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TUNA AND BILLFISH RESEARCH AT THE SOUTHWEST FISHERIES CENTER

U.S. Department of Commerce NOAA
National Marine Fisheries Service

TUNA AND BILLFISH RESEARCH

At The

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An Informal Report, Prepared for the 20th Regional Technical Meeting on Fisheries, South Pacific Commission, Noumea, New Caledonia, 1-5 August, 1988

Tuna and Billfish Research at the Southwest Fisheries Center[1]

TABLE OF CONTENTS

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Tuna and Billfish Research at the Southwest Fisheries Center

INTRODUCTION

In 1987, tuna researchers at the Southwest Fisheries Center continued to work toward meeting these research goals previously identified to guide SWFC research on tunas:

Goal A. To establish and operate a tuna data collection and intelligence system to provide quantitative data for NMFS research and management and assist the U.S. tuna industry to be more competitive internationally.

Goal B. To produce information on the status of stocks of tuna fisheries and on Pacific and Indian Ocean tuna and billfishes.

Goal C. Acquire new information through research to improve the conservation of the resource or the prosecution of the fishery.

Goal D. Provide to NMFS managers the best possible descriptions of feasible alternatives for developing U.S. strategy for fishing and managing the Pacific and Indian Ocean tuna fisheries, together with the best quantitative and qualitative estimates of the biological, environmental, socio-economic, and political impacts of each alternative.

Dominating events in 1987 was the negotiation and signing of the South Pacific Tuna Treaty on April 8, 1987, a significant milestone in U.S. fisheries policy and one which will have profound implications for the future of tuna research at the Southwest Center and Region. In anticipation that the Treaty would be ratified, the staff of the Southwest Fisheries Center developed detailed plans for port sampling of catches by licensed U.S. purse seiners.

A major accomplishment toward the fulfillment of goal B was the completion of comprehensive status of stocks reports on five major tuna and billfish stocks of interest to the U.S, in the Pacific and Indian Oceans, including an economic overview on worldwide tuna production and trade. These reports were prepared and combined into a single 102-page volume and published as a compendium (Bartoo 1987). The preparation of this volume makes available current information for NMFS managers, other government officials and the public for use in decision and briefing documents.

Scientists at the Southwest Fisheries Center continue to try and relate oceanographic conditions to catch rates. At the

Honolulu Laboratory, a model that predicts the catch of large aku (skipjack) tuna in the Hawaiian fishery was developed. Large aku are the most economically important size in the fishery and their availability appears to be correlated with environmental parameters. Analysts using the model forecast an average catch rate of 2,000 pounds of large aku per standard day fished for 1987. A limited ability to sell fresh aku in the absence of a local cannery has kept catches well below this level, and the standard vessel landed only about 1000 pounds of large aku per day in 1987. For the 1988 forecast adjustments were made to incorporate market limitations.

Programmers at the La Jolla Laboratory developed two new data bases for use by tuna researchers. The first contains catch data by FAO areas for tuna, billfishes and sharks from the Atlantic, Indian and Pacific Oceans. The second contains data for purse seiners fishing in the western Indian Ocean.

Honolulu Laboratory and University of Hawaii scientists recently completed a 3-year study on the physiological ability of skipjack and yellowfin tuna to withstand low ambient oxygen levels. Analyses show that these fish are more sensitive to changes in oxygen than had previously been thought. Combining this information with oceanographic data suggests that oxygen availability may limit skipjack and yellowfin to the upper 200 m of the water column in much of the tropical Pacific Ocean. Tuna tracking, using depth sensitive ultrasonic transmitters continued, concentrating in two new areas: tracking skipjack tuna associated with fish aggregating devices, and tracking large yellowfin tuna.

The cooperative marine gamefish tagging program which began in the Pacific in 1963 continued. Billfish anglers tagged and released 1570 billfish in 1987, 27% over the number tagged in 1986.

In 1982, La Jolla Laboratory scientists tagged a striped marlin with a sonic transmitter and tracked its movements off the southern California coast for 24 hours, the first time this species had been tracked. In 1986 and 1987 an additional 11 striped marlin were tagged and tracked in the same area. In 1987 a black marlin was tagged and tracked by scientists from the Honolulu Laboratory.

Since the Marine Mammal Protection Act was passed in 1972, the U.S. has been committed to long term research programs to conserve and protect these animals. The SWFC has initiated a monitoring program using data collected by observers on research vessels and U.S. tuna vessels. This research represents a major commitment by the Southwest Fisheries Center in terms of personnel and resources, but this subject will not be covered in this report due to lack of relevance in the South Pacific area.

