higher than the catch rate for any charter/fuel subsidy vessel that has participated in this study. The average weight of the albacore which was 22 pounds, range 5-77 pounds, is nearly 10 pounds heavier than the average weight of albacore caught by jig fishing during the summer albacore fishing season in waters along the coast of North America. The number of hooks set ranged from 239 to 1,425 per set and averaged a little over 1,000 per set at a targeted depth of 200 feet in and about the thermocline. A few scattered albacore were also caught by trolling while the vessel was in

transit to the longlining area. Totals of about 36,000 pounds of albacore and 4,000 pounds of bigeye, yellowfin and skipjack were caught.

In January-February the albacore catch for 23 sets ranged from 0 to 86 per set and averaged 32 per set. The mean catch rate was 2.8 albacore per 100 hooks and 3.1 tuna per 100 hooks when bigeye, yellowfin and skipjack were included. The average weight of the albacore was 13 pounds and ranged from approximately 6 to 45 pounds. The numbers of hooks set ranged from 643 to 1,435 per set and averaged slightly more than 1,100 hooks per set. The targeted depth was in or about the thermocline which varied between 320 ft. and 550 ft. As in November-December, a few albacore were caught on trolling gear while in transit to and from the longline fishing area. Totals of about 10,000 pounds of albacore and 5,000 pound of bigeye, yellowfin and skipjack were caught.

The Resolute made use of several modifications in gear and operating methods that have been developed during the albacore longline fishery development study. These included alterations to reduce gear tangling and the use of an all monofilament longline. The adoption of these procedures resulted in a significant increase in catch rate, a significant decrease in fish loss, and a reduction in labor to set and retrieve the gear.

Cooperative Research Studies with Albacore Fishing Industry

The SWFC continued to conduct other cooperative research studies during the past year with the AFRF. The cooperative research activities, which began in 1971, have been extremely fruitful and have yielded considerable new information and understanding concerning the North Pacific resource. Activities conducted during the past year included (1) albacore tagging and release operations in the central and eastern North Pacific, (2) exploratory longline fishery development for albacore in the eastern Pacific, (3) collections of concurrent oceanographic and fishery data, and (4) collection of specimens, tissues, and organs for biological studies of albacore.

In addition to the work with AFRF, much cooperation was received from the San Diego Sports Fishing Association who provided space aboard sports fishing charter boats operating out of San Diego for collecting albacore and other tuna blood samples and conducting biological experiments.

Cooperative research activities planned with AFRF during the upcoming year include continuation of the work noted above plus an experiment to investigate the role of water clarity in the aggregation of albacore, and presumably other tunas, in the vicinity of upwelling boundaries. The experiment will involve use of the NOAA ship, R/V David Starr Jordan to conduct oceanographic observations including water optical characteristics, a fishing vessel chartered by AFRF to conduct acoustic tracking of individual free-swimming albacore, and ocean color measurements made by the Coastal Zone Color Scanner (CZCS) aboard the NIMBUS-7 satellite and possibly by an aircraft.

Albacore Fishery Advisory/Information Services

In 1984 the staff of the Coastal Eastern Pacific Fisheries Environmental Investigation at the La Jolla Laboratory program continued to provide information to the albacore fleet and interested parties.

Information was regularly distributed in three forms: (1) A Daily Albacore Fishing Information Broadcast transmitted over commercial AM and FM radio and on single-sideband, (2) An Albacore Fishing Information Bulletin mailed out twice a month, and (3) Satellite color imagery of fishing areas sent by radio-facsimile transmitter on single-sideband.

The Daily Albacore Fishing Information Broadcast contains information on albacore catches, sea surface temperature, weather and marketing conditions. This information is compiled daily (on weekdays) from fishing vessel radio reports, scientists and port samplers of state fisheries agencies, fish buyers, oceanographic research cruises and fishermen. The daily information is condensed into a 1 1/2 to 2 minute verbal report which is transmitted by telephone for taping by five commercial AM and one FM radio stations, which transmit the broadcast mornings and evenings Monday through Friday and Saturday morning. The NOAA radio station WWD also transmits the report over two single-sideband frequencies twice daily. In 1984 the first broadcast was on July 2 and the final one on October 5, for a total of sixty-five separate broadcasts or 4,550 transmissions of information.

The Albacore Fishing Information Bulletin is a summary of the fishing information and oceanographic conditions from the previous 15 days and outlook for marine weather conditions. The writing, printing and mailing of the bulletin are accomplished quickly so that it is in the mail within 48 hours of the last fishing information included, arriving in time to be of practical as well as historical use. The Bulletin is sent on the 1st and 15th of each month during the albacore season, with the first one containing the forecast of albacore fishing for the season. The distribution list presently numbers 750 persons, including fishermen, scientists, fish buyers and processors, industry representatives and politicians. In 1984 the first bulletin was sent out on June 15 and the eighth and final bulletin on October 15.

The SWFC's Environmental Fisheries group also worked in cooperation with a NASA/NOAA effort to provide fishermen with color imagery showing coastal frontal boundaries known to aggregate albacore. We provide the satellite receiving personnel with information on fishing areas over which to collect CZCS satellite passes, and aid in the transformation of the processed color image to a line drawing depicting color boundaries which is suitable for radio-facsimile transmission to the fishing fleet. Turnaround time from reception of the satellite pass to transmission to the fleet is kept to 24-36 hours in most cases. NOAA radio station, WWD, transmits the boundary chart twice a day for the following five days in conjunction with other weather and surface analysis products. In 1984 several charts were produced throughout the season.

In addition to the three main information services, Dr. Laurs and his staff provide information and answers for an almost continuous series of requests by phone and mail for fishing information. Information on North Pacific albacore is also presented to fishermen at seminars and workshops. During the past year Dr. Laurs gave several presentations on the results of recent albacore research studies and the outlook for the fishing season to fishermen's groups, including the General Membership meeting of the Western Fishboat Owners Association in Las Vegas, Nevada, several presentations at the Board of Directors meetings of the American Fishermens Research Foundation, and the San Diego Sportfishing Association.

Spatial Variation in Albacore Feeding Relative to Surface Environmental Features Observed by Satellites

Dr. Michael Laurs and associates in their 1984 paper demonstrated that fishable aggregations of albacore tuna are found just offshore of the color/temperature front at the edge of productive California coastal waters in late summer. Theories of researchers here are that this distribution pattern may be related to the feeding habits of albacore.

From August 15 to September 1, 1983, albacore, skipjack, and yellowfin tuna, and bonito were sampled off central and southern California during a cruise conducted by scientists of the Oceanic Fisheries Division. From August 8-25, 1984, albacore were sampled off southern California by biologists working on albacore population dynamics. Technician Hannah Bernard analyzed the stomach contents of fish caught in 1983 and is beginning the same task on stomachs from fish taken in 1984 (see below).

Oceanographer Paul Fiedler processed CZCS and Advanced Very High Resolution Radiometer imagery which showed that some albacore in 1983 were caught very near the oceanic/coastal water boundary, while others were caught farther offshore in warm, blue oceanic water. Fielder and associates are now trying to relate variations in gut fullness and diet composition to the distribution of the fish. Results obtained in 1984 will be analyzed by the same method. Both 1983 and 1984 were years of El Niño off California, so this study is expected to yield insight into the effects of this major oceanographic and weather perturbation.

Age Structure of Albacore Population Investigated

Fishery biologists David Holts, Earl Weber and Norm Bartoo of the Oceanic Fisheries Resources Division at La Jolla have recently analyzed the results of their gillnet sampling experiment conducted in August 1984. The aim of their research was to provide an unbiased estimate of the size structure for the local albacore population using passive fishing gear.

The Pacific albacore is harvested by several fisheries, and the fisheries catch different sizes of fish and use different types of fishing gear. To date, the only measure of the size structure for this population is that derived from the commercial troll and baitboat catches. These gears do not provide an unbiased sample of the underlying population from which they are taken. In the experiment, gillnets, a less selective gear, were used to sample the population.

The sampling plan included chartering the commercial gillnet vessel, Steel Fin II, to set and retrieve the specially designed gillnets. These nets consisted of several different mesh sizes from 4 to 10 inches (in one inch intervals) and were fished in various depth strata from the surface to below the thermocline. A total of 12 night and 2 daytime sampling sets were made at depths from 1 to 20 meters. Time needed for retrieval was approximately three to six hours, depending on the number of fish caught and sea conditions. The length of the set averaged 11.3 hours.

The gillnet catch included 454 albacore, 276 skipjack tuna, two bigeye tuna and several incidental species. The F/V Steel Fin II also sampled the population using the commercial trolling gear to compare catches from the gillnets. This produced 513 albacore and 155 skipjack. Although the gillnet captured a slightly wider size range of albacore, both gears appeared to capture one main size class.

The horizontal and vertical catch distribution within the net varied in several ways. Generally the catch tended to be clumped or grouped into one or more sections of the net. Often fish would be hauled aboard in groups of three or more and long sections between the groups would be empty. The fish were rarely scattered throughout the net. Groups within each set also tended to be located at similar depths in the net. With only one exception all catches came from above the steepest part of the temperature break in the thermocline. In addition to albacore and skipjack tuna, there were 11 other species of fish taken by gillnet (Table 1).

Table 1. Incidental catch taken in gillnet.

Bigeye tuna	Thunnus obesus	2
Bullet mackerel	Auxis rochei	13
Pacific mackerel	Scomber japonicus	12
Jack mackerel	Trachurus symmetricus	8
Swordfish	Xiphias gladius	5
Blue shark	Prionace glauca	332
Bigeye thresher	Alopias superciliosus	1
Bonito shark	Isurus oxyrinchus	34
Scalloped hammerhead	Sphyrna lewini	5
Pacific pomfret	Brama japonica	5
Louvar	Luvcrus imperialis	3

There is no way to estimate fish loss due to sharks, although net damage was heavy during some sets. Several fish were recovered from the net which had been badly mauled by California sea lions (Zalophus californianus). The sea lions were observed during two sets. No sea lions were tangled in the net.

This study shows that gillnets are a useful sampling tool for albacore and that it is possible to quantify the effects of gear selectivity with adequate sampling results. With an increase in sampling stations, an adequate sample size can be obtained that will allow for a rigorous statistical analysis. This in turn can provide an unbiased estimate of the age structure of the local albacore population.

Results of Tuna Food Habits Study Presented at CalCOFI Meeting

Hannah Bernard, Biological Technician at the La Jolla Laboratory, presented preliminary results of a food habits study of scombrid fishes at the annual CalCOFI Conference in October. Skipjack (Katsuwonus pelamis) (n=31), Pacific bonito (Sarda chiliensis) (n=42) and albacore (Thunnus alalunga) (n=94) were collected with troll gear off the coast of southern California during cruise 166 of the NOAA Ship David Starr Jordan in August and September 1983.

Crustaceans (especially euphausiids) appeared more frequently and in greater numbers in the stomachs of bonito and skipjack than in albacore stomachs.

