NATIONAL MARINE FISHERIES SERVICE
SOUTHWEST FISHERIES CENTER
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SOUTHWEST FISHERIES CENTER

MAY 1981

DIRECTOR'S REPORT
To The
THIRTY-SECOND TUNA CONFERENCE
On
TUNA AND TUNA-RELATED ACTIVITIES
At The
SOUTHWEST FISHERIES CENTER
LA JOLLA, CALIFORNIA
For The Period
MAY 1, 1980 TO APRIL 30, 1981

ADMINISTRATIVE REPORT LJ-81-09

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MAY 18-20, 1981

SWFC ADMINISTRATIVE REPORT NUMBER LJ-81-09

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INTRODUCTION

For a decade, almost all research on tuna in the federal government has been conducted at the Southwest Fisheries Center's two laboratories in Honolulu, Hawaii and La Jolla, California.

With the exception of research on Atlantic billfishes and bluefin tuna which is conducted at the Southwest Fisheries Center in Miami, Florida, fishery biologists at the Honolulu and La Jolla Laboratories are involved in studies of the population dynamics of most other species of tuna on a worldwide basis.

At the Honolulu Laboratory the emphasis is on assessment and understanding of the abundant skipjack tuna resources of the Pacific and Indian Oceans. Because of its mid-ocean location and capability for holding large tropical pelagic fishes at the laboratory, fishery scientists study the sensory and physiological reactions of tunas to their environment. Other tuna-related programs include assessment of the South Pacific albacore populations and recreational fisheries research, principally the sport fishery for billfishes. Results of this research are provided for consideration by fishery managers in such international forums as the Indo-Pacific Fisheries Council and the Indian Ocean Fishery Management Council.

At the La Jolla Laboratory, the staff of the Oceanic Fisheries Resources Division provides basic fishery analysis and management information on tunas and billfishes to international fisheries bodies and commissions, and conducts studies on the status of porpoise involved in the eastern tropical Pacific tuna purse seine fishery. The staff of the Coastal Fisheries Resources Division at the La Jolla Laboratory conducts biological research on North Pacific albacore directed toward an understanding of the fish/fishery/environment interactions.

To improve the Center's near-term and long-range tuna research plans, two internal Workshops on Tuna and Billfish Research were convened in December 1979 and December 1980. Detailed plans were formulated which are within the framework of the principal objective of the Center's tuna research program, namely: To deliver information and advice to NMFS, the Department of State, U.S. Commissioners to international commissions, U.S. delegates and negotiators participating in bilateral or international negotiations, and fisheries managers in both the international and national arenas.

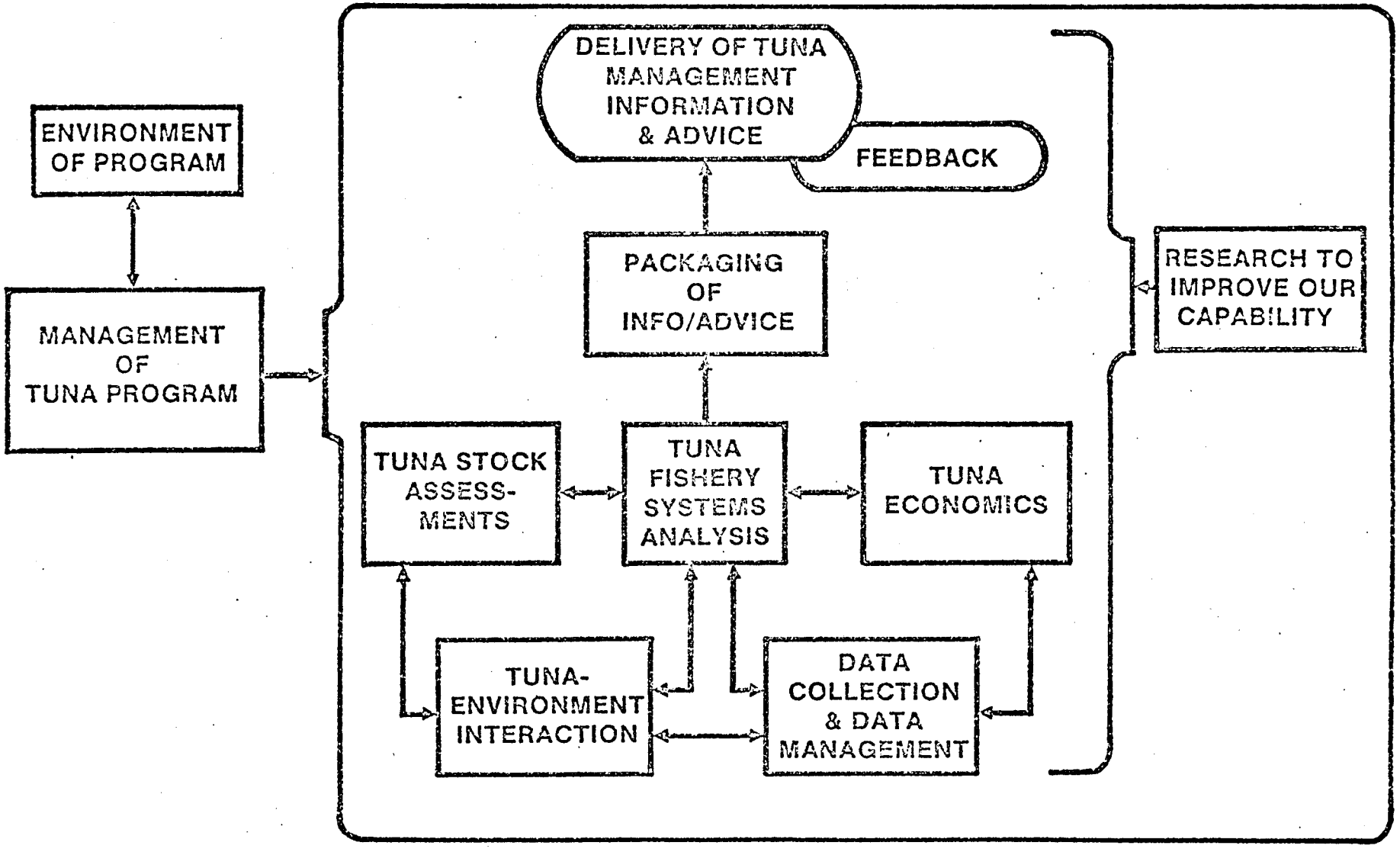
On the following page is a functional model of the SWFC Tuna Program. Among the functions which must be performed to deliver the information rquired for good management decisions are: stock assessments, economic analysis, data management, analysis of fish environment interactions, and system analysis which effectively ties the specialized information together.

These studies are being actively pursued at the SWFC, in cooperation with research organizations of many fishing nations throughout the world, and with international fisheries organizations. Our knowledge of these international fish and fisheries, based on these national and international studies, is growing steadily and is forming an increasingly valuable base for the rational management of tuna fisheries worldwide.

Izadore Barrett, Director
Southwest Fisheries Center

May 1981

SWFC TUNA PROGRAM: FUNCTIONAL MODEL



IN SUPPORT OF EXISTING INTERNATIONAL AGREEMENTS

NMFS/SWFC COOPERATION WITH THE INTER-AMERICAN TROPICAL TUNA COMMISSION

The historical commitment of Federal agencies to the Inter-American Tropical Tuna Commission (IATTC) is set out in the enabling legislation (Tuna Conventions Act of 1950)..."All agencies of the Federal government are authorized on request...to cooperate in the conduct of scientific and other programs, or to furnish facilities and personnel for the purpose of assisting the Commission in the performance of their duties."

At the 33rd meeting of IATTC in October 1976 it was agreed that the IATTC should concern itself with the problems arising from the tuna/porpoise relationship in the eastern Pacific Ocean as well as problems with the fish stocks themselves; some aspects of the tuna/porpoise work are carried out in cooperation with NMFS.

The staff of the Southwest Fisheries Center and the Inter-American Tropical Tuna Commission conducted a cooperative aerial photographic study of porpoise schools off the coast of Mexico, from November 3-December 15, 1980. This study was designed to obtain high resolution photographs which will permit measurement of lengths of animals and will validate the accuracy of aerial observer estimates of porpoise school sizes. Porpoise schools were photographed off the coast of La Paz, Puerto Vallarta, Acapulco, Zihuatanejo, and Tapachula, Mexico. Participating in the study from the La Jolla Laboratory were LCDR W. Perryman of the NOAA Corps assigned to the Southwest Fisheries Center, and F. Ralston. IATTC participants were M. Scott, J. Laake, and J. Niehaus.

Conditions for photography were very favorable and the party returned with an extensive collection of high resolution photographs. Commander Perryman headed up a team which has now completed cataloging and preparing the film for data extraction and analysis. The team used image enlargement and enhancement equipment at the NASA facility in Bay St. Louis, Mississippi, to enumerate individual animals in each suitable photograph. Data from this experiment will be useful in the estimation of absolute abundance and vital rate parameters of porpoise stocks in the eastern tropical Pacific.

INTERNATIONAL COMMISSION FOR THE CONSERVATION OF ATLANTIC TUNAS

A major and continuing obligation of the staff of the Tuna and Billfish Resources Program staff is to provide basic fishery analysis and management information on tunas and billfishes in support of the U.S. commitment to the International Commission for the Conservation of Atlantic Tunas (ICCAT) and to ICCAT's Standing Committee on Research and Statistics (SCRS).

In 1980 the SCRS meeting was held in Madrid, Spain, from November 3 to November 12. Scientists representing about 15 countries attended the meeting and participated in a review of scientific information to evaluate the condition of the Atlantic tuna and billfish stocks and to plan research activities for 1980-81. SWFC scientists attending the meeting included Dr. G. Sakagawa, Dr. W. Parks, Dr. N. Bartoo,and Mr. Dick Evans.

Eighty-six documents were reviewed by SCRS scientists who prepared status of stock reports on Atlantic tuna and billfish stocks to assist the Commission to identify needed conservation measures.

The SCRS appraisal of yellowfin tuna stocks remains unchanged from that in 1979. On an Atlantic-wide basis, yellowfin appear to be exploited at levels near MSY. Considered separately, yellowfin in the eastern Atlantic are fished near MSY while yellowfin in the western Atlantic are underexploited. Analyses suggest that there has been a slight recent increase in yield-per-recuit of yellowfin tuna. This increase is due to recent increases in the proportion of large fish in purse seine catches rather than a result of the 3.2-kg minimum size limit. No new management measures were recommended.

The committee's assessment of the condition of Atlantic skipjack stocks remains unchanged from that of last year. The resource appears to be exploited at a high level in the eastern Atlantic. However, the relationship of recent catches to MSY is unknown because it has not as yet been possible to estimate the potential yield of the stock. No management measures are currently needed.

The SCRS found that Atlantic bigeye tuna stocks are currently fished at levels below MSY. Increased effort would probably result in only marginal increases in yield. Increasing age at first capture would increase yield-per-recruit. It is too early to assess the effect of the 3.2-kg size limit enacted by ICCAT in September 1980. No additional management measures were recommended. Highlights of the SCRS appraisal area as follows:

The SCRS appraisal of albacore stocks indicated that both the northern and southern stocks are fished at levels somewhat below MSY. Recruitment for the northern stock shows a slightly downward trend while yield-per-recruit has increased slightly. The SCRS concluded that both stocks appear healthy, that some increase in catch could be realized with increased effort on the southern stock, and that no management is necessary.

The SCRS analysis of Atlantic bluefin tuna status has changed little from

that for 1979. Indications are that recruitment levels for both eastern and western stocks have been average or slightly below average since 1978. The 1973 year-class (west Atlantic) and 1974 year-class (east Atlantic) provided infusions of recruits (twice the average in the eastern Atlantic and four times the average in the western Atlantic) to the fishery and these fish are now making their presence felt in older age classes. These fish will not add to numbers of large fish (200 cm, age 10+) until 1983. Given current effort levels, the abundance of adult fish and very large fish is forecast to decrease over time. The average annual catch of age-0 and age-1 fish has apparently decreased 38% since the implementation of current minimum size limit and fishing mortality regulations. The committee recommended continuation of these measures.

The SCRS considered marlins, sailfish, and spearfish separately from swordfish. Catch and CPUE continue to decline for blue marlin, white marlin, and sailfish, and the exact status of these stocks is unknown. Assessment is complicated by the fact that white marlin catch data include catches of two and possibly three species which have been reported as white marlin. The SCRS recommended no management action for any of these species but indicated that they should be monitored closely.

The general lack of data on swordfish precludes any firm decisions on stock status at this time. Small increases of CPUE have occurred for both the Canadian harpoon and Japanese incidental longline catches. Yield-per-recruit analysis for the developing Florida straits longline fishery indicates that yield-per-recruit may be below an optimum level. No management action was recommended.

The SCRS prepared reports on multi-species aspects of fisheries for both temperate and tropical Atlantic tuna species. Multispecies interaction, especially for tropical species, will demand an increasing proportion of scientific attention in the future. The 3.2-kg size limit for yellowfin implemented in 1972 apparently led to misreporting of yellowfin as bigeye. The extension of 3.2-kg limit to bigeye in 1979 partially alleviated the problem. However, difficulties with enforcement and the discarding of small fish (yellowfin and bigeye) at sea makes consideration of alternate management schemes necessary. Management options designed to increase yield-per-recruit for yellowfin and bigeye must consider potential losses of skipjack catch as well as potential gains to catches of yellowfin and bigeye. The SCRS recommended that a wide range of data be collected to allow investigation of the multi-species aspects of tuna fishery management.