Since 1972, the SWFC staff has produced the Tuna Newsletter which presented results of research on tuna underway at the Center's laboratories. In late 1987, the format and editorial policy of the Newsletter were revised and the publication standardized at four times per year. The new series covers research and events in the tuna industry, worldwide. A major addition is a regular column featuring the most recent statistics of the U.S. tuna industry. During the past year, researchers of the Southwest Fisheries Center published 30 papers on tuna and tuna-related subjects. The report which follows here is not intended as a comprehensive account of our work on tuna and tuna-related subjects, but rather as an informal statement of major activities and events.

Most of the information presented in this report was compiled for the Director's Report to the 39th Tuna Conference (Barrett 1988). The original report was compiled by Lillian Vlymen, Technical Writer on the SWFC staff, with editorial assistance from Wes Parks of the Pelagic Fisheries Resources Division, from material supplied by Center scientists at laboratories in Honolulu, La Jolla and Monterey (Pacific Fisheries Environmental Group), and by the staff of the Southwest Region in Terminal Island, California. The information was edited and updated by Chris Boggs for this report to the South Pacific Commission Technical Meeting.

THE U.S. TUNA INDUSTRY IN 1987

U.S. cannery receipts[2] of domestically-caught and imported albacore (white meat) and tropical (light meat) tunas (skipjack, yellowfin, blackfin, bluefin, and bigeye tuna) continued to rise in 1987, reaching 532,704 short tons (tons), an increase of 2% from 1986. Deliveries by domestic vessels to U.S. canneries totaled 253,936 tons, up 12% from 1986, while imports of raw (frozen, not sashimi) tuna fell 6% to 278,768 tons. The total pack of canned tuna by U.S. processors reached 33.6 million standard cases[3], up 3% from 1986.

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

[3] A standard case consists of 48 6.5-ounce cans or 19.5 pounds.

Wes Parks, Fishery Biologist, and Sam Herrick, Industry Economist, of the SWFC, La Jolla Laboratory and Pat Donley, Fishery Reporting Specialist, SWR, recently compiled statistics on the industry for a column in the SWR/SWFC Tuna Newsletter. Their analysis shows that seventy-two U.S. tropical tuna purse seiners, with an overall carrying capacity of 77,677 tons, made at least one fishing trip during 1987 - one less vessel and a 4% reduction in carrying capacity from 1986. More vessels operated in the eastern Pacific than in the western Pacific during the year. Despite the reduction in fleet size, receipts of domestically-caught light meat tuna totaled 251,100 tons in 1987, 12% above receipts for 1986. This total comprised 87,315 tons of skipjack tuna and 163,457 tons of yellowfin tuna (includes bigeye, bluefin and blackfin tuna), a 4% drop in skipjack deliveries and a 27% increase in yellowfin deliveries from 1986.

Imports of light meat tuna decreased 4% in 1987, falling to 177,407 tons. Imports of yellowfin amounted to 82,349 tons, up 4% from 1986. Skipjack made up the balance of light meat imports decreasing 9% from 1986. The total cannery supply of raw light meat tuna--domestic deliveries plus imports for 1987 was up 5% from 1986, and was 4% above the 1983-86 annual average.

Contract prices for domestically-caught light meat tuna delivered to U.S. canneries increased dramatically during 1987. The price of skipjack tuna 7.5 pounds and greater went from a low of $685 per ton at the beginning of the year to $1,000 at year's end. The contract price for 20 pounds and greater yellowfin tuna increased from $765 per ton to $1,125.

In the U.S., skipjack, yellowfin, bigeye, and bluefin tuna are collectively canned as light meat tuna. The 6.5-ounce can of chunk style, light meat tuna in water has in recent years been the most popular tuna product consumed in the U.S. The domestic pack of all light meat products totaled 26.4 million standard cases in 1987, a 7% increase from 1986.

Wholesale list prices for canned light meat tuna also increased during 1987. Prices for advertised-label, light meat tuna canned in water ranged from $42.45 to $45.00 per case at the close of 1987, up 4% to 24% from those of the first quarter. Private label light meat prices at year end were $29.00 to $31.50 a case, up 19% to 26% from those of the first quarter.