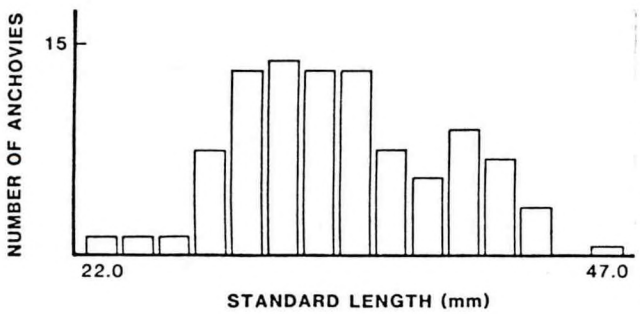

Figure 1. Length-frequency distribution of northern anchovy (Engraulis mordax) obtained from gut content analysis of 85 albacore caught during August-September 1983, off the coast of southern California.

The primary prey item in the diet of albacore was fish. An Index of Relative Importance (IRI = sum of percent number of prey and percent volume of prey multiplied by the percent frequency of occurrence of the prey) was calculated for prey items in the diet. The results showed that northern anchovy was consumed almost as much in quantity and frequency as all other fish species combined (IRI for anchovies = 7360.32; IRI for all other fish = 8061.76). Young-of-the-year anchovy (mean standard length of 33.6 mm, S.D. = 4.97, range = 22.0 - 47.0 mm) were found exclusively in the diet (Figure 1).

Effects of Weather Conditions on Albacore Catch Rates Studied

Albacore fishing operations are subject to weather conditions. Oceanographer Paul Sund of the Southwest Fisheries Center's Pacific Environmental Group, to inveestigate in how variations in weather affect monthly and annual catch rates. He has been attempting to develop a wind-fishability index. Such an index could be used as input to albacore modeling studies to investigate the effects of the weather on the interpretation of catch-effort. Recently, Sund studied information provided by members of the Western Fishboat Owners Association (WFBOA) on windspeeds at which they stop fishing.

Sund found that larger vessels were able to fish in higher winds, although there was a high degree of variability. This variability is not unexpected because the estimates of windspeed are subjective (few boats have instruments to measure windspeed), and because the reports came from vessels of varying characteristics, construction and sea-keeping and from operators with varying tolerances to weather and sea condition.

Sund also found that there appeared to be about a five-knot difference in windspeeds at which operations were stopped, depending on whether the boats were engaged in fishing or not. A further five-knot difference occurred between the speed at which operations would stop while not fishing and the windspeed at which it was felt that no operations at all were possible. The baitboat reports received indicated that all fishing operations ceased at windspeeds of 35 knots. Jig fishing appeared unaffected by winds up to about 20 knots, and in a few cases fishing occurred in winds as high as 65 to 70 knots.

Overall, in the Northeast Pacific, winds above 30 knots occur only about 3% of the time, yet, if fishing truly were not affected by winds below 30, windspeed statistically would not be a significant factor limiting fishing. The general perception seems to be, however, that weather conditions do indeed sometimes significantly affect catch rates. To further investigate this apparent paradox, alternative data sources were obtained. These included charter fishing vessel day logs, the Navy climatic atlas, and climatologies of computed winds at times and places where fishing stopped. These sources indicate that winds can begin to affect fishing at speeds as low as 10 to 15 knots and that when winds reach 35 to 40 knots almost all fishing is stopped.

Commercial Passenger Fishery for Albacore Reviewed

David Holts, Fishery Biologist at the La Jolla Laboratory, recently completed a review of the commercial passenger fishing vessel industry for Pacific albacore (Thunnus alalunga). In his review, Holts discusses the fishing vessels that are provided by the industry to recreational fishermen who want to fish offshore or in remote areas. These vessels include charterboats for hire by individuals or groups as well as partyboats with a first come, open seating policy. Both types of vessels normally go out for one- or two-day trips. Trips of three to five days are also common in southern California where the vessels are large and often very comfortable, if not luxurious. On the average, over 20,000 angler trips per year are logged by west coast albacore anglers in the fishery; their catch represents about 2% of the U.S. commercial catch in the north Pacific.

The catch of Pacific albacore makes up a significant portion of the catch in the southern California sport fishery during the summer and fall months. Normally albacore begin moving into coastal Mexican and southern California waters in June, as the waters warm to 15-18°C, and catch rates peak in late July and August. Above Pt. Conception and north to Washington, albacore are present normally from mid-July through early September. The fishery in this area focuses more on Pacific salmon and less on albacore.

Chromosomal Analysis Completed for Albacore, Yellowfin and Skipjack Tunas

Chromosomal analysis is being used as part of an investigation of the population stock structure of the North Pacific albacore, Thunnus alalunga.

Dr. Michael Laurs, Dr. Frank Ratty, San Diego State University (SDSU) and Dr. Y.C. Song, SDSU and Wuhan University, Peoples' Republic of China, have completed a chromosomal analysis for albacore from the proposed North Pacific southern substock and compared the results with similar results they obtained for yellowfin tuna (Thunnus albacares) and skipjack (Katsuwonus pelamis).

The diploid chromosome numbers of albacore, yellowfin, and skipjack tunas were found to be 2N=48. The chromosome morphology of the albacore is more similar to that of the yellowfin than the skipjack. The albacore and yellowfin have three pairs of biarmed chromosomes and 21 pairs of uniarmed chromosomes while all of the skipjack chromosomes are uniarmed. C-banding showed variability in comparable chromosomes. The results support placing the albacore and yellowfin in one genus (Thunnus) and the skipjack in another (Katsuwonus).

These results are from part of a larger study to determine if genetic heterogeneity exists in the North Pacific albacore population. Information on chromosome characteristics is scarce for fishes and this appears to be the first time chromosome analyses have been reported for scombrid fishes.

mtDNA of Albacore from Different Ocean Basins Studied

At the La Jolla Laboratory, Dr. John Graves is analyzing the mitochondrial DNA (mtDNA) of albacore to determine intraspecific stock structure. In order to obtain mtDNA in its intact (closed circular) form, Graves developed a new approach for treating and preserving albacore tissue samples. Using Pacific mackerel as an albacore model, Graves analyzed a series of mackerel tissues under a variety of rinsing and freezing regimes to determine which tissue type/rinse/freezing regime produced the greatest yield of intact mtDNA.

The results indicate that ovarian tissue produces the greatest yield of mtDNA. This is probably because mature ova have about 3,000 times the number of mitochondria, one-half the amount of nuclear DNA and fewer nucleases (DNA degrading enzymes) than other cells.

Graves examined the magnitude of mtDNA differentiations between albacore from different oceans. In an analysis of the mtDNA from 10 albacore caught off San Diego and 6 albacore which had been caught off Cape Town, South Africa, Graves found that no significant nucleotide sequence differentiation was demonstrated between the mtDNAs of the fish from different ocean basins. Graves used 17 restriction endonucleases to survey more than 250 nucleotide base pairs, or approximately 1.5% of the mtDNA molecule. The data indicate that there is sufficient gene flow between albacore of all ocean basins on an evolutionary time scale to prevent genetic differentiation. Consequently, any stocks identified for management purposes will have to be based on non-genetic criteria.

IN SUPPORT OF

DOMESTIC REQUIREMENTS

1984 U.S. TUNA TRADE SUMMARY

Introduction

For the U.S. tuna industry, 1984 was a year of frustration and disappointment. As the year ended only one continental U.S. tuna cannery remained in operation, Pan Pacific Packers located at Terminal Island, California. Van Camp, San Diego, California and Starkist, Terminal Island, California shut down their mainland tuna processing operations in favor of lower cost production at offshore sites located in American Samoa and Puerto Rico. The closure of the Van Camp and Starkist canneries left approximately 2,400 cannery workers without jobs, and severely affected those businesses supplying the canneries with goods and services. One group in the latter category consists of U.S. tuna vessels that have traditionally relied on the canneries located in California to purchase their catches.

With the tremendous reduction in California canning capacity, and a 20% to 30% decline in ex-vessel prices during 1984, vessels participating in the U.S. tuna fishery found themselves in a desperate economic situation. While many of the larger, more mobile, U.S. flag vessels were able to survive 1984 by operating throughout the Pacific and delivering their catches to offshore sites, the cannery closures and depressed ex-vessel prices forced a significant number of California based vessels out of the fishery. Several were sold or chartered to foreign interests, and a few were even converted for operation in the north Pacific trawl fisheries. While the impact of these events will probably extend well beyond 1984, the U.S. tuna fleet which numbered more than 109 active vessels at the beginning of 1984 was down to 102 active vessels by the end of the year.

According to the U.S. tuna industry, foreign competition was the most significant factor contributing to the cannery closures and economic problems of the U.S. fleet during 1984. From 1979 through 1984 the amount of canned tuna imported into the U.S. more than tripled, increasing by almost 40 percent between 1982 and the end of 1983 alone. This increase has consisted almost entirely of tuna canned in water which has surpassed tuna packed in oil in popularity among U.S. consumers, and is subject to a much lower import tax than tuna packed in oil. The problem of canned imports was considered severe enough to prompt various segments of the industry (vessel owners, processors, and cannery workers) to join together and petition the U.S. International Trade Commission (I.T.C.) for tariff relief from imports of canned tuna packed in water. While the I.T.C. acknowledged that the U.S. tuna industry was facing difficult times, it decided that the substantial increases in imports of relatively low-cost tuna canned in water, while a contributing factor, were not the primary cause of the industry's current economic plight. Rather, the majority of Commissioners found that overinvestment in boats, plants and inventories during a period of exceptionally high interest rates was just as important, if not more so, in terms of bringing about the industry's present economic condition. This finding thwarted industry's bid to erect trade barriers limiting the flow of canned tuna imports into the U.S. A subsequent attempt by the industry to have the U.S. Congress enact protective tariff legislation also failed.

With the cannery and vessel dislocations that occurred during 1984, domestic cannery receipts[1] of imported and domestically-caught albacore and tropical tunas (skipjack, yellowfin, blackfin, bluefin and bigeye tuna) were slightly below those for 1983. The total volume was 524,028 short tons (tons) a decrease of less than 2% from 1983, which is also 8% below the 1979-1983, five-year average volume of annual cannery receipts. Domestically-caught cannery deliveries amounted to 254,581 tons 11% below the 1983 level but 3% above the 1979-1983 average. Imports made made up the 269,447 ton balance in total cannery supplies for 1984, a 9% increase in raw tuna imports from 1983, but 16% below the 1979-1983 average.

A significant occurrence in 1984 was the increase in deliveries of U.S.-caught tropical tuna to foreign canneries. Vessels of the U.S. fleet landed 29,570 tons of tuna for export, most of which was transshipped to European canneries. This compares to only 583 tons exported in 1983, and a 1979-1983 average of 2,888 tons. When domestically-caught raw tuna exports are combined with domestically-caught deliveries to U.S. canneries total U.S. deliveries amounted to 284,151 tons for 1984, less than 1% below the corresponding amount for 1983. The surge in U.S. exports indicates the internationalization of tuna trade in general, and more specifically what is expected to be an increased reliance of U.S. vessels on foreign markets.

The western Pacific Ocean[2] continued to be the most productive tuna fishing area for U.S. vessels during 1984, accounting for 188,000 tons, or 66% of total domestically-caught U.S. cannery receipts and U.S. exports of raw tuna by oceanic area. This represents a 10% increase from 1983, and is three times the 1979-83 average volume of annual domestically-caught cannery receipts and raw tuna exports from this area.