Several SCRS sub-committees and working groups met during the SCRS meeting. The sub-committee on Statistics met and reviewed progress and problems associated with the submission and quality of data. Numerous suggestions were made to improve data handling and quality. The sub-committee on Skipjack met and reviewed progress to date on the International Skipjack Year. Principal discussions concerned the data to be collected and the methods for archiving and later analyzing the data.

Two working groups, the Working Group on SCRS Organization and the Working group on Juvenile Tropical Tuna, met during the SCRS meeting. The Working Group on Organization suggested that the format used in 1980 be used again in 1981, incorporating a few small procedural changes. The Working Group on Juvenile Tuna recommended that a biostatistician or highly qualified sampler be sent to Africa to review the overall sampling scheme and help national scientists develop a sounder, more efficient sampling scheme for juvenile tunas.

The SCRS voted to allocate one day of its future meetings to discussions of a single important research issue. In 1981 the SCRS will discuss the topic of interactions between tuna and their environment. Participation by all segments of the research community will be encouraged.

The scientific quality of papers presented at ICCAT continues to be high. The foreign scientists, particularly the French, seem to have an excellent knowledge of their fisheries and tuna fishing in general, probably a result of their participation in at-sea fishing and sampling.

The ICCAT Commission met from November 12 to 18 to consider the SCRS findings and to deal with housekeeping matters. In attendance were representatives of 18 of the 19 member countries and a number of observers. No new management measures were adopted by the Commission. The Commission selected November 11-17, 1981, for its next meeting and proposed to hold the meeting in Spain but not in Madrid.

INTERNATIONAL SKIPJACK YEAR PROGRAM

During the past year Center scientists continued their involvement in the development of an intensified Atlantic-wide skipjack tuna research program sponsored by the International Commission for the Conservation of Atlantic Tunas (ICCAT). Almost three years in the planning, the program, now known as the International Skipjack Year Research Project, was developed and is being coordinated by ICCAT. The rationale for the research is that scientists believe skipjack tuna is the most abundant of the commercial species of tuna in the Atlantic. It was not exploited on a large scale until recently; since 1961 catches have increased rapidly, reaching a maximum of 117,000 metric tons (MT) in 1974, of which 19,973 MT were taken by United States flag fishing vessels. This catch represents a revenue of more than 20 million dollars to U.S. fishermen at today's prices. In 1977 the catch reached a peak of 107,000 MT, and the estimated catch for 1979 is about 90,000 MT.

With growing world demand for tuna and the fact that little increase in catch can be expected from the larger species of tuna from any ocean, including the Atlantic, there is an obvious opportunity for expanding production of Atlantic skipjack tuna. However, apart from a general feeling among fishery scientists that these stocks are not yet fully exploited, there is at present insufficient information to plan this expansion in a rational manner, avoiding on the one hand any failure to take advantage of

opportunities where they exist, and on the other hand, damaging the stocks and the fisheries on them through overdevelopment and overexploitation.

As currently designed, the program will extend four years. A planning phase was executed during 1979 and a limited execution phase was begun during 1980. The "International Skipjack Year," when most research will take place, is now fully underway. The final year, 1982, will focus on evaluating data collected.

The program is designed as one in which ICCAT coordinates the collective inputs of the 19 ICCAT member countries who supply vessels, gear, and research expertise.

As part of U.S. contribution to this international program, the Southwest Fisheries Center conducted a skipjack tuna tagging cruise in the Caribbean and western Atlantic during early 1980. A report of cruise activities, including preliminary results, was presented in a paper by R. Rinaldo and R. Evans of the SWFC, and P. Vergne of Living Marine Resources in San Diego. The paper was submitted as a U.S. document to the 1980 meeting of ICCAT's Standing Committee on Research and Statistics.

International Skipjack Year tag recovery stations have been established in La Jolla and Puerto Rico to collect tag recovery and related information on recaptured tuna that are retrieved by fishermen and by unloading and cannery workers, as well as scientific technicians working in ports and aboard vessels. To date 80 ISY tags have been recovered at the U.S. stations. Of these, 7 were from fish tagged during the U.S. tagging cruise.

Atilio Coan, Mathematician, and Fishery Biologist Ronald Rinaldo of the Southwest Fisheries Center, together with ICCAT representative Philip Symons, collaborated on the design and preparation of port sampling, shipboard sampling, and laboratory manuals for the ISY. It is expected that these manuals will greatly enhance ISY data collection and processing activities.

INDIAN OCEAN TUNA RESEARCH AND DEVELOPMENT

Richard S. Shomura, Director of the Honolulu Laboratory, SWFC, and U.S. Alternate Delegate, participated in the 19th Session of the Indo-Pacific Fishery Commission (IPFC), May 21-30, 1980, and attended the Symposium on Development and Management of Small-Scale Fisheries, May 21-23, in Kyoto, Japan. Among the agenda items of this session was management of tuna in the IPFC area. A report was presented of the Sixth Joint Meeting of the Indian Ocean Fishery Commission (IOFC) Committee on Management of Indian Ocean Tuna and IPFC Special Committee on Management of Indo-Pacific Tuna which was held in February 1980, in Perth, Australia. Relative to tuna, IPFC recommended that (1) FAO should seek funding to add a tuna scientist to the FAO/UNDP Project for Tuna Management in the Indian and Pacific Oceans, (2) in consultation with the IPFC and IOFC Tuna Management Committees, FAO should develop a program and seek funds for the program, and (3) the FAO/UNDP Project

for Tuna Management in the Indian and Pacific Oceans should prepare a field manual for the collection of fishery statistics.

SOUTH PACIFIC COMMISSION

In November 1980 Dr. Jerry A. Wetherall, Leader of the Stock Assessment Study Task, Honolulu Laboratory, SWFC, attended the South Pacific Commission's (SPC) Twelfth Regional Technical Meeting on Fisheries in Noumea, New Caledonia. The meeting considered various past and ongoing fishery projects in the SPC area including some results from the SPC Skipjack Survey and Assessment Programme. Working papers on tuna presented at the meeting included those relating to skipjack tuna and yellowfin tuna migration in the SPC area; skipjack tuna blood genetics analyses, growth and cannibalism; size and maturity of tunas; and a comparison of wild and cultured baitfish species for pole-and-line fishing.

Fishery Data Provided Government of Niue

The Honolulu Laboratory maintains a data base on catch and effort statistics of Japanese, Korean, and Taiwanese longline fisheries in the Pacific Ocean. Many South Pacific island political entities regard fishery resources as one of the few resources available to them for foreign exchange. Because these island governments lack data on the fishery resources in their area, they have often turned to the Southwest Fisheries Center's Honolulu Laboratory for such data.

In February 1981 the Government of Niue, through official State Department channels, requested assistance in obtaining historical data on fish catches in Niue waters. In response to this request, the Honolulu Laboratory provided estimates of the total tonnage of tunas and billfishes caught by longline vessels in Niue waters (based on an assumed 200-mile exclusive economic zone around Niue) during the period from 1965 to 1978. The annual catch of yellowfin tuna in the area ranged from 5 to 70 metric tons between 1965 and 1978. Albacore catches ranged from 31 to 277 metric tons during the same period. Other tunas caught in the area included bigeye, bluefin, and skipjack tunas. The catch of billfishes included blue marlin, striped marlin, black marlin, swordfish, and sailfish.

IN SUPPORT OF POSSIBLE FUTURE INTERNATIONAL AGREEMENTS

NORTH PACIFIC ALBACORE

Fifth North Pacific Albacore Workshop

The Fifth North Pacific Albacore Workshop was held June 30 through July 3, 1980, at the Southwest Fisheries Center in La Jolla, California. The North Pacific Albacore Workshop series began in 1974 as an informal agreement between the Far Seas Fisheries Research Laboratory (FSFRL) and the Southwest Fisheries Center (SWFC) and includes scientists from Canada, Taiwan, state agencies, and universities. The purpose of the 1980 Workshop was to investigate the population dynamics, biology, and ecology associated with the North Pacific albacore.

Attending from the SWFC were N. Bartoo, R. M. Laurs, R. Lynn, W. Parks, G. Sakagawa, and E. Weber. Representing the states of Washington, Oregon, and California were B. Culver, L. Hreha, and F. Hagerman, respectively. L. J. Bledsoe attended from the University of Washington. Japan was represented by M. Honura, S. Kume, and I. Yamanaka. Canada and Taiwan were represented by K. Ketchen and R. T. Yang, respectively.

A summary of papers presented to the Albacore Workshop by U.S. participants follows:

M. Laurs and R. Nishimoto presented results on the evaluation of otolith daily growth ring increments. The authors concluded that for practical purposes, the rings are indeed deposited daily and this opens the way to resolve the controversy concerning the size of albacore on their first and second birthdays. The ageing procedure, however, is extremely tedious and time-consuming, and a less arduous technique of age determination obviously would be preferable.

Through the cooperation of various fisheries agencies, finray samples from a wide size range of fish are now at hand from several areas of the North Pacific. Collection of more samples and re-examination of existing material are required to resolve current difficulties. In addition, further study of tetracycline-injected specimens is urgently required to calibrate the method and verify annual deposition of a single growth check.

Laurs et al. also presented new information from ultrasonic tracking of albacore. Telemetered data (covering up to 30-hour time spans) on swimming depth and water temperature show that, contrary to earlier information and assumptions, albacore may spend relatively lengthy periods beyond the bounds of their so-called preferred temperature range (15°-20° C). These short-term studies revealed that tagged fish will not only occupy water of 10°- 13° C but will make rapid sorties over a depth range in which temperature change is as much as 5° C. Telemetered data also showed apparent day-night depth preferences and differences in the behavior of assumed migrating versus nonmigrating fish. This new information has implications in understanding variations in the availability of albacore to conventional surface fishing gears.

Yield-per-recruit studies by Bartoo, and investigation by Weber of possible interaction among the three principal North Pacific fisheries, were presented. Both fields of investigation depend on age structures generated from the von Bertalanffy growth evaluation. Reliability of the conclusions, therefore, hinge in part on the accuracy of assumed growth parameters. Some revisions in results can be anticipated as better information on the latter emerges from current age and growth studies.

Catches of North Pacific albacore by Korean and Taiwanese longliners based in American Samoa were reviewed by J. Wetherall and M. Yong. These catches are still insignificant in terms of impact on the North Pacific albacore stock. North Pacific albacore from American Samoan-based Korean longliners totaled 13 metric tons in 1977 and 4 metric tons in 1978. Landing totals for the Taiwanese vessels in this area were reported by Dr. Yang. Taiwan began fishing albacore with measurable effort on the high seas of the North Pacific for the first time in 1977. Albacore catches in this multi-species longline fishery totaled 551, 6, and 35 MT for the years 1977, 1978, and 1979, respectively. Albacore catch for the first quarter of 1980 is an estimated 150 MT. Number of vessels operating in the fishery in the entire Pacific was 309 in 1977, 302 in 1978, 157 in 1979, and 160 thus far in 1980. Landings for the Taiwanese inshore tuna longline fishery is estimated to be in the range of 15-47 MT annually since 1964.

Canadian catch of albacore in 1979 was estimated at 520 MT, substantially more than in the preceding 4 years. This was despite a late start, inclement weather, and an imposition by the U.S. of an embargo on tuna products from Canada. The fishery was concentrated along a temperature front off the entrance to Queen Charlotte Sound. Most of the catch was made in the last two weeks of August during which period catch rates averaged 112 fish per boat day. Average weight of individual fish caught was 6.8 kg and 60% were in the 5.9 to 7.3 kg range.

The workshop participants evaluated the condition of the stock, given available data and analyses.

The production model analysis suggests that MSY is in the 104,000-236,000 MT range. However, of the models used to fit the data, the best fit model fits the data only 6% better than the worst-fit model so it is impossible to objectively choose a particular MSY from the 104,000-236,000 MT range. Assuming that any MSY in this range is equally likely, the midpoint value, 170,000 MT, might be reasonable. Effort corresponding to this MSY is not identified.

An additional estimate of MSY is obtained by multiplying maximum yield-per-recruit and recruitment from cohort and yield-per-recruit analyses. This procedure suggests an MSY in excess of 113,000 MT.

The 170,000 MT estimate of MSY is 40% greater than the maximum historical recorded catch of about 124,000 MT taken in 1976. The 113,000 estimate is 7% less than this maximum. Thus, the comparison of MSY with recent catches suggests that the recent fishery may be operating in the neighborhood of MSY. Previous North Pacific albacore workshops have estimated likely MSY values in

the range of 100,000-130,000 MT. As stated in the past, these MSY estimates are put forth with a great deal of caution and additional work is needed.

As noted in the 1979 report, increasing catches of small albacore may eventually reduce spawning stock size which, in turn, may reduce subsequent recruitment. Whether the latter will, in fact, occur cannot be determined until a reliable stock-recruitment model is developed.