Albacore is the only species that may be canned as white meat tuna in the U.S. The volume of domestically-caught albacore delivered to U.S. canneries in 1987 totaled 2,836 tons, 20% less than the volume in 1986. Imports of raw albacore totaled 101,361 tons in 1987, a 10% decrease from 1986, and accounted for 97% of the total cannery supply of albacore, the same as in 1986. The total cannery supply of raw albacore in 1987 was 10% below the 1986 level, and 2% above the 1983-1986 average. The domestic pack of white meat tuna for 1987 amounted to 7.2 million standard cases, down 11% from 1986.

For the first time in recent years, the volume of canned tuna imports declined. Total canned imports were 10.8 million standard cases in 1987, a decrease of 11% from 1986. Imports were dominated by tuna packed in water which is subject to a much lower import duty than tuna packed in oil. When canned imports were combined with U.S. production, the total addition to U.S. canned supplies in 1986 was 44.4 million standard cases, less than a 1% decrease from 1986.

Worldwide, the demand for canned tuna, and hence raw tuna, was up during 1987, while harvests were down. This contributed to the increases in production, processing, and prices within the U.S. tuna industry described above. Production of light meat tuna, particularly from the Atlantic and Indian Oceans, was down creating tight supplies in a strong global market and as a result higher prices at the ex-vessel level. On the other hand, the U.S. fleet, which fished almost exclusively in the Pacific, experienced improved landings, and therefore a significant increase in earnings. While these circumstances meant U.S. canners paid more for raw tuna, they also faced less competition from imports of canned tuna which translated into increased demand and higher prices for domestically packed tuna. Competiton from foreign processors eased in 1987 as the dollar weakened against foreign currencies and European markets for canned tuna expanded. Much of the foreign processed and foreign caught raw tuna was diverted to European markets because the European tuna industry, being much more vulnerable to the shortfall in raw tuna production from the Atlantic and Indian Oceans, was unable to satisfy this growth in demand for canned tuna.

RECENT TRENDS IN GLOBAL TUNA PRODUCTION AND PROCESSING REVIEWED

In a report entitled "Recent Trends in Worldwide Tuna Production and Trade," Industry Economist Sam Herrick, SWFC, La Jolla, examines circumstances within the Japanese and U.S. tuna industries that have fostered the rapid expansion and development of tuna harvesting, processing, and worldwide trade during the 1980s.

Globally, the production of frozen tuna has increased rather steadily in recent years, from 1.796 million metric tons (mt) in 1980, to 2.099 million mt in 1984, an increase of 17% in 5 years (Table 1). Simultaneously, global processing of canned tuna rose from 588,000 mt to 777,000 mt, an increase of 32% (Table 2).

Table 1. World tuna production by major tuna fishing nations, (thousand metric tons, live weight) 1980-1984.

Nation	1980	1981	1982	1983	1984
Japan	723	642	674	696	788
United States	226	222	199	266	263
Spain	101	122	131	126	132
Indonesia	73	84	90	103	115
Philippines	79	95	103	119	104
France	72	69	69	84	100
Taiwan	106	90	104	104	99
Mexico	34	68	45	38	78
Republic of Korea	110	105	108	89	71
Venezuela	4	6	4	39	53
Solomon Islands	23	26	20	34	36
Maldives	28	26	20	26	32
Ecuador	19	19	21	15	29
Ghana	9	15	29	33	22
Brazil	10	24	17	17	22
Panama	21	16	25	14	20
Sri Lanka	20	21	22	23	18
Australia	14	18	21	22	16
Other	124	119	109	98	101
TOTAL	1,796	1,787	1,811	1,946	2,099

Table 2. Canned tuna producers, 1980-84 (thousand metric tons).

Nation	1980	1981	1982	1983	1984
United States	275	287	246	268	275
Japan	95	111	113	117	124
Italy	48	49	48	52	59
Thailand	*	8	15	28	59
France	25	23	30	35	38
Spain	43	40	37	37	30
Ivory Coast	18	26	29	26	23
Philippines	11	18	19	24	23
Mexico	15	20	13	11	22
Taiwan	*	14	11	15	13
Ecuador	5	12	11	7	12
Others	53	70	65	74	99
TOTAL	588	678	637	694	777

Source for Tables 1 and 2: Food and Agriculture Organization of the United Nations, Yearbook of Fishery Stastics, Fisheries Commodities, 1984.