Despite the loss in west coast processing capacity and intense competition from foreign producers, resulting in a record level of canned tuna imports, overall U.S. canned tuna production in 1984 rose 4% from 1983. Total volume was 31,045 thousand standard cases[3], 3% above the 1979-83 average total annual volume. When canned imports are combined with U.S. production, the total addition to U.S. canned supplies was 39,369 thousand standard cases for 1984 which is 8% above 1983 and 15% above the 1979-83 average annual additions to canned supplies.

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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]The eastern and western Pacific are distinguished at 150°W longtitude.

[3]As used here, a standard case contains 48, 6.5 ounce cans of chunk style tuna for a case weight of 19.5 pounds.

Increased competition between foreign and domestically produced canned tuna has favored U.S. consumers. The retail composite canned tuna price which decreased nearly 7% during 1983, fell an additional 3% in 1984. The downward price trend has contributed to corresponding growth in overall consumption which increased 2% in 1984, following an increase of 7% for 1983. Water packed products led sales in all categories during 1984, with a gain of almost 10% from 1983. Since water packed items account for more than 60% of toatl sales, this increase helped offset reduced sales of light tuna in oil and health oriented canned tuna products which occurred in 1984.

Structure, Operations and Performance of U.S. Albacore Fleet Investigated

Industry economist Sam Herrick at the Center's La Jolla Laboratory reports that he and fellow economist Kevin Carlson recently completed a manuscript entitled, "Vessel characteristics and performance of the North Pacific albacore fleet coastwide summary data base, 1974-1976." The manuscript provides baseline information on the structure, operations, and performance of the harvesting sector of the north Pacific albacore fishery based on data contained in the Coastwide Data Base (CWDB), a comprehensive landings database for all vessels active in west coast fisheries from 1974-1976.

The report describes the characteristics, fishing operations and landings of those vesels in the U.S. fleet that were active in the fishery between 1974 and 1976. During this period over 4,500 vessels landed albacore in the states of Washington, Oregon, and California, and the value of their albacore landings averaged over $18 million annually. Using the CWDB, it was possible to select a subset of the vessels that were active in the albacore fishery and for which albacore contributed significantly to their economic well-being. These vessels were then collectively described and analyzed in terms of their fishing operations and corresponding landings. The CWDB also allowed the short-term dynamics of the fleet to be examined.

Results of analysis suggest that there is no single representative vessel in the albacore fleet. Different vessels land many alternative species; most vessels that land albacore also participate in the chinook - coho salmon and groundfish fisheries, and the high ex-vessel revenue vessels participate in the other tuna and dungeness crab fisheries. Given a certain size vessel and ports of operation it is possible to describe a typical albacore vessel using the CWDB as summarized by the Panel fleet.

In general, an albacore vessel from the CWDB is between 35 and 54 feet long, uses troll gear and often lands chinook - coho salmon or groundfish. For the years 1974-1976 average albacore landings for such a vessel was 14.5 tons and accounted for 51% of its total annual fishing revenues. This vessel generally lands fish at two distinct port areas.

Financial Analysis of U.S. Troll Vessels Participating in the North Pacific Albacore Fishery Underway

A trip cash flow model has been constructed by Dr. Sam Herrick, Industry Economist at the La Jolla Laboratory for U.S. troll vessels participating in the North Pacific albacore fishery. In the model, revenue and cost elements for an albacore fishing trip were analyzed using an electronic spread sheet.

Cost equations relating catch and cost elements to a vessel's physical characteristics were derived using cost and earnings data, and catch and effort data were provided by 57 vessels that participated in the North Pacific albacore fishery during the years 1976-1982. Hold capacity was found to be the most significant physical characteristic in explaining a vessel's daily catch rate while fishing and daily fuel consumption while at sea. The catch rate and fuel consumption relations were then used to predict the vessel's respective gross revenue and fuel cost for an albacore fishing trip of specified length. Galley, gear and labor costs were also estimated for the trip. The model predicts the net cash flow for a trip of given length for a particular vessel, which is described by its physical characteristics.

Results from the model were then used to derive cost functions that relate the cost per ton of albacore caught to the level of catch. The cost functions were in turn used to conduct a break-even analysis, which determines the level of albacore catch necessary for a vessel to just cover its fishing trip costs.

Results of exercising the model suggest that, in 1982, the break-even catch for vessels greater than 40 tons hold capacity was approximately 45 tons; for vessels of 40 tons capacity or less the break-even tonnage was approximately 5 tons. Catches greater than these amounts would result in a positive contribution to the vessel's fixed costs of fishing.

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 National Marine Fisheries Service in cooperation with the International Game Fish Association; James Squire, fishery biologist at the NMFS Laboratory in La Jolla, California, coordinates the Pacific program, as he has from its beginning.

World Trend in Billfish Catches

The worldwide catch of billfish and other species of fish and shellfish is recorded annually by the United Nations Food and Agriculture Organization (FAO). These catch records are published by FAO; the most recent summary includes information on catches through 1982.

In the early years of the tagging program major emphasis was placed on tagging striped marlin about the southern tip of Baja California, Mexico and from the major ports along the west coast of Mexico. Also, the tagging of black marlin off the coast of Queensland, Australia in cooperation with the Cairns Game Fish Club was an important part of the program. This activity in Australia is now fully supported by the New South Wales Fisheries, Sydney, Australia; the tagging program is directed by Dr. Julian Pepperell. The NMFS has supported tagging by New Zealand anglers by providing supplies.

With the support of the National Coalition for Marine Conservation (Pacific Region), increased emphasis in now being placed on the tagging of striped marlin off southern California. In 1983, 225 striped marlin were tagged off southern California. As a result of the 1982-1983 El Niño condition, catches increased in the northwestern sector of southern California. In 1984, catches again increased in the northwestern sector of southern California and 198 striped marlin were tagged off southern California. Increased catches were made in the more usual fishing areas such as around Catalina Island.

In 1984, 848 billfish were reported tagged and released, 366 fewer than the number tagged in 1983. Tagging of blue marlin increased in 1984; 23 blue marlin were reported tagged about the Hawaiian Islands.

Tag Recoveries in 1983--Pacific Area

Nine billfish tags were returned to Squire at the Southwest Fisheries Center in 1984, a decrease from 21 fish recovered in 1983. All billfish tag recoveries were from striped marlin. One of the longer recoveries was from a striped marlin tagged and released near Santa Rosa Island in

September 1983 and recovered by a Hawaiian longliner east of Maui in June 1984.

Early in 1985, information was received from Japan on the recovery of a black marlin. A 130-pound black marlin was tagged and released off Cabo San Lucas in January 1983 by a Monsieur J.P. Carlier of Paris. This marlin was recaptured by a Japanese longliner 613 miles northeast of New Zealand in September 1984. The fish traveled (straight-line distance) about 5,670 nautical miles in its migration from the northern hemisphere to the southern hemisphere and across the Pacific Ocean. According to Squire who has consulted with other experts, this is the longest distance on record traveled by a tagged billfish.

The world commercial production of billfish appears to be holding steady at a catch level of 94,000 to 97,000 metric tons. This figure is near the previous high recorded in 1965 of 115,000 metric tons. Although the total world production of billfish has held relatively steady, there has been considerable variation in catch in some of the fishing areas. Since 1975, Pacific billfish catches have remained relatively steady with the exception of the catch of Pacific sailfish which showed a considerable decline in total catch after 1975. However, 1982 catches are about at the same level as catches before 1975.

Substantial declines in catch were recorded in the mid-1960's for striped marlin and in the early 1970's for blue marlin. Blue marlin catches have increased slightly to about 18.5 thousand metric tons in 1982. Total catches of black marlin and swordfish catches have remained steady; 1982 catches of swordfish were 16,000 and black marlin were 3,000 metric tons.

Of particular interest to U.S. anglers who fish in the eastern Pacific is the trend in catch for striped marlin and sailfish. These species became target species for the longline fishery starting in the early 1960's. The longline fishery off Baja California was and is focused on striped marlin and swordfish. Off the central west coast of Mexico south to Central America large catches of sailfish were made in the mid-1960's. Catches of striped marlin in the eastern central Pacific peaked in 1965 at about 16,800 metric tons. Catches declined rapidly until about 1972, and 1982 catches were about 4,300 metric tons. Sailfish catches peaked in 1965 at about 9,500 metric tons and declined to a mere 2,500 metric tons in 1982.

1972 MARINE MAMMAL PROTECTION ACT

In implementation of the Marine Mammal Protection Act (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.

Major activities conducted by the staff of the Oceanic Fisheries Resources Division in 1984-1985 included (1) the completion of reviews by panels organized to examine the Center's research related to the status of stocks of dolphin and (2) the beginning of planning for an expanded program to monitor abundance of dolphins using research vessels and aircraft. A total of 27 manuscripts documenting results of analyses and 10 reports of panel meetings were completed during the past year.

In its 1983 reauthorization of the Marine Mammal Protection Act (MMPA), Congress called for an expanded stock monitoring program. The Division staff began activities to design a program to use research ships to collect data for monitoring population size. Factors addressed in developing the design included season, survey area, stratification of area and allocation of searching effort to strata. The number of ships required, use of helicopters to augment data collection and interpretation, and consistency of survey methods over time were considered. Analytical models incorporating these factors were developed and used to determine levels of precision required to detect different levels of population decline.

A review panel of scientific experts, consisting of members from the Marine Mammal Commission, the Inter-American Tropical Tuna Commission, the Porpoise Rescue Foundation, the Environmental Defense Fund, and North Carolina State University, was formed to assist the Division in reviewing the results of the models. Based upon the panel's advice, the Division staff is in the process of preparing a design for monitoring dolphin stock abundance in the eastern tropical Pacific with research vessels.

Biological research on dolphins of the eastern tropical Pacific also continued with studies of age determination and growth, reproduction, bioenergetics, and stock relatedness. The validity of growth layer groups in teeth is being tested using known-age and tetracycline-labeled specimens. Teeth from female dolphins are being examined for parturition marks and other layers that may be used to estimate frequency of pregnancy.

Age and sex segregation of the spotted dolphin are being investigated by examining material from animals in single schools. Computer simulation modelsare being developed to compare the bioenergetics of spotted dolphin and yellowfin tuna in the eastern tropical Pacific as part of an investigation to identify the basis for the association of tuna and dolphin. Work is also progressing on the use of recombinant DNA to estimate relatedness among and between racial stocks of dolphins in the eastern tropical Pacific.

Optimum Season for Dolphin Sighting Surveys Reviewed

Drs. Steve Reilly, Operations Research Analyst, Doug DeMaster and Rennie Holt recently completed a review of average weather conditions which are prevalent at different seasons in areas of the eastern tropical Pacific Ocean in which dolphin sighting surveys are conducted. The review consisted of compiling data on average sea state and frequency od hurricanes.

The review was prompted by the recent reauthorization of the Marine Mammal Protection Act which mandates a four-year program for monitoring the abundance of dolphin. The program emphasizes shipboard surveys to estimate relative abundance on an annual basis as opposed to the more expensive aerial surveys used in previous years to estimate absolute abundance. In order to conduct shipboard surveys, it is necessary to evaluate which season is the most favorable for conducting surveys.