Cooperative NMFS-AFRF Albacore Studies

The NMFS La Jolla Laboratory and the American Fishermen's Research Foundation (AFRF) continued cooperative albacore studies designed to obtain information to increase the understanding of the North Pacific albacore resource and to improve harvesting of the resource by U.S. fishermen.

During the 1980 season, joint NMFS-AFRF research activities included (1) a tagging program off northern Baja California and central California of the "southern" group of albacore as part of a study of the migration patterns of this group of fish, (2) a within-season exploratory/research survey in waters several hundred of miles off the Pacific Northwest, (3) tagging in the western Pacific, and (4) albacore exploration in mid-winter 1981.

Albacore Tagging Studies

During 1980, 1094 albacore were tagged and released, bringing the total number of albacore tagged since the start of the cooperative NMFS-AFRF tagging program in 1971 to 17,731. A summary by year of the number of albacore tagged, recovered, and percent recovery is given in Table 1.

Table 1. Summary by year of number of albacore tagged and percent recovery for joint NMFS-AFRF albacore tagging program.

Year	Number of tagged fish released	Number of tagged fish recovered	Percent recovery
1971	887	34	3.83
1972	2082	181	8.69
1973	1805	111	6.15
1974	2486	175	7.04
1975	1349	116	8.60
1976	1581	88	5.57
1977	2061	129	6.26
1978	2719	164	6.03
1979	1667	47	2.82
Unknown	+	6	0.09
Total	17731	1051	5.93
1980	1094	-0-	--

Exploratory Albacore Longlining Operation Conducted in Mid-Winter, 1981

Three chartered commercial fishing vessels using modified halibut longlining gear conducted an exploratory albacore longlining operation 700 to 900 n. miles west of San Diego during January-February 1981. The objective of this investigation was to evaluate the potential for establishing a U.S. fishery on the southern substock of North Pacific albacore tuna during winter months in eastern North Pacific waters. The U.S. albacore fishery currently does not operate in the winter, and in the selected area limited exploratory troll fishing has taken place only during other seasons of the year. Among the purposes of the study were to (1) conduct exploratory fishing using trolling and longline fishing methods to evaluate the feasibility of catching albacore; (2) make scientific observations to determine oceanographic conditions that may influence albacore distribution and relative abundance; and (3) collect data for albacore biology and fishery studies.

This cooperative study was carried out by the NMFS Southwest Fisheries Center and the U.S. albacore fishing industry's American Fishermen's Research Foundation (AFRF). Saltonstall-Kennedy funds awarded to the AFRF were used to charter fishing vessels and finance other costs to conduct the study. Fishery scientists at the Center planned the overall project and worked with the AFRF to organize the study. The actual operational aspects of the study were carried out by the AFRF. The SWFC provided scientific equipment and three Center scientists went aboard one of the chartered fishing vessels to make scientific observations and keep detailed records related to the fishing operations.

Results from this study suggest that the U.S. albacore fishery can be expanded to operate during the winter months. Within a large area 700 to 900 miles west of San Diego, albacore were caught each day during exploratory longline fishing operations. Logistic considerations limited the westward extent of this study; it is believed, however, that good fishing success may also be expected farther to the west, probably to at least the longitude of the Hawaiian Islands.

It appears that albacore production may average approximately 3,000 pounds per set using a longline with 1,500 to 2,000 hooks. This production estimate is based on an extrapolation of fish catches made using about 300 hooks. Experience gained during the study indicates that a 3-man crew can handle a 1,500 to 2,000 hook longline and that 50 to 75 foot vessels, typical of the U.S. albacore fleet, can operate in the latitudes of the area under study during winter months. More exploratory effort is needed in trolling to arrive at conclusions regarding potential yields. However, the catches made as a result of the small effort expended during this study were encouraging.

A detailed report of the results obtained during the study is available from the Director, Southwest Fisheries Center (NOAA-Technical Memorandum-NMFS-SWFC-10. March, 1981, 40 pages).

1980 U.S. Albacore Fishery Sampling

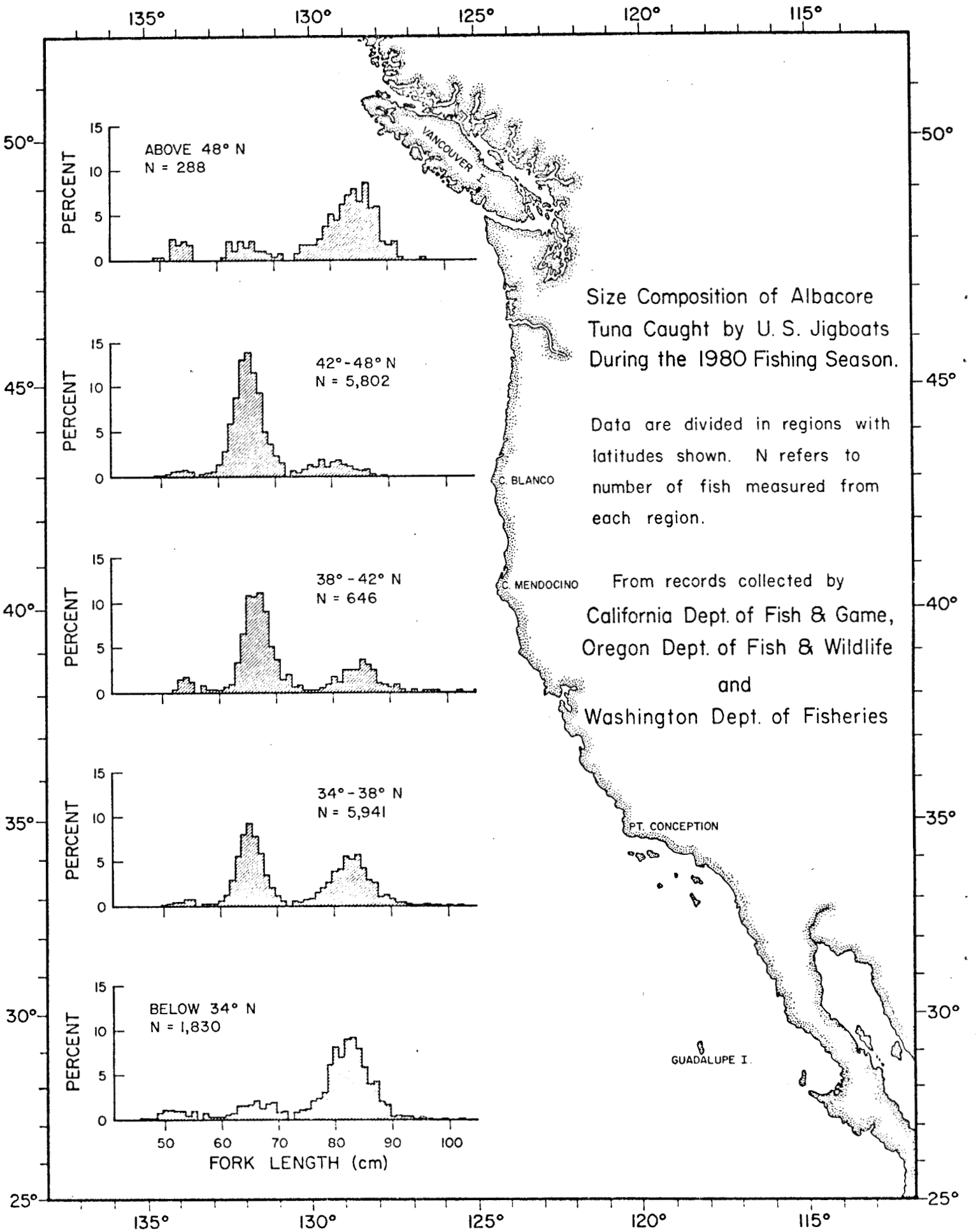
In 1980, the U.S. albacore fishery was intensively sampled for catch, effort, and length-frequency data. With cooperation from the state fisheries agencies in the states of Washington, Oregon, and California, Pacific Marine Fisheries Commission, and members of the Western Fishboat Owners' Association, voluntary logbook data and catch length-frequency data were collected, compiled, and summarized. The summary data, prepared by Fishery Biologist Tony Majors, were distributed to interested scientific and industry individuals and groups.

A total of 17,807 fish were measured for fork length. The data, summarized by gear and area, are shown in the accompanying figures.

Investigation of Albacore Growth Parameters

Estimates of growth parameters for North Pacific albacore, based on tag-recapture statistics, were investigated using the standard von Bertalanffy model and an extended model. Sequential estimation of L and K was used to test hypotheses concerning variation in growth rate between tagged albacore recaptured in different ocean regions.

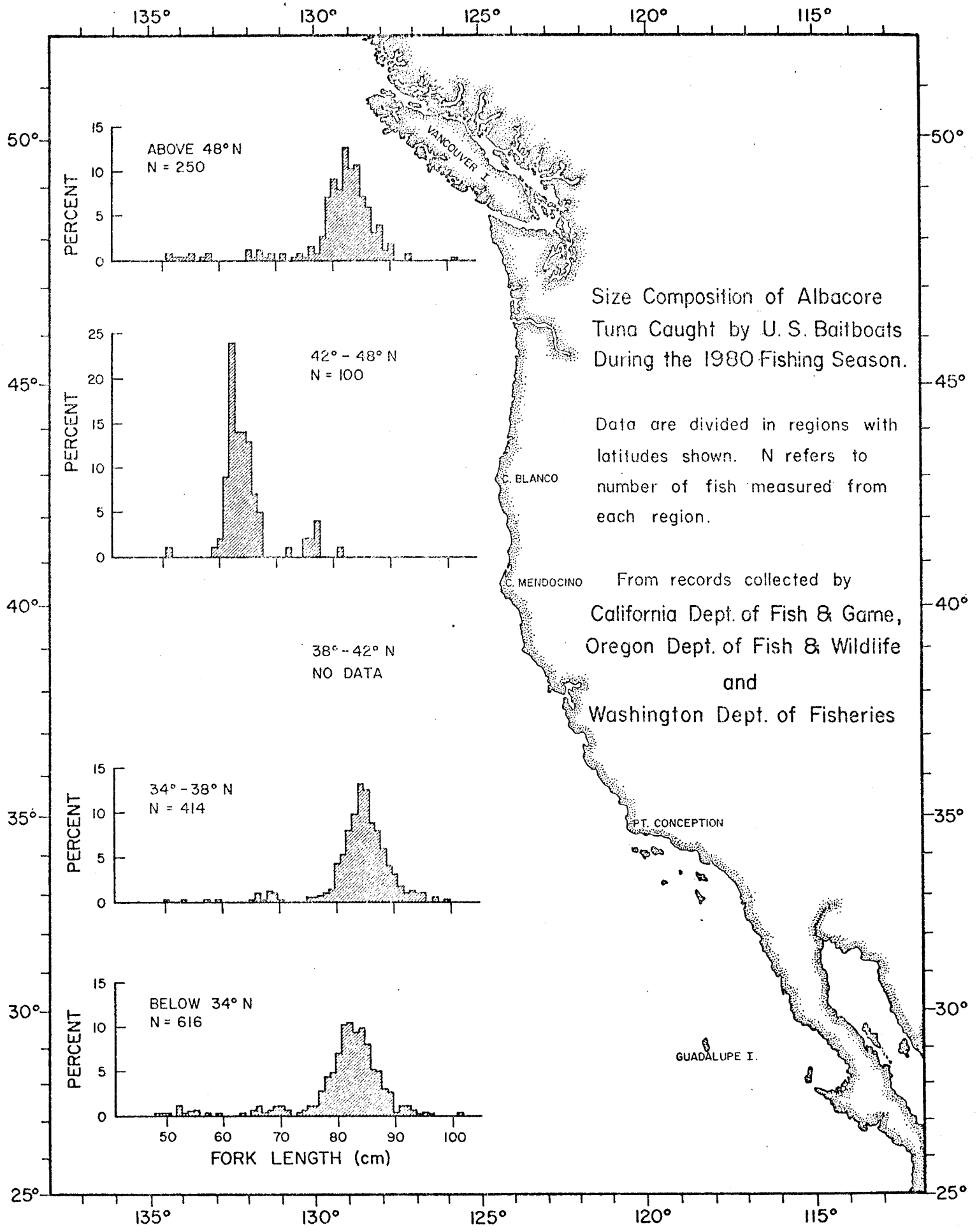
Results show that the growth rate of North Pacific albacore recaptured either off the coast of North America north of lat. 40° N or in the western North Pacific off Japan was significantly lower than for tagged albacore recaptured off North America south of lat. 40° N during 1972-1978. The differences in growth rate of tagged fish are remarkably consistent with differences in length-frequency distributions of albacore caught off North America north and south of lat. 38° N during the period when most recaptures were made. These findings add to a growing body of evidence that North Pacific albacore are not as homogeneous as usually assumed, and that there may be at least two subgroups of albacore: one which supported the Japanese pole-and-line fishery and the United States and Canadian fisheries in waters north of about lat. 40° N from 1972-1978, and another which did not contribute significantly to the Japanese surface fishery, but supported the U.S. coastal fishery south of lat. 40° N during this period. If such a distinction is valid, the situation is surely more complex and dynamic than supposed, with each stock's contribution to each fishery varying from year to year. Presumably such variation would be tied directly to changes in oceanographic conditions. Likely the latitudinal boundary was not fixed exactly at lat. 40° N during 1972-1978, as was assumed; however, analyses based on assumed boundaries at lat. 38° N and 42° N gave the same results. If an accurate assignment of tagged fish to "stock" were possible, a more powerful test of growth differences could be made.