Although these increases in production and processing are impressive in themselves, perhaps more notable is the substantial development in the harvesting and processing capabilities of less developed countries relative to that of Japan and the United States, the dominant tuna producers and processors in the past. The rapid development of tuna industries in southeast Asia, Latin America, the western Pacific and Africa in most cases has been due largely to their proximity to abundant tuna resources, relatively low-cost labor sources, and active government participation. However, although these may be necessary conditions, the impetus for developing tuna industries in these areas comes from real and perceived opportunities to penetrate lucrative tuna markets in the U.S. and Japan.

In Herrick's report, conditions within the Japanese and U.S. tuna industries leading into the early 1980s are reviewed in order to gain a better understanding of how these market opportunities came into existence and, therefore, why patterns of global tuna production, processing, and trade have evolved in the way that they have.

U.S.-SOUTH PACIFIC ISLANDS REGIONAL FISHERIES TREATY

The Treaty on Fisheries Between the Governments of Certain Pacific Island States and the Government of the United States of America

The negotiation and signing of the South Pacific Treaty is a significant event in U.S. fisheries policy. Most coastal nations claim 200 nautical mile jurisdiction over tuna. The U.S., however, neither claims nor recognizes 200 nautical mile jurisdiction over tuna beyond 12 nautical miles. Given their highly migratory nature, the U.S. believes that tuna are best managed internationally. This treaty is a significant step toward such international management. Equally important, for those nations party to it, the new treaty should end the cycle of seizures of U.S.-flag tunaboats and the subsequent imposition of retaliatory U.S. embargoes mandated by the Magnuson Fishery Conservation Act. The U.S. tuna industry strongly supports the agreement.

The South Pacific Tuna Treaty came into force when it was ratified by the U.S. and twelve Pacific Island States: Australia, Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Solomon Islands and Tuvalu. The treaty provides U.S. tuna fishermen with access to treaty area fishing grounds in the South Pacific through a regional licensing program and will, as noted above, eliminate the threat of vessel seizures by island states which do not recognize the U.S. juridical position regarding tuna.

The U.S. Senate gave advice and consent to ratification on November 6, 1987, and President Reagan ratified the treaty on December 21, 1987. Implementing legislation was passed by the U.S. Senate (S. 1989) in June 1988. This bill gives the U.S. legal authority necessary to carry out U.S. obligations under the treaty.

The NMFS Southwest Region (SWR) has established a tuna fishery monitoring program office in American Samoa to handle treaty data collection and fish sampling requirements and to coordinate placement of observers on U.S. vessels. The office is staffed by a fishery biologist and two biological technicians. SWR staff will handle treaty administration, license processing and record keeping from its headquarters at Terminal Island, California.

Collection of U.S. Purse Seine Data Under the South Pacific Regional Tuna Treaty Planned

The staff of SWFC has developed plans for implementing provisions in the agreement with respect to port sampling of catches made by licensed purse seiners. Recognizing the need to coordinate planned activities with SWR as well as with the Forum Fisheries Agency (FFA), the agency designated by the South Pacific Island governments, the Center held a meeting on January 6, 1988 with all parties.

Attending this meeting were representatives from SWFC, SWR, FFA, SWFC, and the South Pacific Commission. Geographic sampling strata and procedures for taking length and species composition samples of catches from the licensed purse seiners were agreed to pending review by the South Pacific Island governments. The sampling procedures are based on methods developed by staff and international tuna organizations. The parties also agreed that NMFS will conduct port sampling in 1988 and exchange information with the FFA. The sampling procedures will be reviewed by all parties at the end of the 1988 fishing season.

The planning meeting and subsequent agreement on the plan for sampling for the 1988 season fulfills an obligation to the South Pacific Island states that was made by U.S. negotiators of the South Pacific Tuna agreement. It also permits NMFS to proceed with the collection of fisheries data from the licensed vessels with confidence that the procedures will meet the needs of the South Pacific Islanders as well as requirements for assessing the condition of the exploited tuna stocks.

Sample Size Requirements Determined for Tuna Length-Frequency Sampling

Fishery Biologist Jerry A. Wetherall, and Mathematician Marian Yong, SWFC, Honolulu recently completed a study of sample size requirements for monitoring length composition in tuna purse seine catches. The work, which is to be published in the NOAA Technical Memorandum Series, was motivated by the new tuna access agreement in the South Pacific and by the need to review existing sampling protocols at Pago Pago, American Samoa, where many U.S. tuna seiners off-load their catches.

The sample size question was explored with respect to a specific statistical criterion; namely, the detection of a given difference in the length-frequency distribution between any pair of time-area strata, with specified probabilities for Type I and Type II errors. This criterion is appropriate for sampling objectives in the early stages of the tuna catch monitoring program, when patterns of heterogeneity in size composition and adequacy of time-area stratification schemes should be evaluated.