Previous surveys have shown that the efficiency of dolphin sighting decreases markedly when white caps become prevalent, which occurs at sea state Beaufort 4 and above. The frequent occurrence of sea states of Beaufort 4 and greater in the area west of 12°W longitude and north of the equator has been a continuing problem during previous surveys which had been conducted in the winter. The optimum time for the four-month surveys was found to be mid-August to mid-December.

Guidelines Completed for Reducing Dolphin Kills During Tuna Purse Seining

More than a decade has passed since the passage of the Marine Mammal Protection Act of 1972. During that time the Unites States tuna purse seine fleet reduced its incidental porpoise mortality rate by more than ten-fold. This was made possible, in part, through the efforts of the Marine Mammal Technology Program (MMTP) at the Southwest Fisheries Center in close working cooperation with the U.S. tuna industry. The staff of the MMTP developed gear and techiques which helped to reduce the frequency of events that contributed to the kill. The major results of that program have now been published as a NOAA Technical Report, NOAA-NMFS-SWFC-13 entitled, "Guidelines for Reducing Porpoise Mortality in Tuna Purse Seining" by James Coe, David Holts, and Richard Butler.

The guidelines describe the most effective methods available for preventing dolphin mortality during tuna purse seining operations. THe authors show the success of the U.S. fleets in reducing mortality from 170,000 dolphins in 1970 to less than 20,000 in 1981. During this period the number of sets in which zero dolphins were killed increased from 12% to nearly 70% and skilled operators, using the techniques described in the guidelines, were able to release more than 99.9% of all the dolphins they captured. The immediate goal of the staff of the MMTP was to identify the obvious and most serious mortality-related problems and institute corrective measures. At the same time they began work on a long-term goal aimed at understanding the dynamics of the vessel, deck gear, and purse seine and how they interacted with dolphin behavior. Several methods were

used to bring all pertinent information, and techniques to the fishing community on a timely basis.

In the guidelines the authors discuss the primary reason dolphins are killed--suffocation after being entangled or entrapped in folds and canopies of the net (Table 1). The configuration of the net, both before and during the backdown release procedure was a major determinant of the number of the porpoise killed. Environmental conditions and mechanical failures of net configuration can cause high dolphin mortality unless mitigated by skilled maneuvers by the fishing boat captain or by the use of speedboats to adjust the net. Speedboats used to chase dolphins could also be used to tow on the corkline and prevent net collapse and also to adjust the net configuration to reduce canopies before backdown (Figure 1). Additional strips of webbing to deepen the net further reduced the probability of dolphins being killed by pre-backdown net collapse.

The backdown procedure remains the only means to release captured dolphins effectively from a purse seine. It is also the time during the set when most of the mortality occurs. The use of small mesh safety panels and aprons in the backdown areas of net reduces dolphin entanglement, and increases the probability of an effective release. The tie-down points of the net for preparing the bakdown channel must be properly located in order to optimize dolphin release (Figure 2). A simple method to calculate the precise tie-down points was developed for the net regardless of its depth. Understanding the dynamics of the backdown (Figure 3) permitted development of a thorough guide for troubleshooting backdown performance, thus preventing the repetition of poorly executed backdowns and higher mortality rates.

Dolphins that are not released during backdown must be rescued by hand. A rescuer in an inflated raft can rescue dolphins any time during a net set. This was shown to be most useful during the later stages of backdown where rescuers were able to remove any dolphins that were reluctant or unable to leave the net. This significantly increased the number of zero kill sets. In all circumstances, the skill and motivation of the captain and his crew were the final determinants in the prevention of incidental dolphin mortality in tuna seining.

Table 1. Numbers of porpoise killed by general cause in sets with greater than 15 porpoise killed; NMFS observed trips, 1977-1980.

Year	Number of sets (%)	Total kill (%)	Backdown Canopies Bow	Stern	Other	Total	Pre B.D. net collapse	B.D. channel collapse	Malfunction mortalities	All other causes	Unknown
1977	135 (4.0)	5,277(51.6%)	749	1,539	774	3,062	440	346	329	339	780
1978	73 (4.6)	4,932(68 0%)	478	486	872	1,836	1,897	338	397	243	221
1979	54 (3.5)	2,879(47.1%)	960	173	43	1,176	284	326	84	925	84
1980	30 (2.9)	2,647(65.7%)	106	206	220	532	29	1,504	303	140	139
Total	292 (3.9)	15,735(67.0%)	2,293	2,404	1,909	6,606	2,650	2,514	1,113	1,647	1,224
Percent of total kill		100%	15	15	12	42	17	16	7	10	8

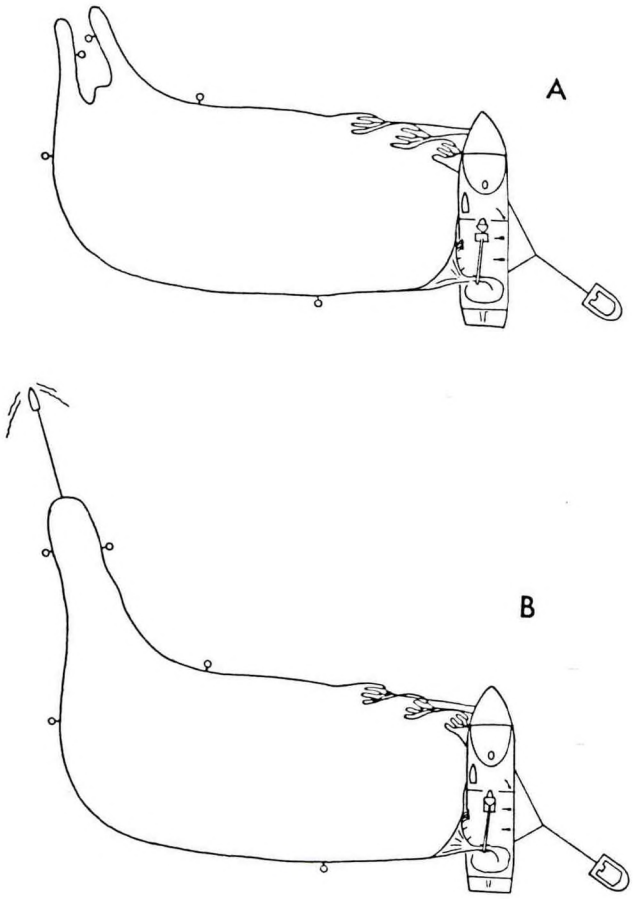

Figure 1. Use of a speedboat to pull out or straighten a collapsed section of net was found to be a simple way to eliminate potential problems.

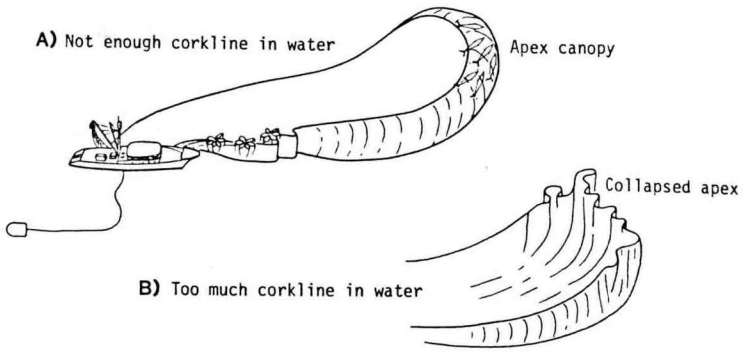

Figure 2. The proper amount of corkline in the water for backdown is directly related to the depth of the net. Too little corkline (a) results in apex canopies, too much corkline (b) produces a collapsed and wrinkled corkline. To ensure that the precise amount of corkline was in the water every set, the precise tie down point was calculated and clearly marked.

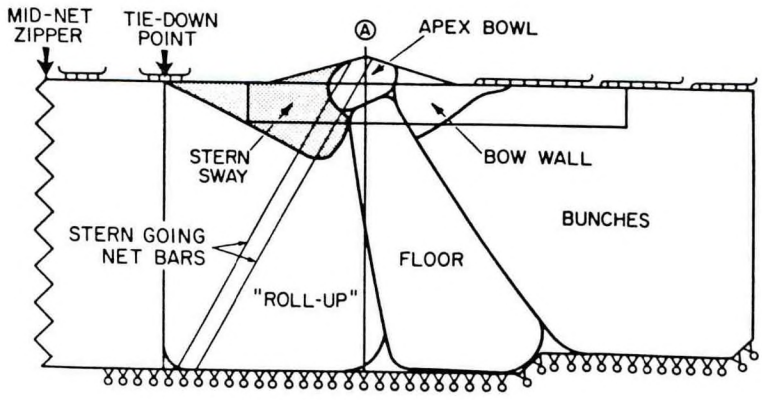

Figure 3. The functional distribution of webbing in a stabilized backdown channel, identified by divers, helped researchers to understand the dynamics of the purse seine during backdown.

Data Analyzed on Dolphins Tagged in ETP

From 1969 to 1978 Southwest Fisheries Center personnel tagged dolphins in the eastern tropical Pacific (ETP) from tuna purse seiners. Data on release and resightings were recently organized and a comprehensive computer database was prepared as a first step in reanalysis of the data by fishery biologist John Hedgepeth. The database is in three parts: releases, resightings, and recoveries. A CPM-operating system microcomputer program called dBASE-II was used to construct the three files; linking was accomplished through common data-fields shared among the files.

The data base has been used initially to review sightings of dolphins tagged in the 1978 dedicated vessel cruise of the tuna purse seiner, Queen Mary. The majority of the sightings were of spotted dolphins. There were also two westernmost sightings, which are unconfirmed sightings made shortly after tagging operations, and a single sighting was made of an eastern spinner dolphin near the coast of Mexico (Figure 1).

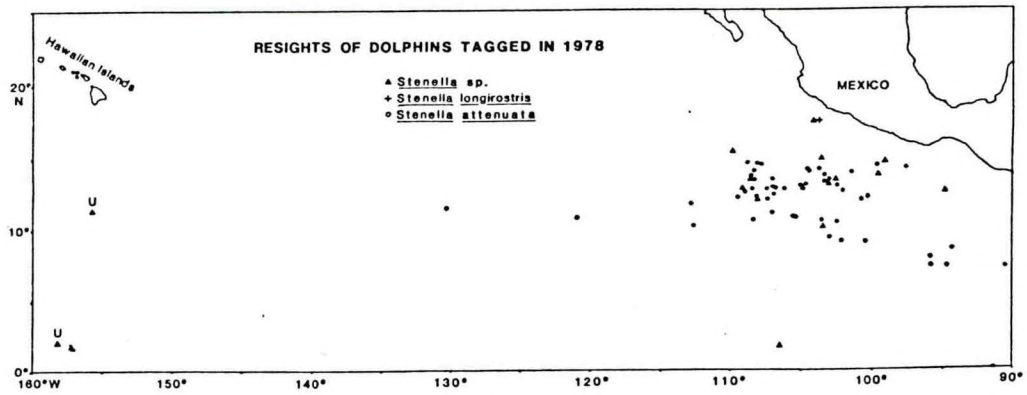

Figure 1. Locations of resightings of dolphins tagged in 1978. The two westernmost resightings are unconfirmed, here labeled with a U. Points may indicate resightings of more than a single animal.