Size Composition of Albacore Tuna Caught by U. S. Jigboats During the 1980 Fishing Season.

Data are divided in regions with latitudes shown. N refers to number of fish measured from each region.

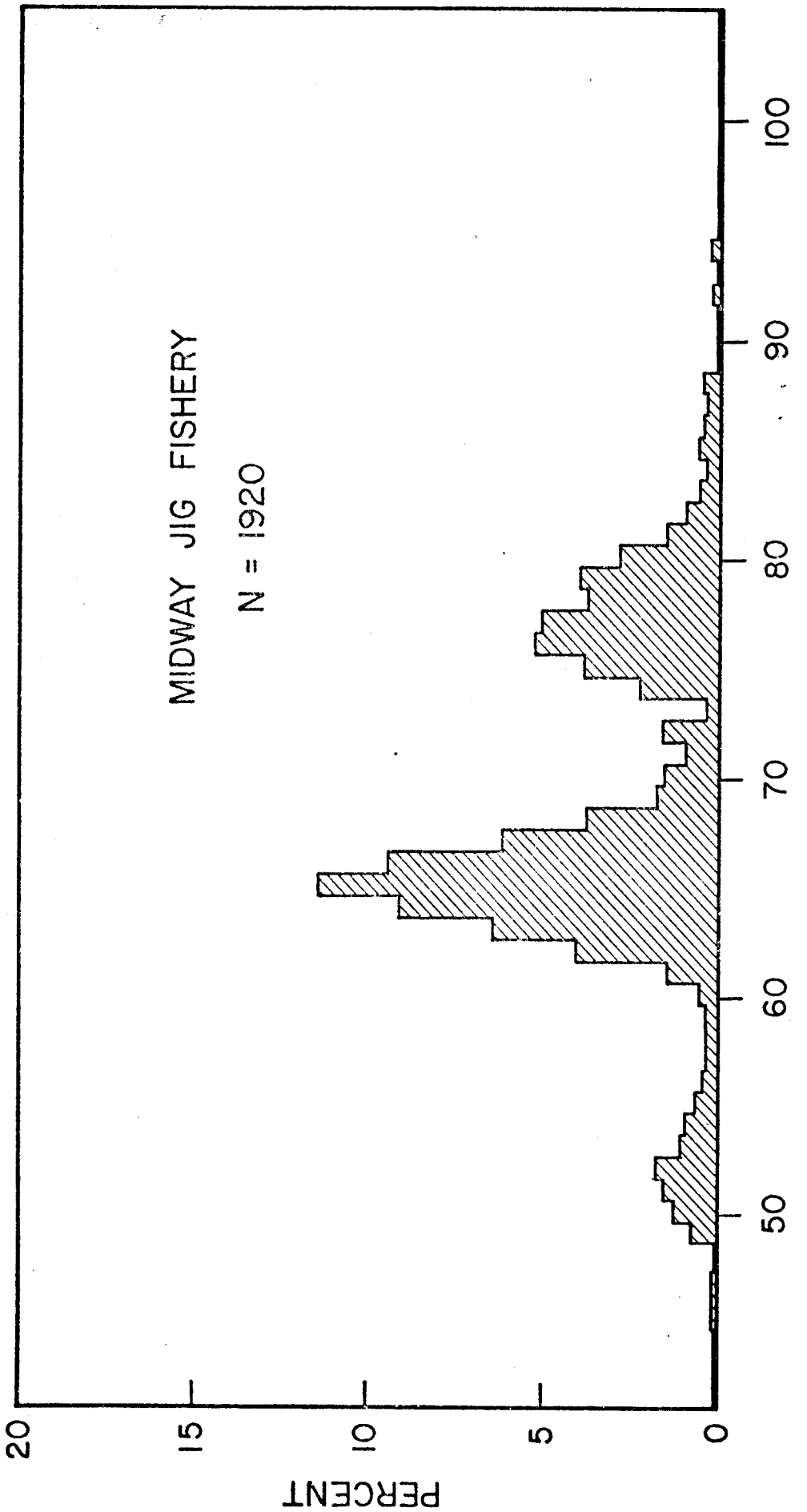
From records collected by California Dept. of Fish & Game, Oregon Dept. of Fish & Wildlife and Washington Dept. of Fisheries



Size Composition of Albacore Tuna Caught by U. S. Baitboats During the 1980 Fishing Season.

Data are divided in regions with latitudes shown. N refers to number of fish measured from each region.

From records collected by California Dept. of Fish & Game, Oregon Dept. of Fish & Wildlife and Washington Dept. of Fisheries



The size composition of North Pacific albacore caught in the U.S. Midway jig fishery in 1980.

A finding that more than one subpopulation or stock is involved in the North Pacific albacore fisheries would have important consequences, both for stock assessment, fishery evaluation, and management policy analysis, and for development of accurate catch forecasting systems. It is important that further work be done to identify stocks, and to elucidate their origins, migratory habits, and degree of interchange.

Results from Tetracycline Experiment to Evaluate Otolith Daily Ring Increment Method for Age Determination in North Pacific Albacore

The daily ring increment method of ageing fishes assumes that there is a daily ring deposition on the otolith. An experiment is being conducted to determine if this assumption is valid for albacore.

A total of 2,544 albacore was injected, tagged, and released during the field operations of the tetracycline/otolith daily ring study. There have been 140 recoveries of the tetracycline-injected fish. However, in some cases the otoliths or information on time at liberty were not available, so there were not sufficient data from all the recoveries to use in the analysis of the results. Otoliths from 104 albacore injected with tetracycline were examined. Otoliths from eight of these fish did not show any tetracycline "mark." This was found to have resulted (1) from a defective tetracycline solution which was used to inject a small number of fish at the start of the experiment, and (2) apparently from improper injection techniques where the hypodermic needle was withdrawn too quickly and the tetracycline solution leaked out. Tetracycline "marks" were apparent on otoliths from 96 fish. Under ultraviolet illumination, the appearance of the "marks" ranged from bright and clearly visible, to faint and sometimes difficult to see. However, in all 96 cases it was possible to locate the "mark" and make the ring counts.

The results obtained thus far from this experiment indicate that for tetracycline-injected albacore, the relationship between otolith ring increments and days at liberty is nearly 1:1. This finding suggests that the basic assumption of the otolith daily ring increment ageing method is valid for albacore, at least over the size range of fish that were injected, and that the method may be successfully used to age North Pacific albacore.

Albacore Physiology Studies

A scientific team of marine biologists, oceanographers, and medical scientists participated on a 14-day albacore physiology cruise aboard the NOAA research vessel, David Starr Jordan, off the coast of southern California in late July. It was the fourth in a series of annual albacore "environment/physiology" cruises. Cruise participants included scientists from the Southwest Fisheries Center, the University of California at San Diego (UCSD) School of Medicine, Scripps Institution of Oceanography, and the Scripps Clinic and Research Foundation.

The overall purpose of the environmental physiology research on albacore tuna is to provide a basic knowledge of the physiology of the fish and its ocean environment with the objective of understanding causal factors underlying albacore-oceanography relationships important in determining their migration, distribution, and availability.

Researchers participating on the cruise made a number of significant findings, including (1) the simultaneous measurements of cardiac output, heart rate, blood pressure, and regional blood flow; (2) successful culturing of whole blood for chromosome isolation and isolation of chromosomes for karyo-typing studies; (3) the first measurements which demonstrate thermoregulation and the effects of various drugs on the thermoregulation process in albacore; (4) blood chemistry and hematology studies; (5) vascular anatomy studies; (6) anesthesia studies; and (7) further developments and improvements in a life-support system for holding and transporting live albacore.

In addition to the physiology and biochemistry studies conducted on live albacore aboard the Jordan, oceanographic measurements were also made during part of the cruise in support of albacore acoustic tracking studies carried out on the F/V Shrike, on charter to AFRF. Several albacore equipped with acoustic transmitters that telemetered depth of swimming were tracked for varying periods up to about 8 hours. The experiments yielded similar results to those found in 1979 which showed that albacore (1) spent most of the time in water temperatures considerably below what has been believed to be within the optimal temperature preference for albacore, (2) spent most of the time in or below the thermocline, and (3) spent virtually no time in the upper mixed layer.

1980 U.S. Albacore Landings Low for Second Consecutive Year

Relatively poor fishing success in 1980 marked the U.S. albacore fishery for the second consecutive year. Landings through October are estimated to total a little over 8,000 metric tons. This is only slightly higher than the total landings made in 1979, and considerably below the seasonal 10-year average of about 23,000 metric tons.

There appear to be a number of factors contributing to the low landings of albacore in 1980 including: (1) the late arrival of the northern substock of fish into waters off the Pacific Northwest, (2) the failure of the fishery to develop fully off southern and central California despite an initial early appearance of fish, (3) the low availability of 12 to 15-pound (5.5 to 6.8 kg) fish off California south of Cape Mendocino (this size of fish normally makes up a significant portion of the U.S. catch), (4) fish not biting, in particular in the Cortes Bank and San Juan Seamount areas and off central California, and (5) high winds and rough seas hampering fishing effort, notably off California.

Some of the most consistent catches during the 1980 season were made during the last half of October. A fleet of approximately 75 to 100 jig and

baitboats operated in the area centered approximately 140 miles off the coast between Pt. Sur and Pt. Arena. Catches were generally 1/2 to 3/4 metric tons per day for jigboats and 1 to 5 metric tons per day for baitboats, with top daily scores of about 1 ton for jigboats and 9 tons for baitboats. The fish caught were large, ranging mostly between 25 to 35 pounds (11.4 to 15.9 kg), with some fish over 50 pounds (22.7 kg) being landed. The catches were reported to have been made in waters with sea surface temperatures of 60 to 61° F (15.6 to 16.1° C).

Development of Dynamic Albacore Management Model Started

A new Southwest Fisheries Center initiative is to model the North Pacific albacore fisheries with variables of the ocean environment as input. The effectiveness and success of the model depends on inputs from a broad range of sources of information.

The purpose of the albacore modeling project is to improve the assessment of albacore stocks by (1) making a mathematical statement of current hypotheses on albacore stock dynamics (growth, mortality, recruitment, and migration as related to environment) for comparison with observed data (fishery, tagging, oceanographic et al.) as a test of the consistency of these hypotheses; (2) developing alternate hypotheses to explain inconsistencies revealed by (1); and (3) guiding plans for further research to illuminate areas of inconsistency revealed by (1) and (2). Success in the above objectives will lead to improved management advice.

The basic model development is being done by Dr. L. J. Bledsoe of the University of Washington's Center for Quantitative Science, in consultation with Center scientists.

SOUTH PACIFIC ALBACORE

Operations of American Samoa-Based Longline Fleet in the North Pacific Analyzed

Dr. Jerry A. Wetherall, Leader, Stock Assessment Study, and Marian Y. Y. Yong, Mathematician, completed an analysis of catch and effort data of American-Samoa based longliners operating in the North Pacific. Although the American Samoa-based fleets from Taiwan and Korea still fish mostly south of the Equator in the South Pacific albacore grounds or in equatorial waters, a small number of fishing trips have been made in the northern winter into the midlatitudes of the North Pacific in recent years. North Pacific albacore comprise most of their catch in the area between lat. 10° and 35° N. Wetherall and Yong summarized the results of their study in an Administrative Report for presentation at the 5th North Pacific Albacore Workshop held at the Southwest Fisheries Center, La Jolla, from June 30 to July 3, 1980.

NORTH PACIFIC BLUEFIN TUNA

Bluefin Tuna Study

The first phase of the cooperative Southwest Fisheries Center-California Department of Fish and Game Pacific bluefin tuna study was completed at the end of 1980. During that time California Department of Fish and Game Marine Biologist Doyle Hanan established a computer-accessible data base, including the raw data from the CF&G tuna fisheries monitoring and tagging studies. Much of these data were summarized and together with an overview of northern bluefin formed the final contract report.

The second phase of the cooperative study has started with Hanan utilizing the data base to analyze and evaluate the northern Pacific bluefin fishery.

The 1980 commercial catch of northern bluefin in the eastern Pacific was 3,128 metric tons, representing the lowest total catch since 1952 (2,076 metric tons). The 1980 catch continues a 19-year decreasing trend of eastern Pacific catches which began in 1966 (16,846 metric tons). The 1980 commercial passenger fishing vessel (partyboat) catch was 482 fish, also one of the lowest catches on record and continuing a decreasing trend that parallels the commercial catch.

SOUTH PACIFIC FISHERIES AGENCY

The primary activity of the Southwest Fisheries Center with regard to the Forum Fisheries Agency (FFA) has been to monitor its activities. Mr. Philip Muller of Western Samoa was recently appointed Director of the FFA. Mr. Richard James who served as Acting Director was appointed as Deputy Director. Mr. James previously headed the fisheries department of the Solomon Islands Government. Copies of a draft document, "South Pacific Forum Fisheries Agency Approved Work Programme 1980/1981," were made available to participants at the South Pacific Commission's Twelfth Regional Technical Meeting on Fisheries. Included in the document are proposed guidelines on the work program of FFA in marketing, statistics, negotiations, development and management, research, technology, surveillance, and enforcement and training.