Sample size requirements were estimated by using Monte Carlo techniques. A set of alternative hypotheses was defined with respect to the length distributions in a typical pair of time- area strata. Length distributions were assumed to be mixtures of Gaussian components with specified means, coefficients of variation, and mixing proportions. Each alternative hypothesis (contrast) was characterized by differences in the underlying distribution parameters. For each pair of hypothetical distributions, a microcomputer algorithm was used to generate random samples of specified size and to compute the two-sample Kolmogorov-Smirnov (K-S) maximum absolute difference statistic. The sampling process was repeated for a large number of replicates, and empirical probability distributions for the K-S statistic were generated for each contrast.

Because the K-S test is conservative when applied to discrete data and is affected by the grouping interval used in compiling length-frequency statistics, preliminary computer simulations were done to estimate the true "size " of the K-S test under typical sampling conditions. Specifically, it was assumed that the hypothetical tuna were measured to the next lowest whole centimeter, as is usually recommended in field manuals, and grouped by 1-cm intervals for the analysis. Under these circumstances, experiments showed that theoretical critical values for the two-sample K-S test, as tabled in standard statistical references, should be multiplied by a factor of 0.93 to provide a test of correct size, i.e., with the desired nominal Type I error probability. As expected, power curves proved to be quite sensitive to this adjustment.

Monte Carlo experiments were then conducted to estimate power curves for the K-S test with respect to 16 contrasts--10 involving bimodal length-frequency distributions and 6 involving unimodal situations. Limited trials were also carried out with some trimodal cases.

The Monte Carlo results show that, if the distributions in Experiment B7 hold, about 1,000 fish should be measured in each stratum to provide an 85% chance of rejecting the null hypothesis at the 5% significance level, with the adjusted K-S test. Under the conditions of Experiment B8, only about 300 length measurements in each stratum would be needed to satisfy the same objectives.

As expected, the simulations showed that sample size requirements increase in proportion to the number of components in the length-frequency distributions, i.e., in proportion to the number of ways a pair of distributions may differ. Further, they suggested that present rules for length-frequency sampling (e.g., 500-650 fish per time-area stratum) assure only minimal power with respect to many contrasts likely to be of interest to researchers. Of course, in setting sample size guidelines, the choosing of criteria is a critical step. Unfortunately, it is usually given scant attention. In the absence of a rigorous analysis of sampling objectives for tuna length-frequency sampling, it would be prudent to take larger samples than are now typically recommended, say 1,000 fish per time-area stratum.

NORTH PACIFIC ALBACORE

Albacore Management Information Document

The present North Pacific albacore research and development program has been heavily influenced by several historical factors. First, the National Marine Fisheries Service and other U.S. and foreign agencies have already carried out a large amount of research prior to this program. In addition, many of the research studies completed during the current program were started before this program was initiated; in particular, in 1981, the Southwest Fisheries Center established an Albacore Task Force whose recommendations resulted in a significant reorganization of the albacore research program and placed a major emphasis on the development of a "state of the art" fishery simulation model.

Second, the U.S. Pacific albacore fishery has had an unusually large component of industry-sponsored research due primarily to the efforts of the Western fishboat Owner's Association, the American Fishermen's Research Foundation, and the foresight and cooperation of many individuals in the albacore fishing industry. This work has involved a wide range of activities including tagging programs, fisheries oceanography research, fishery development, exploratory fishing, and processing technology. This effort has been carried out in close cooperation with the National Marine Fisheries Service's research and development programs.

The final factor is that the albacore fishery has had a tradition of international cooperation for research. The United States and Japan have been the principal nations harvesting the north Pacific albacore resource and they have shared both their research information and fishery data for several decades. More recently, Canada, South Korea and Taiwan have taken small numbers of albacore in the North Pacific and these nations have also contributed to cooperative research on the resource.

The Albacore Task Force is coordinated by Fishery Biologist Dick Parrish, SWFC Pacific Fisheries Environmental group, Monterey. As part of a multiyear research and development program for Pacific albacore, the Task Force has completed an Albacore Management Document which describes the current knowledge of the North Pacific albacore resource, the present status of the resource and the status of the fishery.

The albacore program was the first NMFS program which was designed through an interactive planning process in which a 'constituent' group, who collectively represented a wide range of public interests related to albacore, developed the strategic plan for the program. This plan was then translated into an operational plan by the Albacore Task Force which included technical personnel from the Southwest Region and four SWFC Divisions.