The tags used were bright orange or yellow disks, 62.2 cm diameter; pairs weere fixed on either side of the dorsal fins and held together with a single bolt through the fin. There were 651 tags released and 115 subsequent sightings of the tagged animals. Only a single recovery, approximately a year after release, has been reported.

Preliminary analysis of the sightings data show a principal east-west movement with dolphins tending to move offshore in the late spring to early summer, as was the first suggested by Dr. William Perrin and others at the Southwest Fisheries Center, and an inshore movement in the winter.

Scientist Investigates Large-Scale Spatial-Temporal Patterns in Distribution of Dolphins

Dr. Steve Reilly, Operations Research Analyst at the La Jolla Laboratory is conducting research on the season and spatial variation in dolphin distribution and relative abundance, and how this variation relates to the marine environment.

Preliminary results suggest that there are significant seasonal changes in dolphin distribution and relative abundance in the eastern tropical Pacific (ETP) and that the existence of an El Niño-southern oscillation condition has noticeable effect on the seasonal patterns.

Reilly hypothesizes that much of the observed pattern and variability in ETP dolphin distribution and relative abundance is related to major physical features of the environment. This hypothesis is being tested through statistical comparisons of dolphin school encounter rates from tuna vessel observer data and about 30 measured or derived variables representing the physical oceanography of the ETP. If his investigation provides positive resutls, Reilly plans to execute a second phase of his research, that of testing the hypothesis with smaller scale, more "real-time" data, such as data gathered from a single research vessel cruise in the ETP. For this future effort, satellite imagery will be an important tool.

Analysis Completed of Observer Effect on Incidental Dolphin Mortality in Eastern Tropical Pacific Fishery

Bruce Wahlen, Statistician, reports that he and Dr. Tim Smith, Fishery Biologist, submitted their paper, "Observer effect on incidental dolphin mortality in the eastern tropical Pacific tuna fishery," to the U.S. Fishery Bulletin.

Wahlen and Smith's paper establishes the existence of an observer effect on incidental dolphin kills, which they defined as a differential in levels of dolphin kill between purse seine fishing trips made with and without a scientific observer. Establishment of the existence of such an effect is significant because it implies that estimates of total dolphin kill derived from data collected by these non-crew member observers are in fact underestimates.

Wahlen and Smith established the existence of an observer effect by comparing dolphin kill data collected by scientific observers who differed in their purposes of data collection. Some observers collected data for research purposes only, while other observers collected data for both research and enforcement of dolphin-release regulations. The latter observers with both purposes of data collection were considered to be more obtrusive to vessel operators than the observers whose sole purpose was research. This method is analogous to the indirect method of testing for the existence of a tagging effect on fish in which the researcher compares proportions of tags returned from fish tagged under different conditions.

Comparisons were made between data collected by observers with both research and enforcement purposes of data collection and observers with research purposes only. Data collected by observers with both purposes of data collection evidenced a significantly larger percentage of dolphin sets in which no dolphins were killed then data collected by observers with research purposes only (Figure 1).

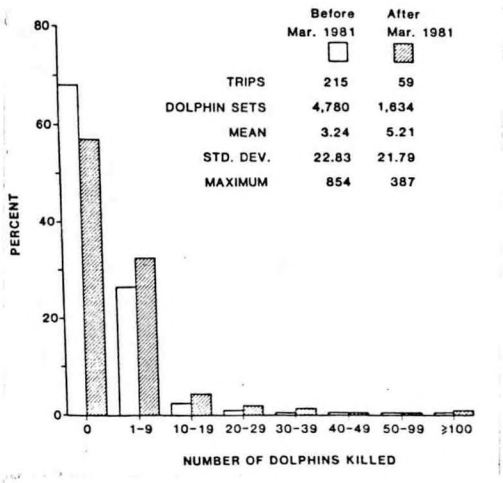

Figure 1. Relative frequency distributions of number of dolphins killed incidentally during sets of NMFS scientist-observed trips from 1978 through 1982, by trip departure date. (Before March 1981, NMFS observers were allowed to collect data for both research and enforcement purposes. After March 1981, NMFS observers were under court order to collect data for research purposes only.)

This one-sided difference between data collected by more and less obtrusive observers implies the existence of an observer effect on incidental dolphin kills. However, since only limited data are available from fishing trips made without a scientific observer, the absolute magnitude of this effect cannot be estimated.

The final draft of this paper incorporated suggestions received from members of pre-SOPS Panel D who met at the SWFC in December 1983 to review papers dealing with the estimation of dolphin mortality incidental to purse seining.

Programs to Display Search Patterns of Tuna Vessels Developed

Dr. Tim Smith, Fishery Biologist, and Paul Robertson, Operations Research Analyst, at the La Jolla Laboratory have developed a series of computer programs designed to display graphically the search patterns of tuna vessels in the eastern tropical Pacific. This work is one phase of a larger research effort exploring the use of data collected by scientific techicians aboard tuna purse seiners for assessing the relative abundance of the dolphins that are incidentally killed in some purse seine sets.

Smith and Robertson's work follows one of the directions suggested by Dr. Tom Polacheck in his Ph.D. dissertation at the University of Oregon. In Polacheck's study, which he completed in 1983 while at the SWFC. Polacheck noted that in 1979 most of the purse seine sets made by tuna vessels occurred in close proximity to each other in clusters of 3 to 30 sets. These clusters were separated from each other by relatively longer distances where searching was less successful. Smith and Robertson exploited this observation and simplified the complex data recorded by the scientific technicians, thus allowing effective graphic presentation of the search pattern of entire fishing trips.

These graphic displays are generated on an IBM-PC compatible microcomputer, using the built-in machine-dependent color graphics routines. A standard color monitor (690 by 240 pixel resolution) is used for the actual display. Many details about the fishing trip can be displayed along with the track between the actual sets by using different patterns of color. Versions of these programs have been developed which show, by color coding, the types of sets (school fish, log, and dolphin) made in the several segments of the fishing trip.

This approach can be extended to explore the implications of some other observations made by Polacheck. He suggested, based on examining data from 1979, that searching was not spatially random in most of the cruises, that the vessels tended to return to the area of previous sets, and that a large fraction of the searching occurred in a small fraction of the total area. To investigate the degree to which different vessels searched the same areas, Smith and Robertson modified the programs for plotting the search pattern for individual cruises to display contemporaneous portions of the tracklines of all vessels carrying scientific technicians.

These programs produce a moving image of the searching by the vessels, which can be enhanced to show ancillary information by color coding. Examination of the image generated for the data collected in 1979 suggests a high degree of overlap, with the areas of concentration moving markedly throughout the year. Such behavior would result in sample biases where certain areas are over-represented in the data collected by the scientific technicians.

The present programs are designed to use a minimal number of the variables in the detailed data collected by the scientific technicians. For the basic display only the location, date, and details about each set are required, although additional data about vessel movements and ancillary sightings allow more elaborate displays. There are two directions for extension of this approach. One is to apply the same procedure to the more extensive but less complete data that exist for nearly all of the fishing vessel trips. Comparisons of those data with the scientific technician data would allow appraisal of the representativeness of the scientific technician data, and would allow identification of the influence of the vessels which did not carry a scientific technician on the overall search pattern of the fleet.

A second direction to extend the graphic displays described here is to use the greater resolution available in the data recorded by the

technicians to describe the path that the vessels searched in much greater detail than allowed by just considering the sets made. Comparison of more resolute displays of the data would allow a better evaluation of the degree of oversampling.

At present only the data collected in 1979 have been examined using these programs. Further analysis of these data, including more critical evaluation of the details of the data for certain cruises, is planned. Additionally, these data will be used for other graphic displays involving more of the variables. Data from other years will be examined in the near future to determine the degree to which the patterns seen in 1979 data appear, and to look for expected differences associated with changing fishing patterns such as increased emphasis on school fish in some years. Also, these displays of the search patterns will be compared in years with different environmental features, such as the presence of the El Niño phenomena, to determine the effect of such changes on the search patterns, and hence on possible sampling biases that will have to be accounted for in order to use the tuna vessel data to monitor the abundance of dolphins.

Tuna/Dolphin Data Bases Completed for 1984

Data collected on all eleven observed 1984 NMFS tuna/dolphin cruises have been edited and put onto the data base. These data, collected by biological technicians placed aboard commercial tuna seiners fishing in the eastern tropical Pacific, describe cetacean sightings and sighting effort, vessel fishing effort and gear deployment and cetacean mortality incidental to the tuna fishery.

Biological Technician Al Jackson of the La Jolla Laboratory reports that a summary of the 1984 tuna/dolphin data shows the eleven cruises included 640 days at sea during which the technicians logged 2,935 hours of cetacean watch effort. A total of 1,429 cetacean sightings were recorded including 599 sightings that contained one or more of the species historically impacted by the fishery. The seiners set their nets a total of 426 times; 388 of these sets involved cetaceans. A total of 9,077 tons of yellowfin tuna, 812 tons of skipjack tuna and 26 tons of bigeye tuna were loaded aboard vessels having a combined fish capacity of 11,578 tons. The technicians counted a total of 2,999 individual cetaceans killed in the seiner's nets. This kill is composed of 1,255 Stenella attenuata, 1,001 Stenella longirostris and 743 Delphinus delphis. The resultant cetacean kill per set and kill per ton of tuna loaded are 7.73 and 0.34, respectively. A more detailed summary of these data will be provided in a forthcoming administrative report.

Systematic Evaluation of Biological Parameters of ETP Dolphin Stocks

Using improved and calibrated age estimating techniques on considerably expanded specimen samples, Dr. Al Myrick, Operations Research Analyst Dr. Jay Barlow, Zoologist Aleta Hohn, and Fishery Biologist Priscilla Sloan with the help of Susan Chivers, Cathy Dargan and Laurie Patia, are methodically reanalyzing the age-specific biological parameters of the dolphin stocks involved in the yellowfin purse seine fishery in the

eastern tropical Pacific Ocean. The objective is to evaluate the biological consequences of the incidental take of dolphins by the fishery.

The first series of studies conducted used over 1000 female and approximately 800 male northern offshore spotted dolphins collected by observers on tuna boats between 1973 and 1981.

For females the findings included a 3.1 year calving interval, a 12-year old average age at sexual maturity, no significant changes in age-specific pregnancy rates, longevity of up to 40 years, and individual reproductive activity at least 20 years in duration.

Males apparently enter reproductive maturity at an average age of 15 or 16 years. Among other results, the use of age class frequency distributions has permitted the scientific staff to detect dips in the population age structures of of sampled male and female spotted dolphins. These unusual frequency dips occur between the ages of 5 and 14 years for both sexes, although the dip is less pronounced in males. It is of perhaps considerable importance to the population dynamics of these animals that when the age frequencies are stratified by sampling year, the dips do not shift with time, as would be the case if reproductive failure, during a given period, were the cause.

A second series of studies is about to begin--this time on the three major eastern tropical Pacific spinner dolphin stock (Stenella longirostris), the eastern spinner dolphin, and the northern and the southern whitebelly spinner dolphin. For these studies more than 2,400 specimens collected between 1973 and 1982 are being used. Teeth have already been prepared and read and age estimates are being accumulated and edited in the three spinner dolphin computer files. When edit programs of these data bases are completed, joint project analyses will generate growth curves, age structure, and age-specific vital rate statistics. Analyses comparing vital statistics by stock, by year, and by area are then anticipated.