IN SUPPORT OF DOMESTIC REQUIREMENTS

WESTERN PACIFIC FISHERY MANAGEMENT COUNCIL BILLFISH MANAGEMENT PLAN

In cooperation with the Western Pacific Regional Fishery Management Council, the staff of the Honolulu Lboratory completed a variety of tasks related to the Council's effort in preparing a Fishery Management Plan for the Billfishes of the Western Pacific. Data on total landings and vessel statistics for the foreign longliners based at Pago Pago, American Samoa, were summarized for inclusion in the FMP. Also, Japanese tuna and billfish catch and effort statistics were summarized by 1° squares around Guam. The latter summarizations were used by Dr. Steven S. Amesbury of the University of Guam, to develop policy alternatives concerning foreign fishing within the U.S. Fishery Conservation Zone around Guam for the billfish FMP. Similar policy alternatives were developed earlier for foreign fishing in the FCZ around Hawaii and American Samoa based on the Honolulu Laboratory tuna and billfish data base.

Except for a few final adjustments, the billfish FMP is ready for forwarding to Washington for public clearance.

PACIFIC FISHERY MANAGEMENT COUNCIL BILLFISH AND OCEANIC SHARK MANAGEMENT PLAN DEVELOPMENT

The process for development of a Fishery Management Plan (FMP) for billfish and oceanic shark began in early 1978 when joint development of a FMP between the Western Pacific Fishery Council and the Pacific Fishery Council was approved by the Secretary of Commerce, the two Fishery Councils, and their respective Scientific and Statistical Committees. This arrangement was subsequently changed, and each Council was given the go-ahead to develop its own management plan.

In May 1979 the first draft of the FMP for Billfish and Oceanic Shark, prepared by the FMP Development Team, was submitted to the Pacific Fishery Management Council for their review. In late 1979, development of the FMP was delayed pending litigation over the state's authority over its citizens and beyond the limits of the territorial sea (three nautical miles).

In May 1980, the Pacific Fishery Management Council decided to continue development of the second draft of the FMP. The California State Supreme court's decision was favorable to the state to control the activities of its citizens with regard to swordfish fishing outside the territorial sea. One of the major factors in the decision was that, since the Federal Government did not have any conservation regulations in effect, the state should continue to administer management. The case (Teague versus California), resulting from an arrest of a harpoon swordfish crew and boat for using an aircraft to locate and direct swordfish fishing operations, was later appealed to the U.S. Supreme court. Preliminary arguments were presented and the Court refused to hear the case at this time.

The FMP Development Team and the Advisory Panel have revised the list of objectives. Two working drafts have been prepared since mid-1980 and currently a final working draft is being edited and prepared for presentation to the Advisory Panel and later the Council.

A range of management options have been defined and the FMP team has ranked the options relative to their meeting the FMP objective. The second draft, which will include the management options and their ranking, is expected to be given to the Council by mid-summer, 1981.

PACIFIC COOPERATIVE MARINE GAME FISH TAGGING

Since 1954, billfish have been tagged by cooperative marine game fish tagging programs in many of the major sportfishing areas of the Pacific. The marine game fish tagging program is currently supported by the National Marine Fisheries Service in cooperation with the International Game Fish Association.

James Squire, Fishery Biologist at the La Jolla Laboratory who coordinates the tagging program, reports that 1,725 fish were reported tagged and released in 1980. This is a 57% increase in number of fish tagged over the 1979 record of 989 fish. Billfish accounted for 1,438 or 83% of the fish tagged in 1980.

1980 was a record year for the tagging of striped marlin (Tetrapturus audax): 1202 (84%) of the tags reported received at the Southwest Fisheries Center was for this fish. Other tagged billfish included sailfish (Istiophorus platypterus), 157 tagged, (11%); blue marlin (Makaira nigricans), 21 tagged (1%); black marlin (Makaira indica), 54 tagged (4%); shortbilled spearfish (Tetrapturus augustirostris), 2 tagged (< 1%; swordfish (Xiphias gladius), 1 tagged (< 1%); and one marlin, unidentified.

Increased tagging of billfish (striped marlin, swordfish) and species of oceanic shark (thresher, mako and blue shark) is being encouraged in the U.S. waters off Southern California, in cooperation with the National Coalition of Marine Conservation, the State of California Department of Fish and Game, and the National Marine Fisheries Service. The tagging program for billfish (blue, striped, sailfish, and shortbilled spearfish) in the central Pacific is being coordinated by the Pacific Gamefish Foundation, Honolulu, Hawaii. Dr. Richard Brill, Scientific Director, heads that program.

Of the fish tagged in past years, a total of 24 were reported recovered in 1980, an increase of 7 recoveries over the number reported in 1979. One of these was the first recovery of a striped marlin in southern California waters from a marlin tagged about the southern tip of Baja California, Mexico. On June 9, 1980 Mr. Mark Bryant of Mission Viejo, California, tagged and released the striped marlin off Cabo San Lucas while fishing with Captain Jim Donnelly. The marlin was recovered in October near Santa Barbara Island by Mr. Boyd F. Groom of Santa Barbara. Only two other tagged striped marlin have been

recovered off southern California, having been tagged off southern California one year previous to recovery.

Another interesting recovery tends to indicate that the giant black sea bass (grouper) common to the southern California coast and offshore islands have limited migration. Divers from the Los Angeles Council of Divers have reported tagging 19 giant sea bass, all near Anacapa Island off the southern California coast. On August 16, 1980 a tagged black sea bass was recovered that had been tagged on September 8, 1973, near the original tagging location. Of the seven tags recovered, only one was recaptured away from the general area of tagging, and this only a short distance. Of the 19 fish tagged, 7 have been recaptured, for a total recapture rate of 37%.

Other recoveries include two yellowtail (New Zealand), two mako sharks (New Zealand), one white-tipped whale shark (Australia), one trevally (New Zealand), and one dog-tooth tuna (Australia).

PACIFIC INTERNATIONAL BILLFISH ANGLER SURVEY

The Pacific International Billfish Angler Survey is conducted annually throughout the Pacific area in cooperation with the International Game Fish Association, and with the assistance of the Pacific Gamefish Foundation and marine angling clubs. Information collected through this annual survey, started in 1969, is made available to any interested organization.

The 1980 survey (now in progress) is the 12th annual survey conducted in the Pacific area to determine the trend in billfishing in terms of catch per angler day for billfish fishing locations. The information derived from this survey is summarized by geographical areas and species caught and is "public information" available to anyone interested in the trend of billfish fishing. These data have been used by governments and organizations in development of management plans for billfish fisheries common to their countries' waters.

This is the only international survey conducted to determine trends in angler billfish catch and effort. Historically, the commercial fisheries such as the Japanese longline fishery have maintained an excellent logbook system and much of the catch-effort data available on the trends of commercial billfish fishing and determination of the general status of stocks have come from these logs. Information on the trends in catch-effort for the recreational or sport fishery for billfish is most important to the future management of billfish resources. These catch/effort estimates are given in terms of catch per angler day, as numbers of fish per day, or as days of fishing per billfish caught. The catch rates may vary according to the variations in availability and catchability of billfish in the sportfishing areas and the abundance level of the stock upon which the fishery is operating. These factors may fluctuate considerably, resulting in highly variable catches in some areas, and less so in others.

James Squire, Fishery Biologist at the La Jolla Laboratory, reported that the 1979 billfish angler survey data show 12,343 angler days, a decrease from 14,681 in 1978. The number of billfish reported captured in 1979 was 3,796, down slightly (8%) from 4,142 fish in 1978. The overall billfish catch rate (fish per angler day) for 1979 was 0.31 or 3.25 days fishing per fish. This is slightly (11%) more than that observed in 1973 (0.28 fish per day, 3.54 days fishing per fish), and continues to be well below the 1969-1972 average of 0.55 fish per day and of 1.80 days per fish.

Inspection of the total Pacific catch for marlin (striped, blue and black), sailfish, and shortbilled spearfish, 1960-1976, indicates that most species are now being caught in fewer numbers than observed prior to 1970. Catches of blue and striped marlin are down substantially. Blue marlin catches appear to have reached a "high" in the early 1960's and striped marlin in the mid to late 1960s. There continues to be a high commercial demand for the marlins, swordfish, and sailfish and tnis is resulting in increasing commercial fishing pressure on the billfish resources.

Striped Marlin

The CPUE for the striped marlin in the major fishing area (about the tip area of Baja California Sur, Mexico) is down from the levels observed in the early 1970's and may be assumed to be substantially lower than those recorded in the early 1960's prior to the start of extensive longline fishing for striped marlin in the northeast Pacific. This assumption is based on the fact that the decline in angler catch rate parallels the decline in CPUE observed for the longline fleet operating off Baja California. An analysis to determine the correlation between longline CPUE for striped marlin and the CPUE of the recreational striped marlin catch in the same general area off Baja California, Mexico, shows a reasonable correlation ($r = 0.81$). The CPUE of the Japanese longline fleet was much higher in the early and mid-1960's prior to start of the billfish angler survey in 1969. A total of 1,948 striped marlin were caught in the 12,343 reported angler days in 1979.

Blue Marlin

Data for blue marlin catches off Hawaii indicate a current catch rate of about 0.15 fish per day. The CPUE has remained nearly stable, with a possible slight upward trend since 1974, the year in which a larger sample size was obtained, relative to preceding years. In 1979, 487 blue marlin were caught in 12,343 reported angler days.

Black Marlin

Black marlin CPUE data indicate a peak during 1970-1973, with overall average continuing to be about 0.65 days per fish during 1974-1979. A total of 405 black marlin were reported caught during 12,343 angler days in 1979.

Sailfish

The trend of CPUE for the major sailfish fishing area in the eastern Pacific (Acapulco) showed an increase during 1976-1977, compared to a general

downward trend in recent years. The catch trend at Mazatlan has been slightly downward since 1975. Sr. Hector Zurita, INP billfish biologist at Acapulco, indicated that a CPUE of 1.0 fish/day was recorded in 1979 from extensive sampling in the recreational fishery. The CPUE for the 1979 angler survey was 0.82 fish per day. A total of 956 sailfish (including shortbilled spearfish) were caught during 12,343 reported angler days in 1979.

IN SUPPORT OF OTHER DOMESTIC REQUIREMENTS

TUNA/PORPOISE INTERACTION - MARINE MAMMAL PROTECTION ACT OF 1972

Research on porpoise associated with the tropical tuna fishery of the eastern Pacific has been a continuing program at the Southwest Fisheries Center since 1969. The research, which is collectively referred to as the tuna/porpoise program, is designed to meet responsibilities assigned to the Center. These responsibilities are: (1) to assess the condition of the porpoise stocks involved in the purse seine tuna fishery, (2) monitor the incidental take, (3) develop gear and fishing procedures to reduce the incidental take of porpoise in the fishery, and (4) provide advice to U.S. federal government administrators on the effects of management actions on the porpoise stocks.

Tuna/porpoise research activities at the Center are organized under approximately 11 projects, each with specific objectives, and under two major groupings: Marine Mammal Biology and Technology Program, and Marine Mammal Assessment and Monitoring Program. Research at the La Jolla Laboratory devoted to the problems of conflicts between fisheries and marine mammals is supervised by Dr. William Perrin, Leader of the Marine Mammal Biology and Technology Program and by Dr. Tim Smith, Leader of the Marine Mammal Monitoring and Assessment Program. On-going research by staff members include estimating growth and reproductive parameters, research to develop improved porpoise rescue gear and methods, development of better research tools, monitoring of the incidental kill, and assessment of the condition of the stocks involved in the fisheries. Some highlights of research during the past year are as follows:

Gear Technology

The major goal of the Gear Technology project is the reduction of incidental porpoise kill through development of improved porpoise-rescue methods and equipment. The project staff also provides extension services to the United States fleet, in the form of technical advice and assistance in installing and operating improved gear, and carries out staff assignments concerning causes of kill and fleet performances.

This project is provisionally scheduled for termination at the end of fiscal year 1981.

Studies of Causes of Porpoise Mortality in Purse Seines, Particularly in Sundown Sets

Previous analyses by NMFS personnel have indicated relatively high porpoise mortality in sets made on porpoise schools in the late afternoon. The apparent reason for the higher kill is the effect of darkness on the vessel's "backing down" rescue procedures, but details of the causes of mortality are not yet clear. Regulations for the 1981 season prohibiting sets within the 90 minutes prior to sundown have been suspended, pending further review.

Development of a data file for the analysis has been ongoing with input from the tuna industry and scientists working for the Inter-American Tropical Tuna Commission (IATTC), so that the file could serve as a common data base for evaluating fleet performance of sundown sets. When completed, the file will incude NMFS observer data collected during 1977-1980 as well as IATTC data for 1979-1980. Computer programs to reformat the NMFS data have been written, tested, and executed.

A highlight of the work to date is the use of a computer algorithm to calculate the local time of celestial events, including sundown. Given a position and date, the algorithm calculates sunrise and sunset times, as well as the times of astral, nautical, and civil twilights. The program is accurate to within + 3 minutes for locations between 30° S and 30° N latitude. The algorithm is also used in editing observer data that sometimes does not specify local time when a set is made.