Historically, the U.S. albacore fishery has marketed its product almost exclusively to canneries. The distant water nature of the fishery, the reliance on the cannery market, and the recent great reduction in local canning of tuna has resulted in a situation where it has been very difficult for the fishery to market as much albacore as it can land. The principal mechanism used by NMFS to assist the albacore fishery in regaining economic stability has been through grants to industry sponsored programs. Twelve Saltonstall-Kennedy grants were used to assist in the development of new markets for albacore. Four of these grants concerned market development ($279,350), three were concerned with onboard processing methodology and new product development of albacore ($124,400) and five were for albacore fishery development ($433,000). In addition to the S-K grants, NMFS personnel prepared four economic analyses concerning the albacore fishery. Three of these dealt with the commercial fishery and one with the recreational fishery.

A significant characteristic of the North American fishery is the wide variation in the geographical locations of the most productive fishing grounds. Uniquely, a large proportion of this variability is at the decade rather than the interyear time scale. For example, catches off California dominated the fishery prior to the 1930's and from about 1957 to 1965; catches from Baja California were large from about 1948 to 1956; and those from Oregon and Washington were dominant from during the late 1930's to mid 1940's and from about 1966 to 1975. Catches have been variable throughout the time series with an apparent downward trend since the mid 1970's. Effort levels for the jigboat fishery indicate a peak in the early 1970's, a period of high prices which followed a number of years of high catch rates, with decreasing effort since then. A CPUE decline from about 120 fish/day in the late 1960's to about 40 fish/day in 1980 precedes the decline in effort and catches. More recently the CPUE has increased to near 1960's levels.

A significant proportion of recent NMFS albacore research has centered around the development of a simulation model of the North Pacific albacore population and fisheries. The international North Pacific albacore fishery is carried out by fisheries utilizing different gear types. Each fishery has a different geographical range and seasonality and each fishery exploits a different size distribution of albacore. The model therefore requires gear type, area, seasonal, and fish size resolution. The first use of the model was to study the interaction among the three fishing fleets. The model simulated recruitment, growth, movement, natural mortality and harvest of albacore by three fishing fleets: the Japanese baitboat fleet, the Japanese longline fleet, and the United States jig fleet. At the current level of exploitation, the largest interaction modeled was an 8% loss of longline catch due to a doubling of baitboat effort, suggesting that the population is only moderately exploited.

The stock structure of albacore in the North Pacific is one of the most significant areas for research in the strategic plan. State of the art population genetics analyses, utilizing mitochondrial DNA, demonstrate that albacore from the North Pacific are genetically indistinguishable with presently available methodology from those off South Africa. This implies that it is possible that there is only a single stock of albacore in the entire Pacific. Conversely it does not rule out the possibility that there is more than one fishery stock in the North Pacific. Results from a number of studies, including the cooperative NMFS/AFRF albacore tagging studies, suggest that there are two subgroups of albacore in the North Pacific. These subgroups appear to have different migratory patterns, modal sizes in the U.S. fishery, growth rates, and birth months.

The presently available information suggests that the most likely situation is that there is either one or two stocks of albacore in the North Pacific. If there is only one stock it spawns year round and fish spawned in the summer, more northerly, spawning grounds tend to have a more northerly distribution as juveniles than do those spawned in the winter, more southerly, spawning grounds. If there are two stocks, one spawns in the summer and the other in the winter and the two stocks have different geographical distributions.

If there is only one stock available, evidence suggests that the stock has been moderately exploited and that the population and its recruitment have been remarkably stable. Simulations with the albacore model, made under the assumption of a single stock, show very little interaction between the three major fisheries and suggest that the stock is not heavily exploited. The CPUE's of the major fisheries vary by factors of about 2.6 in the two Japanese fisheries and 3.8 in the American fishery and there is a significant correlation (0.01%) between the CPUE's in the Japanese and American surface fisheries (r=0.554). However, the American fishery is much more remarkable for its geographical variation than its interyear variation in catch or CPUE. In fact, the relatively low variability of catch and CPUE in the American fishery is unusual as this fishery is heavily dominated by a single year class (age three) and such fisheries are often characterized by very large variability. Finally, the size composition in the longline catches in the main spawning grounds where the largest albacore are taken have remained nearly constant from 1965 to 1981 also suggesting that the exploitation level has not been high. However, fishing effort and catch in both the Japanese and American surface fisheries are presently about one quarter of their peaks. In both fisheries the period of decline follows extended periods of reduced CPUE and economics cannot therefore be blamed for all of the decreases in effort and landings. In contrast, recent landings and fishing effort in the longline fishery have been relatively constant.