Simultaneously with the spinner dolphin work, a study comparing age-specific productive parameters between northern and southern offshore spotted dolphins is getting underway. A randomly selected tooth sample of 400 mature northern and southern females has already been prepared and read. After data base edits, the newly-generated data will be available for stock calculation and comparisons of average age at sexual maturity, age structure, and growth rate.

Mitochondrial DNA: A Tool to Study Stock Differentiation

Effective fishery management requires basic understanding of the intraspecific relationships of the exploited species. For studying these relationships, analysis of the sequence of mitochondrial DNA (mtDNA) offers the highest resolution genetic technique currently available. Because of the rapid rate of mtDNA evolution, it is extremely informative to study recent evolutionary events like separation (or the lack) of stocks. Restriction endonuclease analysis of mtDNA has been successfully used to elucidate the racial relationships of several terrestrial animals (including humans) but has just recently been applied to marine animals.

Using the mtDNA methodology, fishery biologist Dr. Andrew Dizon has recently completed the first phase of a study of the intraspecific genetic structure of the eastern spinner and whitebelly spinner stocks of Stenella longirostris. The technique relies on comparisons, between individuals, of restriction fragment length polymorphisms (RFLP's) visualized from DNA treated with specific enzymes. To date, RFLP patterns have been made and scored from 75 samples each treated with 7 different enzymes. These RFLP's will now be used to determine the genetic pedigrees of the tested individuals. The results will be compared with similar studies performed on human racial stocks. By this comparison, our goal is to provide managers some sense of the genetic uniqueness of exploited dolphins.

TUNA BEHAVIOR AND PHYSIOLOGY STUDIES

Experiments Continue to Determine Magnetic Sensitivity of Tunas

For more than 25 years, fishery biologists at the Honolulu Laboratory have conducted research on the behavior, energetics, physiology and sensory biology of tropical tunas (skipjack, yellowfin, and kawakawa) utilizing the Kewalo Research Facility, still the only laboratory in the world where tunas are routinely maintained in captivity for research purposes. This work is directed toward a fundamental understanding of tuna biology necessary for rational management of tuna resources. Presently, current efforts to manage and develop fisheries for tropical tunas are limited by a lack of understanding of basic biological processes, such as reproduction, growth, mortality, and distribution.

Work presently in progress includes investigation of the magnetic compass sense of tunas as it relates to short- and long-term movements, spawning and rearing of tunas and other pelagic species in captivity for assessing the effects of environmental factors on larval survival and growth, investigation of the short-term movements and residence times of tunas around fish aggregating devices (FADs), and study of the physiological reactions and tolerances of tunas to strenuous exercise and low ambient oxygen conditions.

Dr. Richard W. Brill, at the Center's Honolulu Laboratory, reports that research assistant Robert E. Bourke and NOAA Junior Fellow Theresa Villanueva continued work during this period to determine the ability of tunas to detect changes in the earth's magnetic field. The objective of this work is to determine if a magnetic compass sense is responsible for tunas' precise navigational abilities. Experiments were conducted on kawakawa, Euthynnus affinis, yellowfin tuna, Thunnus albacares, and skipjack tuna, Katsuwonus pelamis. In these experiments fish could be easily trained to respond when a light stimulus was paired with a change in magnetic field. However, when the light was removed, the fish appeared unable to detect induced changes in earth's magnetic field alone. These results were unexpected since earlier work by Dr. Michael M. Walker at the Kewalo Research Facility clearly showed that yellowfin tuna can detect changes in the earth's magnetic field.

Physiology of Tunas Studied

In July Dr. Peter Hochachka, University of British Columbia, Dr. Thomas Moon, Huntsman Marine Laboratory, and Dr. Bren Gannon, Flinders University, Australia, joined Jean-Michele Weber, University of British Columbia, and Dr. Brill at the Kewalo Research Facility in a joint continuing study of lactate metabolism and physiological reactions of tunas to strenuous exercise and other possible underlying causes of "burnt tuna." The group investigated lactate turnover rate, gluconeogenesis, i.e., conversion of lactate to glucose, in the various organs of skipjack tuna, as well as further investigating the possibility that tunas' vascular countercurrent heat exchangers may act as lactate exchange systems for

rapidly moving large quantities of lactate from the white muscle, where it is produced, to the red muscle, where it is metabolized.

Also, Dr. David Jones and Mark Haisis, graduate student, both of the University of British Columbia, and Dr. Pat Butler, University of Birmingham, worked with Dr. Brill on joint studies which are part of a larger effort to determine how tunas' physiology affects their distribution, movements, gear vulnerability, natural mortality, etc. Work centered on development of techniques to simultaneously measure ventilation volume, e.g., the volume of water a swimming tuna passes over its gills per unit time, cardiac output, and metabolic rate in free-swimming fish.

Reuben Yost, University of Hawaii graduate student, completed tests on the minimum prey odor concentrations detectable by yellowfin tuna, and responses of yellowfin tuna to single amino acids. Amino acids have been shown to be strong olfactory stimulants in other fish species. Yellowfin tuna responded to prey odor concentrations as low as 10^{-5} g/liter. Odors were made by freeze-drying rinses from tunas' natural prey. Yellowfin tuna appear able to detect compounds in the 10^{-7} molar range, which is as good or better than other teleosts. Surprisingly, however, yellowfin tuna have exhibited almost no reactions to single amino acids.

Study of Oxygen Receptors on Gills Successfully Completed

Dr. William Milson, University of British Columbia, and Dr. Brill have successfully completed a series of experiments to verify the presence of and characterize the oxygen receptors in the gills of yellowfin tuna. The presence of these receptors had previously been suspected but, until recently, never conclusively demonstrated. The technique used involved recording the activity in nerves coming from an isolated perfused gill.

Skipjack Tuna Larvae Reared at Kewalo Research Facility

Thomas K. Kazama, Fishery Biologist in the Tuna Behavior and Physiology Task, continued experiments to rear larval skipjack tuna at the Honolulu Laboratory's Kewalo Research Facility (KRF). During the spawning season around Hawaii in 1984, viable eggs were collected 10 minutes after they had been spawned spontaneously by captive skipjack tuna in the holding tank at the KRF. Observations made earlier indicated that skipjack tuna caught and placed in holding tanks during the spawning season spawn spontaneously due to the stress caused by catching and handling. The eggs were fertilized with sperm from a testis that had been removed from a dead skipjack tuna 12 hours before. Of the approximately 80 eggs collected, 20 viable larvae were produced. Of the 20 larvae that were produced, one survived for 43 days. In earlier years, skipjack tuna larvae had been kept alive for a maximum of only 12 days at the KRF. The larvae were fed a mixed diet of copepods, brine shrimp, and small fish larvae.

Four Yellowfin Tuna Successfully Tracked

Dr. Richard W. Brill, Leader, Tuna Behavior and Physiology Task at the Honolulu Laboratory, reports that four yellowfin tuna, Thunnus albacares,

were successfully tracked with the aid of ultrasonic depth sensitive transmitters on the Honolulu Laboratory's R/V Kaahele'ale during this period. The purpose of this work is to study the short-term movements and behavior of tunas near and around fish aggregating devices (FAD's). This study is being cooperatively conducted with Dr. Kim Holland, Hawaii Institute of Marine Biology, University of Hawaii, and assisting in the study are Randolph K.C. Chang, Fishery Biologist, Lt. (jg) Jeffrey A. Koch, NOAA Corps, and research assistant Robert E. Bourke.

Three of the fish were caught and tracked near the FAD's located off the Waianae coast of Oahu, including the track of 48 hours, which is the longest track conducted to date on the Kaahele'ale. The results of these tracks indicate that yellowfin tuna remain in a relatively small area for up to several weeks and that ultrasonic transmitters and attachment methods do not adversely affect the tagged fish.

Toward the latter part of this period, the Kaahele'ale worked out of the Coconut Island facility of the Hawaii Institute of Marine Biology to obtain tracks around FAD's located on the windward side of Oahu. A 44-cm yellowfin tuna was tagged on April 13, and a 12-hour track of this fish was obtained. Although the duration of the track was shorter than desired, the vertical and horizontal movements of this fish were very similar to those of fish tracked around leeward coast FAD's. In particular, the daytime movements of this fish revealed an extremely small radius of movement around the FAD.

Reproductive Analysis of Skipjack Completed

Biological technician Beverly Macewicz of the La Jolla Laboratory recently completed an analysis of 12 skipjack, Katsuwonus pelamis, ovaries taken in the South Pacific by Dr. Robert Kearney, formerly of the South Pacific Commission, Noumea, and now Chief Scientist with the Inter-American Tropical Tuna Commission. The objective of this project was to determine if the reproductive analysis developed for the northern anchovy, Engraulis mordax, was practical for skipjack. John Hunter and Macewicz concluded that it is practical to do such work, although extensive field sampling would be required.

The analysis revealed that the female skipjack either had spawned recently or had inactive atretic ovaries. Three of the fish had postovulatory follicles of about the same age, indicating a spawning frequency of 25% for the sample. This indicates an average interval of four days between spawnings for the sample as a whole, although individual females might be spawning on a daily basis. The most unusual feature was that although the spawning frequency was high, only 33% of the fish had active ovaries and two of these fish even had some atresia. This indicates that spawning was probably close to ending. A high spawning frequency in a sample with a high incidence of atretic, inactive ovaries is very unusual and has never been seen in northern anchovy populations. It may mean that when skipjack have active ovaries they spawn very frequently, perhaps every 1-2 days, and those that are unable to maintain such a high rate of spawning simply resorb the ovary. They might reactivate the ovary sometime later in the year once their condition improved. If this striking

heterogeneity in reproductive state is characteristic of skipjack, it could provide useful insight into the energetics of skipjack populations.

Manuscript on Metabolic Rate of Tuna Completed

Dr. Brill, has completed a manuscript for publication titled, "The standard metabolic rate of tunas: Effect of body size and acute temperature change," for submission to Physiological Zoology. In this paper Brill describes the effect of body size on the standard metabolic rate (SMR)--the metabolic rate at zero overt muscular activity of yellowfin tuna and kawakawa, Euthynnus affinis, as well as the effect of acute temperature change on the SMR of these two species and skipjack tuna, Katsuwonus pelamis. He shows that tunas have exceptionally high SMR's even when comparisons are made with other active teleosts of the same body size and at the same water temperatures. Tunas can also achieve exceptionally high maximum aerobic metabolic rates. This ability is a result of tunas' large gill surface areas, high hematocrits, and high cardiac outputs. These characteristics, in turn, cause tunas to have exceptionally high cardiac and osmoregulatory energy costs. Brill postulates that tunas' high SMR's are an inevitable consequence of their abilities to achieve exceptionally high aerobic metabolic rates.

Manuscript Completed on Effects of Temperature Change on Acid-Base Regulation in Tuna Blood

A manuscript, "Effects of temperature change on acid-base regulation in skipjack tuna (Katsuwonus pelamis) blood," by S.F. Perry, C. Daxboeck, B. Emmet, P.W. Hochachka, and R.W. Brill has been accepted for publication in Comparative Biochemistry and Physiology. The work is part of a larger study on acid-base regulation, recovery from strenuous exercise, and effects of low ambient oxygen on tuna. The ultimate goal of this research is the determination of the effect of environment on natural mortality, distribution, energetics, growth rates, and specific vulnerability of tunas to gear.