Computer Simulation of Purse Seining

The firm of Beers Associates, Inc., was awarded a contract during the year to continue development of a computer model of purse seining. When completed, the model will be used to simulate a broad range of seiner-compatible fishing systems designed to increase tuna harvest efficiency while reducing or eliminating incidental marine mammal mortality. The cost of evaluating such innovative and untried fishing gear and techniques in full scale precludes this research by any other means.

The purpose of this contract is to research and extend the existing numerical simulations of the purse seine process that have been developed previously by another contractor. The present simulation model is capable of adequately modeling simple net behavior under the influence of gravity, buoyancy currents, and induced forces such as net setting from a vessel and the hauling in of cables attached to the net.

Goals are to improve and extend the system of differential equations for the simulation so that it is capable of smooth transitions from one phase of the seining process to the next. This will necessitate a modularization of the simulation's design to facilitate the restructuring of the differential equation systems at each change in the geometry of the problem being simulated. This same modularization is also expected to enable users to specify, for each run of the simulation, a series of calculated parameters to be output as hard copy at the completion of the run. This capability is essential for adequate evaluation of the performance of the net design being simulated and will be as general and flexible as possible.

Purse Seine Dynamics Charter

A research cruise in local waters aboard the purse seiner, Maria C. J., was conducted, from September 12-19, to investigate purse seine dynamics related to porpoise mortality reductions. The objectives of the experimental operations were to (1) measure certain aspects of net behavior for input into

a computer-based simulation model of the purse seine operation and for comparison with behavior of a scale model; (2) test methods aimed at reducing a persistent backdown channel canopy, or "stern sway"; (3) develop methods of measuring and evaluating purse seine performance; and (4) gather information for a mathematical model that determines the location of the stern-side net-tie-down point without requiring a trial net set.

After this portion of the cruise was completed the Maria C. J. continued fishing in the eastern tropical Pacific with a NMFS technician aboard. He returned to San Diego on December 28 after collecting bathykymograph recordings of net depth performance, net-surface-area estimations, underwater observations of backdown, setting speed observations, and recordings of engine RPM's during backdown.

Verification of Formula for Net Tie Down During Backdown

An empirical formula was tested for calculating the amount of a purse seine to be left in the water in order to have the optimum configuration of backdown channel for releasing porpoise. With the cooperation of the owner and skipper, the 16-strip net of the purse seiner, Carol Linda, was measured and the location of the calculated tie-down point for backdown was marked.

The following day, the Carol Linda performed a trial set off San Diego with Technology Project personnel observing net performance both underwater and from the vessel. Based on these observations and the captain's comments, the optimum tie-down point for backdown was established. The tie-down point derived from the trial set observations and the tie-down point derived from the formula based on stretched net depth were exactly the same. The formula has now been verified for nets of 11, 14, and 16 strips and the staff of the project believe this formula can be used successfully by vessels in the tuna purse seine fleet.

Tagging and Tracking

The Tagging and Tracking project is directed at the development of tagging and marking techniques for use on small cetaceans involved in the tuna fishery, for studies of movements, ranges, school cohesion, mortality rates, and population density.

Completion of development and testing of a prototype satellite (NIMBUS-6)-linked tag is scheduled for summer. Surfacing times were collected by placing radio transmitters on a spotted porpoise off Kona, Hawaii in May 1980. Analysis revealed that about 40% of the surfacings were long enough to transmit the entire signal required by the satellite. Surfacing patterns indicated a general pattern of 6-8 short dives of 4-16 seconds followed by a dive of about 1-3 minutes. To increase the probability of getting off enough transmissions during a normal satellite pass of about 15 minutes, the antenna was raised by putting it on a 17.5 cm pedestal.

Completion of analysis of design and materials for the dorsal-fin disc tag is being performed by Naval Surface Weapons Laboratory under the direction of the Southwest Fisheries Center. The design has been modified to strengthen the tag and eliminate the cutting edges, new plastics and pigments are being evaluated, and the mold has been reworked to eliminate the manufacturing problems incurred with the last batch.

This project is provisionally scheduled for termination at the end of fiscal year 1981.

Population Size Estimation

The objectives of this project are to develop methodology for estimating porpoise sizes in the eastern tropical Pacific with up-to-date techniques, including the planning and execution of aerial surveys and improvement of methodology for estimating dolphin abundance.

The staff of the Southwest Fisheries Center conducted a field experiment during February-April 1981 which tested several key assumptions that have been made in estimating the density of porpoise schools in the eastern tropical Pacific. The major hypothesis investigated was the detectability of large schools of porpoise which are directly beneath the airplane under a range of environmental conditions.

The principal environmental conditions considered were sea state and sun glare. The hypothesis of no difference in detectability will be tested by comparing the density estimates obtained under two classifications of sea state and two classifications of sun angle. In addition, the possibility of missing schools directly on the trackline by the forward observer were partially checked by having a second team member monitor the trackline to determine if the forward observer missed any large schools. Thus, similar flights were made off the shore of Liberia, Costa Rica, under a range of sea states and with different orientations to the sun. Comparisons between the performance of experienced and inexperienced observers were also made.

The scientific party achieved their goal of detecting a minimum of categories. Although they experienced several delays due to weather and mechanical difficulties, the rate of detection of porpoise schools was considerably higher than had been anticipated. Observers flew 121 flight hours and recorded 373 marine mammal sightings.

The results of this study are vital for further evaluation of the reliability of porpoise school density estimates made from aerial survey data.

Species Distribution and Habitat

The Species Distribution and Habitat project's objective is to define the geographical habitat of each porpoise species and to determine for different habitats, the species composition, the school sizes, the relative densities,

and the degree of porpoise interaction with tuna. The studies are designed to provide information for better estimation of porpoise stock size.

Vessels of Opportunity Porpoise Sighting Cruises

Since March 1980, biologists have been studying cetacean populations in the eastern Pacific through participation on the Eastern Pacific Ocean Climate Study (EPOCS), which is a multi-year, NOAA-supported project designed to study how ocean conditions affect global climate. The area of ocean-atmosphere study is from 160° E, eastward to the coast of South America, and to about 15° north and south of the equator.

The cetacean observers have thus far spent 166 days at sea aboard the EPOCS research vessels, Oceanographer, during March and April 1980, Researcher during June and September 1980, and Oceanographer during January and March 1981. These ships had been taking biological and physical oceanographic measurements, generally along the 110° W longitude line between 10° N and 10° S, and also along the equatorial belt in the eastern Pacific. The observers have recorded 579 cetacean sightings along the cruise tracks to date.

Because the major research track along the 110° W meridian is repeated each cruise, it is hoped that the information obtained on species composition, school size, and distributional changes will yield insight into the question of seasonal changes to the populations. This question of seasonality arises naturally because of the relatively large, seasonal oceanographic changes that characterize the eastern Pacific. These changes are the reason for the focus of EPOCS studies in the eastern Pacific.

The cetacean observations obtained thus far have not yet clarified the question of seasonality in these populations. The results, however, strongly suggest that the tropical, equatorial, and subtropical populations btween 10° N and 10° S belong to distinct faunal communities, related somehow to differences in the nature of the epipelagic food web in each zonal area.

Participation by project observers in a fourth EPOCS cruise is planned for May 1981. During this cruise, cetacean surveys are planned along 110° W, the equator, and areas west of Clipperton Island. Observers Robert Pitman, M. Scott Sinclair, and James Cotton were participants in the cruises. The cetacean EPOCS study is supervised by Dr. David Au, Operations Research Analyst.

Results obtained will be compared to those recently described; interesting contrasts are anticipated. A more precisely defined picture of the nature of spotted and spinner dolphin populations along this major part of the area of the tuna/porpoise fishery should result.

The 1980 research cruises were led by Dr. David Au and Mr. Gene Anderson.

Behavior and Physiology

The purpose of the Behavior and Physiology project is to carry out research on porpoise behavior and physiology in relation to developing improved porpoise-rescue gear and methods to reduce incidental mortality in the purse seine fishery, and in relation to assessing the impacts of the mortality on the porpoise populations.

This project is provisionally scheduled for termination at the end of fiscal year 1981.

Study of Comparative Age and Sex Structures of Porpoise Schools

Analysis of data on large portions of porpoise schools captured by the purse seiner, Queen Mary, during the dedicated vessel cruise, have been completed and tabulated. Data were obtained using the porpoise impoundment system and were collected to analyze whole school age and sex structure. The sex ratio of all age classes of spotted porpoise was shown to be nearly 1:1. The age structure of the same schools, based on color pattern data, showed the adults to make up 60% of the population. The "mottled " color pattern phase accounted for 12%, the "speckled" phase made up 19%, the "two-tone" phase made up 8%, and the neonates accounted for less than 1% of the spotted porpoise examined.

Porpoise kill data for the same year show a similar pattern, but only in large kill sets (greater than 40 animals). Large kill sets showed 59% adult, 15% mottled, 15% speckled, 10% two-tone, and again less than 1% neonate, indicating that the kill in large-kill sets may be cross-sectional or close to the composition of porpoise captured. The fishery data have not yet been stratified by the "life history" data (from animals dissected by the observers) in a similar way.

Analysis of Behavior Data for the Hawaiian Spinner Porpoise Stock

A manuscript is in preparation on the energetics of Hawaiian spinner porpoise which describes a method for obtaining a daily energy budget for porpoise using radio tracking data. Scientists have found that during the day, the spinner porpoise had a low respiratory rate but that at night, when this species is most active, the respiratory rate nearly doubles.

Life History and Systematics

The purposes of the above project are to carry out research to define the stocks of tropical porpoise and to estimate and monitor their life history parameters so that the impacts of incidental mortality on the stocks can be

assessed. This project also contributes to international research to develop advice for the management of small cetaceans.

Based on an analysis of specimens from various museums and from the tuna fishery, Dr. William Walker of the Los Angeles County Museum, under contract to NMFS, has concluded that the evidence supports the existence of at least two forms of Tursiops in the eastern Pacific: nearshore and offshore forms. Unfortunately, the specimens of the offshore form in California are few and Walker believes that larger sample sizes are needed before the taxonomic status can be completely defined.

According to Walker's analysis, the best characteristic for separating the two forms is tooth diameter. He also looked at stomach contents in both forms and found the inshore form feeds on larger prey, often demersal fishes, than does the offshore form.

Age Determination

This project has the major objectives of developing and applying new techniques for determining ages of individual porpoise. The research has two components: (1) development of techniques for preparation and reading of hard-tissue, principally teeth, and (2) time calibration of layering in the tissues.

During the past year preparation and ageing of large samples of teeth collected from spotted and spinner porpoise killed in the fishery continued. A new computer program has been employed to aid in analyzing layering patterns in porpoise teeth. All analyses are based upon the fundamental knowledge that, for a given year in each animal of the same age, the teeth deposit a single layer of the same thickness. Further, the thickness of the layer varies by age class and decreases with increased age at a uniform and predictable rate which is species-specific. These layering rates are unaffected by changes in nutrition, water temperatures or salinities, or ill health (except for serious and prolonged illness). Scientists in this project are able to examine these layering patterns by studying stained cross sections of the teeth.

The extraction of tetracycline-labelled teeth from captive porpoise permits the scientists to establish baseline data for comparison of time-layer interpretations from teeth taken from wild specimens. Such labelled teeth from captive Hawaiian spinner porpoise at Sea Life Park which were treated therapeutically with tetracycline were obtained. The staff also hopes to obtain them from bottlenose porpoise labelled while fetuses in utero at Sea World in San Diego, California. These fetal-labeled porpoise, whose mothers were fed tetracycline orally, may allow scientists to determine the gestation period and fetal growth rates for porpoise. It is known that fetuses of the Stenella spp. begin to accumulate enamel layers at about 25-28 cm in body length. Up to 8 months of gestation period could be accounted for using the enamel-layer counts.

Older adult dolphins may also be aged by counting cemental layers in the teeth, which are deposited with dentine layers on a one-to-one basis. Each of the first seven or eight annual layers contains 13 sublayers which correspond in time to lunar months. Although dentine deposition in old adults ceases, cemental layering continues. Back-counting of lunar layers from date of death to the beginning of the dentinal tissue permits an accurate determination of birth wthin 2 months.

It is hoped that comparison of labelled teeth with those from wild specimens will give a better indication of dolphin life expectancy in the wild. The Marine Mammal Age Determination Project will be supplementing current data with planned analyses to estimate age-specific fecundity and survival rates of spotted dolphin, and will analyze teeth layers from samples of eastern spinner dolphin, whitebelly spinner dolphin, common dolphin, and striped dolphin.

SOUTHWEST FISHERIES CENTER WORKSHOP ON TUNA RESEARCH PLANNING

Second Workshop on Tuna and Billfish Research Held at San Clemente

The NMFS Southwest Fisheries Center's (SWFC) second Workshop on Tuna and Billfish Research was held at the San Clemente Inn, San Clemente, California, on December 15-17, 1980. A total of 26 persons participated in the meetings, including 24 from the Center and 2 from the NMFS Office of International Fisheries Affairs.

The purpose of the Workshop was to review the situation regarding a number of tuna and billfish stocks of importance to the U.S. and to improve the Center's near-term and long-range tuna research plans.