If there are two stocks in the North Pacific, either the recruitments or the migrations of these stocks to the California Current region must be extremely variable. The relative stability of the Japanese fisheries in comparison to the fishery in the northern portion of the California Current region would imply the latter. In addition, the pattern of landings in the California Current region (i.e. multiyear series of northern or southern dominance) implies that the variations in the two stocks are negatively correlated. The two stock concept also suggests that the northern stock provides the major component of the North Pacific landings as it is presumably the principal stock in the Japanese surface fishery. However, both stocks have about the same tag recovery rates (5%), and therefore the same exploitation rates, in the adult habitat (i.e. in the Japanese longline fishery). In this regard it is significant that the Japanese longline fishery is extremely limited in the area where the albacore spawn in the winter.

Exploratory Space-Time Forecasting of North Pacific Albacore

At the SWFC Pacific Fisheries Environmental Group, Operations Research Analyst Roy Mendelssohn and Oceanographer David Husby continued their efforts to ascertain if oceanographic conditions can be used to forecast albacore catch-unit-effort (CPUE) by one-degree square and by two-week periods. Previous work suggested that nonlinear transformations of the environmental data greatly improved the ability to forecast albacore CPUE. Further studies have shown that best results are obtained if the axes for the wind data are rotated so that they run from northwest to southeast and from southwest to northeast. When this is done, the northwest-southeast component of the wind vector is much more important for making predictions.

The estimated transformations of the northwest-southeast wind component suggest that there is no significant relationship between CPUE and the wind component until the wind is from the northwest at roughly 3m/sec. The transformation is then window-shaped, with a peak in the range of 7-10 m./sec. These speeds are consistent with when the wind should be strong enough to first affect the surface water, and when upwelling should be strong enough to start plankton blooms. This is in agreement with the observations of Hickey (1979) who showed that upwelling in this region tends to be associated with winds from the northwest. Mendelssohn and Husby indicate they find it encouraging that their empirical methods extract relationships from the data that are physically meaningful and agree with field observations.

Since there are not sufficient CPUE data to estimate these nonlinear transformations in each of the one-degree squares under study, it became necessary to find a way to extend the analysis over the entire region. The area of study was divided into nine subareas, selected on the basis of oceanographic features of the areas. It was assumed that the transformation of any variable has the same shape for any one-degree square in the subarea. Rather than using purely empirical transformations, approximate functional forms were fit for each variable in each subarea. These were then used to calculate the transformed oceanographic variables for each one-degree square from the observed data in that square.

Statistical models of the space-time dynamics of the oceanographic variables have also been developed. These permit examination at what scales the environment is changing and therefore what near or not-so-near neighbors may be affecting the catch in a given square. These models also have been recalculated for the estimated transformations in order to see how the transformations have altered the dynamics of the oceanographic variables.

Mendelssohn and Husby are presently writing up the results obtained thus far in a form suitable for a book or long report; preliminary versions of four chapters describing the work to date have been completed.

Value of Information for Skippers in the Albacore Tuna Fishery Modelled

Kevin Carlson, Industry Economist at the SWFC, La Jolla, is developing a location decision model for the albacore tuna fishery using the logbook data provided by the Staff at SWFC, La Jolla. The average season for the U.S. North Pacific fleet consists of over 5,000 troll fishing days and about 500 separate trips over a maximum of 275 days. For the period 1975 to 1986, over 1,300 skippers participated in the logbook program and over 500 skippers submitted logbooks for two or more seasons.

The modelling consists of two parts. First, using data from 1964 to 1986, Carlson constructed fishing trip paths that yield the highest expected catch per day subject to travel constraints for a set of ports and trip lengths. Two measures of expected catch, E[catch], are used: 1) based on past fleet averages alone without updating from current fleet performances; and 2) based on past fleet averages with updating from current fleet performance. These two measures will provide upper and lower bounds for calculating the value of information used to select a fishing site. The information available to a skipper is hypothesized to consist of four distinct sets: a) historical fleet catch rates, b) the skipper's current catch rate, c) locally shared catch rates, and d) global catch rates.