The manuscript describes the effects of temperature change in vitro on acid-base balance of the blood of tunas. By examining the relationship between blood pH and temperature in vitro under conditions of constant CO_2 tension (open system), it was observed that the rate of change in blood pH with temperature was well within the range of in vitro values reported for other ectothermic vertebrates, and was only slightly different from values obtained in vitro under conditions of constant CO_2 content. The authors concluded that the changes in skipjack tuna blood pH following temperature change can be accounted for solely by the passive, in vitro behavior of a unique chemical buffer system found in skipjack tuna blood. Therefore, the slow, active blood pH regulatory mechanisms of other teleosts need not be postulated for skipjack tuna. This rapid, passive regulation of blood pH with temperature is required by tunas because of the regular 10°-15°C temperature changes to which they are subjected during the rapid vertical movements that are a regular part of their behavior in the open ocean.

A second (revised) manuscript, "Effects of exhausting exercise on the acid-base regulation in skipjack tuna (Katsuwonus pelamis) blood," by the same authors, has been submitted to Physiological Zoology.

Intravascular Parasite Discovered in Yellowfin Tuna

During experiments on the cardiovascular dynamics of yellowfin tuna, Thunnus albacares, Dr. David Jones, University of British Columbia, and Dr. Brill discovered the presence of parasitic worms in the anterior portion of the dorsal aorta in yellowfin tuna. Samples of the parasites were given to Dr. James Brock, Hawaii State veterinarian, who has initially identified the parasite as a species of trematode. Brock is now attempting to identify the genus and species of the parasite.

Since the initial discovery of the intravascular parasite in February, at least a few fish from every group of yellowfin tuna delivered to the Kewalo Research Facility have been found to be infested. The parasites, however, may be species specific since more than 60 kawakawa, Euthynnus affinis, and 10 skipjack tuna have been examined and none was found to be infested.

Research assistant Gregory Weber will begin checking for the presence of this parasite in the large yellowfin tuna landed at the Honolulu fish auction. If significant numbers of large yellowfin tuna are found to be infested, a possible connection between the presence of parasites and "burnt tuna" may be sought.

MISCELLANEOUS

Proposal Made to Develop Methods for Indexing Estimates of Natural Mortality in Exploited Tuna Stocks

A multidisciplinary team of scientists from the Southwest Fisheries Center and the Inter-American Tropical Tuna Commission (IATTC) has completed a proposal for a pilot study directed toward improving the predictive capability of tuna assessment models, by developing methods to index estimates of natural mortality in exploited stocks. Southwest Fisheries Center personnel include Drs. Elizabeth Vetter, Christofer Boggs, Andrew Dizon and Norman Bartoo; the team also includes Robert Olson of the Inter-American Tropical Tuna Commission. Initially, the group will concentrate on developing a variable (indexed) mortality schedule for different sizes of commercially exploited tunas. This variable will be used quantitatively to shape (index) the natural mortality vector. This is a more appropriate formulation than the formulation used in current models, which assumes a constant and equal natural mortality for individuals in all categories.

A priori simulation will be conducted to determine the sensitivity of yield-per-recruit and cohort analysis models to variable schedules of natural mortality. Experimental physiological studies will provide the basis for a Risk Index relating physiological status to a probability of succumbing to natural mortality. The team will develop quantitative methodology to map physiological information into the Risk Index, and subsequently into the fishery models. Field validation and sampling studies will accompany the physiological studies.

The integrated project is specifically directed toward developing better predictive capability for fishery management by drawing on the expertise of complementary specialists, with a plan, a priori for incorporating the data into existing and new or refined predictive tuna models.

THE DYNAMICS OF TUNA MOVEMENT

One of the most powerful tools for tuna management is the analysis of the recoveries of marked fish. These analyses provide information on mortalities, both natural and fishing, as well as movements and exchange rates of individual fish among fisheries. A substantial body of information exists on the recoveries of marked tuna, and major tagging programs continue world-wide. However, assumptions in the analytical models used to analyze tagging data result in uncertainties in the conclusions. These include assumptions that the fished stock is a clearly defined entity (a closed system) and that tagged fish have the same probability of being caught as untagged fish. To investigate these and other model assumptions and to make major advances in knowledge of movements and their predictability, it is evident that application of new approaches, together with the present mark and recapture methods, must be employed.

During an international tuna workshop, convened by the Inter-American Tropical Tuna Commission (IATTC), participants recommended that a series of workshops be held to develop an international research program to address the key issues of movement, distribution and exchange rates of tunas. With financial and logistic support for the meetings provided by the IATTC and the SWFC, fishery biologist John Hunter of the SWFC was asked to chair and organize the workshops on tuna movements.

The plan was to hold four workshops with a panel of six members discussing the issues with a series of invited expert consultants. The principal objective was to identify the optimal technical approaches that could be used to trace the movements of tunas. Top priority was the development of a system that would permit the recovery of a large number of geographic positions of tuna per day over extended periods of 30 or more days. The group was also asked to discuss devices that provide vertical position and environmental data at the position of the fish either in real time or coded and stored within the tag itself for later recovery. Such devices would be of great value for identification of the mechanisms controlling movements and ultimately prediction of tuna movement from habitat characteristics.

The final workshop meeting was held March 25-27, 1985 at the SWFC. The panel, which provided continuity among the series of three workshops and was responsible for writing a final report, strongly recommended the development of archival tags and their use in field studies on tuna movement dynamics. The group concluded that widespread use of the tag in conjunction with conventional mark and recapture studies would result in a quantum advance in knowledge of tuna movement dynamics and could lead to solving many of the fundamental biological problems of importance to tuna management including the unit stock problem, school or school group cohesion, interactions among fisheries and fishing gear, environmental predictions of availability, and size specific differences in habitat selection and vulnerability to the fishery.

The final product will be a report which will contain all the best ideas provided by the round table consultants and panel members. The final report will conceptualize the problem from the point of view of tuna management, define the critical biological and environmental questions, and briefly summarize the present state of knowledge. The final and most important portion of the report will be descriptions of various research approaches for answering the critical questions, including approximate costs, and an overall research strategy.

NMFS Contributions to 35th Annual Tuna Conference

The 35th Annual Tuna Conference, chaired by fishery biologist Dr. Andrew Dizon, OFRD, was held at the University of California Conference Center at Lake Arrowhead, California, May 21 to 23. The main focus of the conference was the relationship of the tuna to its environment, an appropriate theme for the El Niño year of 1983. Papers reporting on research and other topics related to tuna were also presented.

The presentations were organized into four sessions: environment, analysis, biology, and future research. The Southwest Fisheries Center was well-represented in the 25 talks given as follows:

Dr. Michael Laurs of the Coastal Fisheries Resources Division (CFRD) convened the session on, "The scombrid environment", Dr. Roy Mendelssohn of the Pacific Environmental Group (PEG) presented a talk entitled, "Environmental influences on tuna catches in the Gulf of Guinea"; Dr. Steve Reilly, Oceanic Fisheries Resources Division (OFRD), and Hannah Bernard, OFRD, presented, "Feeding habits of four species of scombrids off southern California during summer 1983--an El Niño year", James Squire, OFRD, presented, "1983 sea surface temperature changes in relation to catch-temperature parameters observed for some pelagic species off southern California", and Paul Sund of PEG brought participants at the Conference up to date on albacore research at PEG with a talk entitled, "Descriptive albacore-environmental studies at PEG: a progress report."

Dr. Norman Bartoo, OFRD, convened the next session on "Tuna fisheries and their analysis." During that session, Dr. Sam Herrick, OFRD, demonstrated a cost and earnings budget simulator supporting his talk on "Cost and earnings of U.S. troll vessels participating in the North Pacific albacore fishery." Dr. Pierre Kleiber, OFRD, discussed, "Cohort analysis without age information."

Dr. Elizabeth Vetter, National Research Council Fellow (NRC) working with OFRD, ran the session dealing with "The biology of the scombrid." In that session, Dr. Chris Boggs, NRC Fellow with the CFRD, described results obtained during the course of his Ph.D. research at the Kewalo Basin Research Facility, Honolulu Laboratory, in a talk entitled, "Energetics and tuna movements." Earl Weber, OFRD, after first pointing out that swordfish did not belong in the family Scombridae, gave a talk entitled, "Reproductive potential of swordfish in southern California waters."

Dr. Gary Sakagawa, OFRD, closed the Conference with a session on "Future research." In that session Laurs presented, "The NMFS strategic plan for albacore research and management," authored by David Mackett of the Center Director's office.

Abstracts of all the talks were published and distributed to participants. Copies are also available to other interested individuals upon request to the Director, SWFC.

Honolulu Laboratory Biologists Attend Tuna Conference in Hilo

Richard N. Uchida, Acting Chief, Pelagic Resources Investigation, and Dr. Richard Brill attended the Big Island Tuna Conference, which was sponsored by the County of Hawaii, UH Sea Grant Program, Big Island Aquaculture Development Committee, and the Cooperative Extension Service, on May 15-16 at the Naniloa Surf Hotel in Hilo, Hawaii. Uchida served as a panelist and reviewed the Honolulu Laboratory's ongoing research on tuna and other pelagic species, and Brill made a presentation entitled "Tuna physiology." Other topics covered at the conference were "Overview of Pacific tunas" by Witold Klawe, Inter-American Tropical Tuna Commission;

"Tuna behavior and prey odor tests" by Dr. Kim Holland, UH; "El Niño and tuna" by Dr. Klaus Wyrtki, UH; "Ahi burn research update" by Dr. Robert Nakamura, UH; "Big Island fishing industry concerns" by industry representatives; "New technology in fish handling and packing" by William Kowalski; and "Fishing boat loans" by Al Fong and Gary Kobashigawa for the Hawaii State Government, and Robert T.B. Iverson, Western Pacific Program Office (WPPO), Southwest Region, for the Federal Government.

Meeting of the SWFC Tuna Data Management Committee Held in Honolulu

Al Coan, Chairman of the Tuna Data Management Committee, and computer specialist Fletcher Riggs hosted the 1984 meeting of the tuna data management committee in Honolulu, Hawaii, on August 6-10. The Committee was established at the Center to monitor data collection efforts to avoid nonduplication.

A prototype data catalog, developed by programmers Eugene Sibbald, Christina Show, and Houng Bui of the La Jolla Laboratory on the La Jolla Standard Z80 Microcomputer, for fisheries data maintained by both the La Jolla and Honolulu Laboratories was introduced by Coan to meeting participants and to researchers at the Honolulu Laboratory. The catalog concept was well received and was adopted by the Committee for implementation for all tuna fishery data. Final versions of the catalogs are scheduled to be completed in November after comments have been received from reviewers. The committee also discussed expanding its goal from that of a monitoring committee for nonduplication of data collection efforts to one of also developing systems (mainly micro based). The next step for the committee is the development of a standard catch data base for use at both laboratories.