Before the start of the Workshop, 14 Situation Reports were written by Center staff and collaborators, covering some 25 different species or stocks of Atlantic, Pacific, and Indian Ocean tuna and billfish, and distributed to participants. These reports set out a short description of the fishery, presented an overview of the nature and degree of U.S. and foreign interest in the fishery, and discussed the current status or condition of the stocks. Recommendations for further analyses, data collection, or research programs regarding the fishery were also given. The Situation Reports included most of the world's tuna stocks of direct and indirect interest or importance to the U.S. commercial and recreational fishermen, canning, industry, and consumers. A summary of each of the Situation Reports presented at the Workshop follows:

Atlantic Tunas

Atlantic Yellowfin Tuna: The status of Atlantic yellowfin tuna stocks remained unchanged from 1979 to 1980. Production model analysis indicates that the stocks are being fished at high levels, especially in the eastern Atlantic. Increases in fishing effort with the fishery operating within its present geographical boundaries is unlikely to produce substantial gains in yield.

Atlantic Bigeye Tuna: Recent total annual Atlantic catches of bigeye tuna have averaged 41,000 metric tons. Major participants in the fishery include Japan, Korea, Spain, and the U.S.S.R. The U.S. takes bigeye along with yellowfin and skipjack tuna in its eastern Atlantic tropical tuna purse seine fleet. Recent U. S. catches have been less than 500 MT.

Atlantic Skipjack Tuna: Eastern Atlantic skipjack tuna stocks are currently fished at a high level (100,000 MT in 1980) while western Atlantic stocks are fished at a low level (9,000 MT in 1980). Catch-per-unit-of-effort indices for both the French Ivory Coast-Senegal-Morrocan and Tema-based fleet (which are quite different and show no clear trend over time) are not considered to be adequate estimators of abundance. Available evidence indicates that neither western or eastern Atlantic skipjack stock(s) are overfished at this time, and both stocks may effectively support increased fishing effort.

South Atlantic Albacore: Annual catches from the South Atlantic albacore stock have remained near 22,000 MT for the last few years. Current annual effort levels are near 100 million hooks, the level reached in 1972. Available evidence indicates that the stock is currently producing catches about 25% below estimated MSY and that a relatively high yield-per-recruit of about 7.7 kg is being realized. The South Atlantic albacore fishery supplies about 40% of the U.S. annual composition through imports.

North Atlantic Albacore: The North Atlantic albacore stock is fished by longline and surface gears. Surface catches (38,000 MT in 1979) have declined about 25% since 1960. Longline catches in 1979 were 11,000 MT. Available evidence indicates that MSY is about 60,000 MT, which is 10-15% above recent year's catches. Yield-per-recruit to the North Atlantic albacore fisheries is about 3.8 kg with some increase possible with fishery changes. Recruitment indicates indicate that spawning stock is low and recruitment highly variable. The fishery appears to be heavily exploited.

Pacific Tunas

Eastern Pacific Yellowfin Tuna: Results of production model analyses indicate that the eastern Pacific yellowfin fishery is currently operating at levels above maximum sustainable yield. The age-structured analyses raise concerns over the increased dependency of the fishery on age-1 fish. Recent increases in age-1 catches could lead to a decrease in yield-per-recruit and a diminished potential yield. Heavy fishing on a succession of poor recruit

classes could so reduce the adult population that recruitment failure occurs. Efforts to reverse these trends in the near future are complicated by a failure to reach agreement on a mechanism for implementing an eastern Pacific yellowfin conservation program in 1980.

Eastern Pacific Skipjack Tuna: The stock structure of skipjack tuna in the Pacific Ocean is poorly understood. In the eastern Pacific fishery for skipjack tuna, there appears to be no significant relationship between effort and apparent abundance. Yield-per-recruit analysis on a partial stock indicates a maximum yield-per-recruit could be obtained at a greater fishing effort than is currently applied. According to the Inter-American Tropical Tuna Commission, the fishery for skipjack tuna in the eastern Pacific does not appear to affect stock abundance, and there is no need to restrict the catch.

Western Pacific Skipjack Tuna: The major fisheries for skipjack tuna are located adjacent to continents and islands. In the western Pacific, the Japanese pole-and-line live bait fishery is the largest and oldest established fishery. The stock structure of skipjack tuna in the Pacific is not very well known. Although no production model analyses or other analyses and simulations have been attempted for western Pacific skipjack tuna, all available information suggests that the resource is still underexploited.

Western Pacific Yellowfin Tuna: Although the stock structure of yellowfin tuna is not well known, it has been hypothesized that there are two separable stocks in the Pacific, one in the eastern Pacific and the other in the western Pacific, which are separated by a less clearly defined stock in the central Pacific. A stock production model based on longline catches of yellowfin tuna in the entire Pacific indicated that the stock is capable of sustaining the current level of catch.

South Pacific Albacore: Most of the catch is taken by longline vessels from Japan, the Republic of Korea, and Taiwan. Longline catch-per-unit-effort declined considerably between 1962 and 1974 as effort and catch increased. However, catch rates increased in recent years so that average annual catch has increased in spite of lowered effort. Present average annual catch by longliners is in the neighborhood of the estimated MSY for this fishery, 35,000 MT, and no sustained increase in longline catch can be expected.

North Pacific Albacore: The North Pacific albacore stock is harvested primarily by the Japanese surface and longline, and North American surface fleets. Catches of these fleets have been in the vicinity of 100,000 MT in recent years, with a record catch of nearly 124,000 MT in 1976. The North American surface fishery, comprised primarily of U.S. troll vessels, landed an annual average catch of approximately 20,000 MT during the period 1969 through 1978, but landed less than 5,000 MT in 1979.

Although heavily harvested, the stock is considered healthy. Effort levels in recent years have been below those required to produce maximum average sustainable yields (MASY). Yield-per-recruit (Y/R) analyses indicate a decrease in Y/R following the expansion of the Japanese surface fishery. Slight gains in Y/R are possible through increased effort on larger fish but

substantial gains are unlikely with the fishery in its present configuration. Catch rates for all three major fleets have shown gradual decreasing trends.

North Pacific Bluefin Tuna: The resource appears to be composed of a single stock fished both in the eastern and western Pacific. The western Pacific catch is composed of juveniles and mature adults, while the eastern Pacific catch consists mainly of one, two, and three-year old fish. Presence of a second stock off New Zealand is not confirmed by studies.

Indian Ocean Tunas

Albacore, Bigeye, Yellowfin, and Skipjack in the Indian Ocean

Estimated annual catch of albacore has fluctuated widely since 1962 between 10,000 and 2,000 MT. A yield-per-recruit assessment suggests no gain in yield-per-recruit from harvesting the younger fish as fishing effort moved into more southerly waters. This stock appears fully harvested and there appears to be no reason for concern over the future of the stock at this time.

The estimated annual catch of bigeye tuna in the Indian Ocean reached a high of 48,600 MT in 1978. A production model analysis did not produce a reliable prediction of MSY. The yield curve showed increasing catch with effort and did not reach an asymptote. This stock appears to be only lightly exploited.

The estimated annual catch of yellowfin tuna in the Indian Ocean, which is fished by surface and longline gears, fluctuated widely from 1952 to 1978 but exhibits a general upward trend. The estimated total catch for 1978 was 62,500 MT. Production model analyses based on available longline fishery data suggest an MSY for that fishery of around 40,000 MT. Due to rather inaccurate total catch estimates, however, the MSY may be higher. It is unlikely that longline catch could be increased appreciably above the current level. It is generally felt, however, that there is a potential for increased landings of yellowfin tuna by surface fisheries.

The surface skipjack tuna fishery in the Indian Ocean is relatively undeveloped. Catches have fluctuated from 1965 on a general rising trend. Estimated catch for 1978 was 32,600 MT. There have been no quantitative assessments of the Indian Ocean skipjack tuna stock.

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In addition to the Status of Stocks Report, the Director of the Office of International Fisheries Affairs presented an overview of the status of international tuna fishery problems and the state of international negotiations concerning them. Although the participants in the Workshop concentrated on stock assessment and fishery evaluation aspects of the Center's tuna research program, some time also was devoted to a discussion of the tuna-environment interaction studies.

The Status of Stocks Report will be available for distribution to interested persons about June 1981.

TUNA BEHAVIOR-PHYSIOLOGY

Tuna Energetics

Work has been underway on a National Science Foundation project, "Tuna Energetics and Hydrodynamics: An Interdisciplinary Study of Energy Transfers," involving the California Institute of Technology, the University of Wisconsin, the University of Michigan, and the Honolulu Laboratory.

An important objective of this study is to obtain a long-term measure of energy expenditures by skipjack tuna. Energy expenditure can be estimated by determining the fish's change in weight and energy density at different swimming speeds and feeding levels. These measures can be independently compared with rates derived from respirometry and hydrodynamic studies.

Initial length-weight regressions calculated for fresh, dead skipjack tuna were compared with those for starved fish from the same batch. This provided a rough estimate of weight loss with time, which can be correlated to energy expenditure. The food consumed by individual tuna among schools of six to eight fish has been successfully monitored in feeding trials. This will permit an asssment of energy intake with time under controlled feeding conditions.

Attempts to increase the activity level of captive tuna produced an interesting result. Initially, fish that were force-fed weights swam faster than unweighted fish, overcoming their decreased buoyancy by increasing their hydrodynamic lift. After several days, however, these fish increased their attack angle, swimming "uphill," and slowed to minimum speed. This result was again observed when pectoral fins were clipped to reduce lift. An initial increase in velocity was followed by an increase in attack angle and decreased velocity. The latter technique proved less traumatic to the fish. Most weighted fish died within 2 to 5 days.

More data on tuna at higher activity levels must be collected to determine the efficiency of various swimming speeds. This information will be used to formulate predictive models for tuna migratory behavior.

Navigating Ability in Tunas

Dr. Andrew E. Dizon, Leader, Pelagic Ecosystem Study, Dr. J. L. Kirschvink, visiting scientist from Princeton University, and Michael Walker, University of Hawaii graduate student, have been investigating the navigating ability of tunas. The mystery of how migratory animals can navigate accurately over large distances is one of the outstanding problems of modern biology. Recent studies on migratory birds and homing pigeons have revealed

that these birds have a surprising ability to sense the geomagnetic field and use it to guide their travels. This geomagnetic "map" seems to be accurate to within about 5 km over most of the earth's surface and hence may be one of their most important sensory tools.

When these magnetic effects were discovered, no plausible mechanism through which animals might detect the weak geomagnetic field was known. Recently, however, a surprising variety of animals, including bacteria, honey bees, pigeons, and dolphins, have been shown to synthesize small crystals of magnetite (Fe_3O_4 -- also known as lodestone). These tiny (0.1 m) iron-rich particles in the animal's body act like simple compass needles in the earth's magnetic field and may be the key to the sensory modality which guides the animal's incredible migratory behavior.

The open ocean is an environment impoverished in orientational cues. However, one major pervasive orientational cue conceivably available to migrating tunas in the pelagic oceanic environment is the earth's geomagnetic field. Local and regional variations in the intensity of the earth's magnetic field can provide a considerable amount of useful information to migratory species possessing sensitive magnetic sense organs.

Dissections of tuna heads have revealed concentrations of magnetite within a highly enervated pocket within the ethmoid bones. This presumably biogenic, magnetic material could serve as the sensory mechanism since sufficient amounts are present for both a compass and a map sense. Early experiments conducted by Dizon, Kirschvink, and Walker indicated that yellowfin tuna responded without prior conditioning to an abruptly altered earth's magnetic field. Further experiments have shown that kawakawa and yellowfin tuna could be conditioned to discriminate between normal (Hawaiian) and altered (polar) magnetic fields. These evidence suggest that tunas, like the homing pigeous, possess a well developed magnetic sensory system that could be used for naviagation.

Other Work in Tuna Behavior-Physiology

Dr. Dizon and Martina K. K. Queenth completed experiments on five yellowfin tuna to determine their temperature preference. The experimental setup allows the fish to behaviorly control the water temperature in the tank. To date, two of the five fish have successfully regulated tank temperatures. The preferred temperature was centered around 27.0° C, which is surprisingly high.

In other experiments on tunas, Dr. Dizon, Dr. Richard W. Brill, Pacific Gamefish Foundation, and Walter N. Ikehara, University of Hawaii grduate student, are examining the induced neural activity in the olfactory bulk of skipjack and yellowfin tunas after the fish's olfactory rosettes have been infused with natural prey and artificial odors. They have succeeded in recording the increased olfactory bulb activity in tuna resulting from the presentation of these odors. Although this sort of work is routinely done in freshwater fishes, technical problems make it a more difficult procedure using saltwater species. Because live tuna require especially delicate handling and

surgical procedures, it has taken about 6 months to perfect the techniques to the point where the olfactory bulb activity could be recorded in tuna.

This work is intended to provide information on the natural and artificial odors that will be most attractive to tunas. The eventual goal of the project is to find attractive odors that could be used to enhance the effectiveness of floating fish aggregating devices, skipjack tuna live bait, and other fishing techniques.

Brill, Ikehara, and Dizon decided to use electrophysiological recording techniques, rather than behavioral studies, because a larger number of artificial and natural odors could be tested in a much shorter period of time. Furthermore, recording increased olfactory bulb activity in response to odor presentation is the only way to accurately determine odor detection thresholds.

This work is supported by the University of Hawaii Sea Grant Progam, the Honolulu Laboratory, and the Pacific Gamefish Foundation.

Induction of Spawning in Tuna

A team of researchers including Thomas K. Kazama, Fishery Biologist, Research Assistant Martina Queenth, and University of Hawaii graduate student Sharon D. Hendrix, have been making preparations for this summer's work on inducing tunas to spawn. Last summer Dr. Calvin M. Kaya, visiting scientist from Montana State University, deduced that spawning in captive tuna was induced by some stress factor(s) related to the capture and delivery process. Observations indicated that skipjack tuna ovulated within 7-8 hours after capture. Later, Kazama, Queenth, and Hendrix discovered that kawakawa also has the same stress-induced ovulatory response.

A related activity is to rear the larvae resulting from the induced spawning experiments. In expectation of successfully inducing tunas to spawn this summer, cultures of phytoplankton and rotifers are being maintained at the Kewalo Research Facility. Hendrix has been successful in culturing a harpacticoid copepod, Tigriopus sp., which will be used to feed the larvae. Hendrix has also analyzed stomachs of net-caught skipjack tuna larvae in an effort to relate types and size of prey to larval length and mouth gape. This analysis should provide information on a suitable diet for larval tunas.

FISH AGGREGATING DEVICES

As a result of the Honolulu Laboratory's successful fish aggregating devices (FAD) project, much interest has been generated in the use of FADs to attract and hold tunas and other pelagic fishes. The Honolulu Laboratory provided assistance to American Samoa and Western Samoa in fabricating and deploying FADs. In addition, inquiries for information on FADs have come from many parts of the world, incuding Guam, Palau, Northern Mariana Islands,

Tonga, Fiji, New Zealand, Australia, Tahiti, Spain, Norway, Maldives, Philippines, Canary Islands, British Columbia, Puerto Rico, Cayman Island, and also from California, Florida, and South Carolina.

Fishery Biologist Walter M. Matsumoto, who was the principal investigator in the Honolulu Laboratory FAD project, has been sending copies of his manuscript, drawings, and the FAD workshop report in response to all the inquiries.

In related work around Hawaii, the Honolulu Laboratory is cooperating with Dr. Richard E. Brock, Hawaii Institute of Marine Biology, in an effort to quantify the effectiveness of FADs deployed around Oahu by the Hawaii Division of Fish and Game. The information will be used to develop a colonization of fish communities around these devices.

TUNA DATA BASE USERS MANUAL

In September 1980, a file management system for all tuna data maintained by the Honolulu Laboratory was started. Under the supervision of Fletcher V. Riggs, Fishery Biologist, Mark Scheele, Computer Technician, completed the first draft of the Tuna Data Users Reference Manual. This manual provides information on specific data set names, data formats, procedures used in creating the data sets, and various information on the sources of the data. It also documents the procedures used in testing for errors, editing, redoing formats, renaming, documenting, and creating standard tape-based data files.

Additional effort has been directed toward information obtained from American Samoa which comprises three major sets of data - logbook catch and effort data, cannery landings data, and albacore size-frequency data. A report is being prepared by Scheele to document the rather complex inter-relationships of the data sets and to provide several alternative means of streamlining current coding and capture procedures. Research Assistant Nathaniel T. Shippen has been assisting in the preparation and conversion of several other tuna data sets to conform to the new standards.

SWFC PUBLICATIONS ON TUNA AND TUNA-RELATED SUBJECTS

MAY 1, 1980 through APRIL 30, 1980

PUBLISHED

Au, D. and D. Weihs. 1980. At high speeds dolphins save energy by leaping. Nature 284(5756):548-550.

An observer may wonder whether a school of 'running' dolphins, consisting of numerous, wildly splashing individuals, is using the efficient mode of locomotion, because splashing wastes energy. Dolphins exhibit at least three modes of swimming. In leisurely, unhurried motion, they break the surface briefly and gently, often showing little more than the blowhole. At a faster, 'cruising' speed, frequently at 3-3.5 ms^{-1} (6-7 knots), the animals are seen swimming primarily just beneath the surface, and there is still little splashing. (Behavior and speeds of dolphin schools were observed from a helicopter and will be described elsewhere by D. Au and W. Perryman.) Swimming speeds in this mode have been measured up to 4.6 ms^{-1} (9.3 knots). But in the fastest 'running' mode, the animals clear the water in sequential, parabolic leaps, accompanied by considerable splashing on exit and re-entry. Leaps are interspersed with relatively brief, subsurface swimming. This swimming is common when dolphins are alarmed by vessels approaching within 500 m. We have examined dolphin swimming in terms of energy required per unit distance traveled and report here that beyond a certain 'crossover'speed, leaping must be more efficient than swimming.

Au, D. W., W. L. Perryman, R. L. Pitman, and M. S. Sinclair. 1980. Cetacean populations and equatorial oceanography. Tropical Ocean-Atmosphere Newsletter, No. 4, October, page 6+.

Composition and concentration of cetacean communities in the eastern and central equatorial Pacific are related to oceanographic factors, notably a relatively weak thermocline gradient and an often absent mixed layer. Eighty-two per cent of the sightings are found to occur east of 145° W, where surface divergence and undercurrent effects eliminate the mixed layer. The composition of the cetacean community and attendant bird populations changes with the development and deepening of the surface mixed layer.

Baglin, R. E., Jr., M. I. Farber, W. H. Lenarz, and J. M. Mason, Jr. 1980. Shedding rates of plastic and metal dart tags from Atlantic bluefin tuna, Thunnus thynnus. Fish. Bull., U.S. 78(1):179-185.

Rates of tag shedding were estimated from data collected on double-tagged bluefin tuna during 1971-1977. Overall shedding

rates were not significantly different for plastic and metal tags, but plastic tags had lower rates of shedding in most cases. For the combined data, the Type-I shedding rate, that occurs immediately after tagging, was estimated to be 0.040. Type-II, instantaneous shedding rate, was estimated to be 0.205 on an annual basis. The data suggested that the assumption of constant shedding throughout the life of the tagged fish may be violated. Shedding was found to vary among years and, because of this and the high rate of shedding, the authors recommended double-tagging when possible.

Barham, Eric G., Jay C. Sweeney, Stephen Leatherwood, Robert K. Begg, and Cecilia L. Barham. 1980. Aerial census of the bottlenose dolphin, Tursiops truncatus, in a region of the Texas coast. Fish. Bull. U.S. 77(3): 585-595.

On five replicate aerial surveys in late March 1978, the bottlenose dolphin, Tursiops truncatus, herds were sighted and their numbers estimated in 21 strip transects flown across bays and channels between barrier islands and the coast from Port Aransas northeast to Matagorda, Texas. The transects were spaced at 4.63 km intervals and herds were scouted in about 800 m wide strips totaling 436 km in length, providing approximately 17% coverage of the area. On surveys 1-4 (survey 5 was excluded from population calculations because it was conducted in adverse weather) 133 bottlenose dolphin herds were sighted, containing an estimated 916 animals. Within these strips the mean herd size was 6.95 animals and mean herd density was 0.0947/km^2, extrapolating to a population estimate of 1,319 dolphins and a density estimate of 0.752/km^2 for the entire area. These figures are relatively high in contrast to recent studies in other environments. About half the herds were feeding and approximately one-third were traveling. Sightings were most frequent in ship channels, shallow areas inside barrier islands, and near shore. There were several sources of bias in our measurements, and we consider the results to be conservative.

Bartoo, N. 1981. An updated stochastic spawner/recruit relationship for North Atlantic albacore. International Commission for the Conservation of Atlantic Tunas, Madrid, Spain, November 1980. Collective Volume of Scientific Papers 15(2): 204-210. (Also issued as SWFC Admin. Rep. LJ-80-20.)

Butler, R. W., and J. G. Jennings. 1980. Radio tracking of dolphins in the eastern tropical Pacific using VHF and HF equipment. In: Charles J. Amlaner, Jr. and David W. MacDonald (eds.), A Handbook on Biotelemetry and Radio Tracking. International Conference on Telemetry and Radio Tracking in Biology and Medicine, University of Oxford, 1979, pp. 757-759.

Coan, Atilio L., Jr., and Earl Weber. 1981. Length and age composition of yellowfin tuna catches in the eastern Atlantic Ocean, 1966 to 1977. International Commission for the Conservation of Atlantic Tunas, Madrid, Spain, November 198. Collective Volume

of Scientific Papers 15(1): 26-45. (Also issued as SWFC Admin. Rep. LJ-80-13.)

Coe, James M., and Richard W. Butler. 1980. Results of the chartered cruise of the M/V Maria C. J., September 17 to November 22, 1979. NOAA Technical Memorandum, NMFS. NOAA-TM-NMFS-SWFC-6. July 1980, 26 pp.

Coe, James M., and Warren E. Stuntz. 1980. Passive behavior by the spotted dolphin, Stenella attenuata, in tuna purse seine nets. Fishery Bulletin, U. S. (Note), 78(2): 535-537.

Cramer, Jean I., Richard S. Shomura, and Heeny S. H. Yuan [sic]. 1978. The problem of burnt tuna in the Hawaiian Fishery. Indo-Pac. Fish. Comm., Proceedings, 18 Sess., Sect. III:213-223. [Received November 1980.]

The poor quality of the flesh of 'burnt tuna' results in an economic loss to the tuna industry. Rejection of burnt tuna by the consumer is based on visual and taste shortcomings. The present report describes the extent of this problem in the Hawaiian tuna fishery and provides some preliminary results of an ongoing study to understand the phenomenon.

DeMaster, D. P. 1981. Estimating the average age of first birth in marine mammals. Can. J. Fish. Aquat. Sci. 38: 237-239.

The average age of sexual maturity and the average age of first birth should not be estimated with identical models. The two parameters often differ by at least 1 y because, among marine mammals, ovulation and parturition take place in different years because of the relatively long gestation period. Furthermore, the assumptions necessary to estimate the average age of sexual maturity cannot be made to fit the data used to estimate the age of first birth. Equating the two models is essentially equivalent to assuming that each ovulation will result in a birth. The described procedure lends itself well to age-specific data. Comparisons between populations should be with a Chi-square goodness-of-fit test.

Dotson, Ronald C. 1980. Fishing methods and equipment of the U.S. west coast albacore fleet. NOAA Technical Memorandum, NMFS. NOAA-TM-NMFS-SWFC-8. December 1980, 126 pp.

Two fishing methods, trolling and baitfishing, are used by the U.S. west coast albacore fleet to capture albacore (Thunnus alalunga). This paper reviews the various methods and equipment used in both fisheries. A short history of the albacore fishery is given, followed by detailed descriptions of the vessels, equipment, and techniques used. The trolling and baitfishing fleets are reviewed separately. Methods of locating fish using physical and biological clues are described, as are methods of caring for the catch until landfall. A final section on boat equipment and safety is included.

Evans, Richard H. 1981. Comments on the use of water temperature to delimit tropical tuna distributions. International Commission for the Conservation of Atlantic Tunas, Madrid, Spain, November 1980. Collective Volume of Scientific Papers 15(1): 49-56. (Also issued as SWFC Admin. Rep. LJ-80-15.)

Herrick, S. 1981. A baseline economic analysis of surface tuna fishing activities in the eastern tropical Atlantic. International Commission for the Conservation of Atlantic Tunas, Madrid, Spain, November 1980. Collective Volume of Scientific Papers 15(1): 57-90.

Hohn, Aleta A. 1980. Age determination and age related factors in teeth of western North Atlantic bottlenose dolphins. Whales Res. Inst., Sci. Rep. No. 32, pp. 39-66.

Teeth were taken from 120 bottlenose dolphins, Tursiops truncatus, which had stranded on the mid-Atlantic coast of the United States. The number of annual growth layer groups (GLGs) for each animal was used to construct a growth curve. The growth rate of coastal North Atlantic Ocean Tursiops is similar to other cetaceans in having a high initial rate of growth, with no differences in growth between females and males. In females, the first dentinal GLG is thickest and is followed by GLGs progressively narrower. In males, the second GLG is thicker than the first; GLGs beyond number two become progressively smaller but at a slower rate than in females. In males and females, the translucent layer makes up proportionally larger parts of the GLG as the animal ages, but in males the percent translucent layer remains constant at about 50% while in females it continues to increase up to about 70% of the GLG. These two factors, GLGs width and translucent layer width, indicate that the sex and age of the animal influence the deposition of GLGs. Incremental layers are also present, averaging 12 per GLG, and seem similar to incremental layers described in other marine mammals. A plot of the relationship of percent growth of the last GLG to time of death suggests that the deposition of GLGs is relatively constant, at least during the first half of the year, and that North Atlantic Ocean Tursiops give birth in the fall as well as in the spring.

Holts, David B. 1980. The mid-net zipper ridge, a possible cause of unobserved porpoise mortality. NOAA Technical Memorandum, NMFS. NOAA-TM-NMFS-SWFC-3. May 1980, 3 pp.

Jennings, J. G., and W. F. Gandy. 1980. Tracking pelagic dolphins by satellite. In: Charles J. Amlaner, Jr. and David W. MacDonald (eds.), A Handbook on Biotelemetry and Radio Tracking International Conference on Telemetry and Radio Tracking in Biology and Medicine, University of Oxford, 1979, pp. 753-755.

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