PUBLICATIONS

SWFC PUBLICATIONS ON TUNA AND TUNA-RELATED SUBJECTS
MAY 1, 1984 to APRIL 30, 1985

PUBLISHED

Barlow, J. 1984. Reproductive seasonality in pelagic dolphins (Stenella spp.): implications for measuring rates, pp. 191-198. (July, 1984) In: Reports of the International Whaling Commission (Special Issue 6). W.F. Perrin, R.L. Brownell, Jr., and D.P. DeMaster (eds.), Reproduction in whales, dolphins, and porpoises.

Coe, J.M., D.B. Holts, and R.W. Butler. 1984. The "Tuna-porpoise" problem: NMFS dolphin mortality reduction research, 1970-81. Mar. Fish. Rev. 46(3):18-33.

Hida, T.S. 1984. Pelagic fisheries resources of the Northwestern Hawaiian Islands. In: R.W. Grigg and K.Y. Tanoue (eds.), Proceedings of the Second Symposium on Resource Investigations in the Northwestern Hawaiian Islands, Vol. 1, May 25-27, 1983, Univ. Hawaii, Honolulu, Hawaii, pp. 328-338. UNIHI-SEAGRANT-MR-84-01.

Included in this paper are reviews of data collected by the Hawaiian Division of Aquatic Resources on the fish catch in the Northwestern Hawaiian Islands (NWHI) by longlining and trolling in recent years, the relatively new fishery for albacore, Thunnus alalunga, in the vicinity of the NWHI that is being carried out by U.S. West Coast albacore trollers, and some of the longline, live-bait and gillnet fisheries that are being carried out by Japanese and Taiwan vessels in the North Pacific Ocean (July, 1984).

Johnston, I.A., and R. Brill. 1984. Thermal dependence of contractile properties of single skinned muscle fibres from Antarctic and various warm water marine fishes including skipjack tuna (Katsuwonus pelamis) and kawakawa (Euthynnus affinis). J. Comp. Physiol. B155:63-70.

Single fast fibres and small bundles of slow fibres were isolated from the trunk muscles of an Antarctic (Notothenia neglecta) and various warm water marine fishes (blue crevally, Carangus melampygus; grey mullet, Mugil cephalus; dolphin fish, Coryphaena hippurus; skipjack tuna, Katsuwonus pelamis and kawakawa, Euthynnus affinis). Fibres were chemically skinned with the non-ionic detergent Brij 58.

In general, $Q_{10(15-30^\circ C)}$ values for V_{max} were in the range 1.8-2.0 for all warm water species studied except skipjack tuna. V_{max} for the internal red muscle fibres of skipjack tuna were much more temperature dependent ($Q_{10(15-30^\circ C)} = 3.1$) ($P<0.01$) than for superficial red or white muscle fibres. The proportion of slower red muscle fibres in tuna (28% for 1 kg skipjack) is 3-10 times higher than for most teleosts and is related to the tuna's need to sustain high cruising speeds. We suggest that the 8-10°C temperature gradient that can exist in skipjack tuna between internal red and white muscles allows both fibre types to

contract at the same speed. Therefore, in tuna, both red and white muscle may contribute to power generation during high speed swimming.

Kaya, C.M., M.K.K. Queenth, and A.E. Dizon. 1984. Capturing and restraining technique for experimental work on small tuna in large laboratory holding tanks. Prog. Fish-Cult. 46(4):288-290.

Myrick, A.C., Jr. 1984. Reproductive seasonality in multi-herd groups of northern offshore spotted dolphins, Stenella attenuata, and age-related reproductive parameters for females, p. 480 (Abstract only). In: Reports of the International Whaling Commission (Special Issue 6). W.F. Perrin, R.L. Brownell, Jr., and D.P. DeMaster (eds.), Reproduction in whales, dolphins, and porpoises.

Perrin, W.F. and J.R. Henderson. 1984. Growth and reproductive rates in the populations of spinner dolphins, Stenella longirostris, with different histories of exploitation, pp. 417-430. In: Reports of the International Whaling Commission (Special Issue 6). W.F. Perrin, R.L. Brownell, Jr., and D.P. DeMaster (eds.), Reproduction in whales, dolphins, and porpoises.

Perrin, W.F. and S.B. Reilly. 1984. Reproductive parameters of dolphins and small whales of the family Delphinidae, pp. 97-133. In: Reports of the International Whaling Commission (Special Issue 6). W.F. Perrin, R.L. Brownell, Jr., and D.P. DeMaster (eds.), Reproduction in whales, dolphins, and porpoises.

Perryman, W.L., M.D. Scott, and P.S. Hammond. 1984. A technique for estimating reproductive parameters of small cetaceans from vertical aerial photographs, pp. 482. In: Reports of the International Whaling Commission (Special Issue 6). W.F. Perrin, R.L. Brownell, Jr., and D.P. DeMaster (eds.), Reproduction in whales, dolphins, and porpoises.

Polacheck, T. 1984. Reproductive estimates of a source of information on survival rates, pp. 181-185. In: Reports of the International Whaling Commission (Special Issue 6). W.F. Perrin, R.L. Brownell, Jr., and D.P. DeMaster (eds.), Reproduction in whales, dolphins, and porpoises.

Shomura, R.S. 1983. Pacific tuna fishery resource issues. In: Western Proceedings, 63rd Annual Conference of the Western Association of Fish and Wildlife Agencies, Teton Village, Wyoming, July 10-14, 1983, pp. 159-161.

Several events which have occurred over the past few years suggest that the U.S. tuna fishing industry is at another economic crossroad. In the early 1950s, the tuna industry faced an economic crisis caused by the large influx of imported tunas from foreign tuna fishing nations, especially from Japan. The crisis was resolved by a marked increase in productivity due to improvements in the purse seine method of fishing. The introduction of synthetic fiber and the development of the puretic power block were instrumental in the recovery of the tuna industry. Today, the U.S. tuna industry is faced with a number of problems, including lagging sales of canned tuna; a marked increase in imports of tuna, especially water-packed tuna; access problems resulting from

extended jurisdiction; tuna resources which apparently are being harvested at near the maximum sustainable yields; and the lack of effective tuna management mechanisms.

This paper briefly describes the current status of the various segments of the tuna industry, including the processors (the canning industry) and the producers (the fishing sector), and the tuna resources and tuna management.

Smith, T.D. 1984. Estimating the dolphin population size yielding maximum net production, pp. 187-190. In: Reports of the International Whaling Commission (Special Issue 6). W.F. Perrin, R.L. Brownell, Jr., and D.P. DeMaster (eds.), Reproduction in whales, dolphins, and porpoise.

Walker, M.M. 1984. Learned magnetic field discrimination in yellowfin tuna, Thunnus albacares. J. Comp. Physiol. A155:673-679.

Walker, M.M. 1984. Magnetic sensitivity and its possible physical basis in the yellowfin tuna, Thunnus albacares. In: J.D. McCleave, G.P. Arnold, J.J. Dodson, and W.H. Neill (eds.), Mechanisms of migration in fishes, pp. 125-141. Plenum Press, NY, (NATO Conf. Ser. IV, Mar. Sci., Vol. 14).

Many animals are known to orient to magnetic fields. However, two central problems in the study of magnetic sensitivity have been the almost complete failure of magnetic field conditioning experiments and the lack of evidence for a feasible transduction mechanism. In the studies reported here yellowfin tuna learned to discriminate between two Earth-strength magnetic fields in a discrete-trials/fixed-interval conditioning procedure. Magnetometry experiments, diffraction spectra and electron microscope analyses demonstrated single-domain crystals of the ferromagnetic mineral magnetite in the head of this species. The crystals are concentrated in tissue contained within a sinus formed by the ethmoid bones of the skull. Theoretical analyses show that the crystals would be suitable for use in magnetoreception if linked to the nervous system. The physical properties of the crystals would determine the operation of magnetoreceptor organelles and constrain the capacities of the magnetic sense. Tests of these constraints in appropriately designed conditioning experiments will provide powerful tests of the ferromagnetic magnetoreception hypothesis.

Walker, M.M., J.L. Kirschvink, S.R. Chang, and A.E. Dizon. 1984. A candidate magnetic sense organ in the yellowfin tuna, Thunnus albacares. Science (Washington, DC) 224:751-753.

Single-domain magnetite crystals have been isolated ancd characterized from tissue located in a sinus within the dermethmoid bone of the skull of the yellowfin tuna, Thunnus albacares. Their chemical composition, narrow size distribution, and distinctive crystal morphology indicate that these crystals are biochemical precipitates. Experiments on the interaction between particles reveal the organization of the particles in situ and suggest a possible form for candidate magnetoreceptor organelles. The consistent localization of such particles with similar arrangement within the dermethmoids of this and other pelagic fishes

suggests that the ethmoid region is a possible location for a vertebrate magnetic sense organ.

NOTE: These publications are available upon request to the Director, SWFC, P.O. Box 271, La Jolla, California 92038.

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Matsumoto, W.M. 1984. Potential impact of deep seabed mining on the larvae of tunas and billfishes. SWFC-TM-NMFS-44.

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NOTE: Copies of these and other NOAA Technical Memoranda are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22167. Paper copies vary in price. Microfiche copies cost $3.50.

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Marsac, F. and B. Stequert. 1984. Summary of the exploration for surface tuna resources since 1971 in the western Indian Ocean. La Peche Maritime, February 20, 1984, p. 83-94. (Engl. transl. by W.G. Van Campen, 1984, 25 p., Transl. No. 98; available Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.)

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Foster, T.C. 1984. Size and species compositions of Atlantic tunas from imports landed in Puerto Rico during 1983. SWFC Admin. Rep. LJ-84-25.

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Hedgepeth, J.B. 1984. Report of multispecies assessment task, collection of squids and fishes and observations of seabirds and marine mammals between San Diego and Monterey, California. SWFC Admin. Rep. LJ-84-20.

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Parks, W. 1985. The effects of various sighting factors on estimate sizes of dolphin schools in the eastern tropical Pacific Ocean. SWFC Admin. Rep. LJ-85-07.

Pitman, R. 1984. Report of multispecies assessment task research cruise in the eastern/central tropical Pacific, October 6-December 6, 1983. (Cruise No. RP-9-DI-84, NOAA Ship Discoverer.) SWFC Admin. Rep. LJ-84-43.

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Bartoo, N. and T. Shiohama. A production model analysis of the North Pacific albacore population including estimates of the sensitivity of results to measurement errors in input data. For publication in the Bulletin of the Far Seas Fisheries.

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Bindman, A. An application of Andersen's method of extracting information from the stomach contents of fish. For consideration for publication in Journal du Conseil.

Brill, R.W. The standard metabolic rate of tunas: Effect of body size and acute temperature change. For consideration for publication in Physiological Zoology.

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Hohn, A.A., S.J. Chivers, and J. Barlow. Reproductive maturity and seasonality in male spotted dolphins, Stenella attenuata, in the eastern tropical Pacific. For consideration for publication in Marine Mammal Science.

Laurs, R.M., R. Nishimoto, and J.A. Wetherall. Frequency of ring formation on sagittae of North Pacific albacore, Thunnus alalunga. For consideration for publication in Nature.

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Perrin, W.F., M.D. Scott, J. Walker, and V.L. Cass. Review of geographicalstocks of tropical dolphins (Stenella spp. and Delphinus delphis) in the eastern Pacific. For consideration for publication in Fishery Bulletin, U.S.

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