The second part of the analysis examines actual skipper behavior. Using a subset of skippers who have participated for two or more seasons, Carlson estimated the probability of choosing a particular fishing site as a function of hold capacity, days at sea, the skipper's experience, the expected catch rates for the alternative fishing sites, and the distance to those sites. Alternative fishing sites are defined to be one-degree squares. Assuming profit maximizing behavior on the part of the skippers, the site with the greatest expected profit (profit price * E[catch] - cost * distance) will have the highest probability of being selected. Since the expectation of the catch rate will depend upon the four different sets of information, the weights of the coefficients on the expected catch rate and the distance indicate the relative values of the four different information sets in selecting fishing location.

Recommendations of the Tenth North Pacific Albacore Workshop Published

The Tenth North Pacific Albacore Workshop was held in Shimizu, Japan, in August 1987. The meeting, attended by SWFC scientists Norman Bartoo, Michael Laurs, and Jerry Wetherall produced a number of recommendations documented in the recently printed workshop report.

To improve statistics, the participants recommended that catch, effort and size composition data for albacore caught by Japanese drift gillnet fisheries should be obtained. Efforts to secure these data have been underway and should be continued. Statistics on the amount of fresh albacore that is consumed and albacore that is marketed directly in the U.S. should be collected. Fishery statistics for albacore caught by the Taiwanese squid driftnet fishery should be investigated and data secured. Any information on Korean tuna fisheries in the North Pacific Ocean should be obtained; there is virtually no information on these fisheries. Catch and fishing effort statistics from all participants should continue to be presented on a timely basis.

For stock assessment, the participants made four recommendations. Production model and yield-per-recruit and basic analyses should be continued and reported. An updated spawner-recruit analysis for the stock(s) should be undertaken and modeling of early life history stages (pre-recruit) is encouraged. Simulation model analyses and alternative assessment techniques should be continued to test hypotheses critical to other analyses. Assessments should take in the possibility of a geographically divided fishery stock in the North Pacific.

In the area of biology, ecology and stock structure, the participants recommended that age and growth analysis should continue based on otolith, tag returns and length-frequency data. Special attention should be given to resolving differences between growth models based on otoliths and tag returns. A migration model by age that incorporates all tagging data and other appropriate data available for the North Pacific albacore resource should be developed. A Japanese scientist(s) should work with U.S. scientists in the U.S. to accomplish this task. Spawning areas and seasons should be identified and reported. Juvenile sampling studies at sea are encouraged as well as histological studies of maturity and sex ratios in adult fish.

Physiology studies and further work with ultrasonic tracking should be undertaken as a means of improving understanding of albacore behavior and definition of albacore habitat. Progress in the development in the U.S. of the "archival" tag should be monitored and the use of the "archival" tag to investigate albacore biology should be encouraged. Tagging of albacore in the central and western Pacific should be continued and expanded. Emphasis should be placed on obtaining information for 1- and 2- year-old fish as well as for mature fish of 6 years and older.

To study the ocean environment, a joint Japan/U.S. effort should be conducted to determine oceanographic and other natural mechanisms that affect the migration patterns of albacore. This work should be undertaken when the albacore migration by age model is developed. Since the oceanographic conditions in the western Pacific, notably in the Kuroshio and Kuroshio Extension regions, appear to play key roles in affecting albacore migratory patterns, a U.S. scientist(s) should work with Japanese scientists in Japan to accomplish this task. Oceanographic studies to identify and quantify key habitat processes affecting albacore fisheries should be continued for input into simulation and ecology studies. Extended application of satellite remote sensing data to fisheries research application should be continued.

Analyses Completed on North Pacific Albacore Otolith and Tagging Data

The paper "Growth variation and stock structure in North Pacific albacore" was presented by Jerry Wetherall, of the SWFC Honolulu Laboratory, at the 10th Albacore Workshop The paper was co-authored by Marian Y. Y. Yong, Honolulu and R. Michael Laurs and Robert Nishimoto of the La Jolla Laboratory.

The paper describes analyses of otolith daily increment counts and extensive tag return statistics to 1) estimate models of age and growth, 2) assess geographical differences in growth rate, and 3) elicit information on spawning seasons and birth date distributions. The increment counts were made on lightly etched, whole otoliths. Otolith counts and data on tag releases and returns were carefully screened to remove outliers and unreliable observations.

Both otolith data (from 225 albacore) and tag return data (from 521 tag returns) suggested faster growth for albacore in an hypothesized "south" substock (generally supporting the United States fishery south of lat. 40'N and east of long. 135'W) than for those in a "north" substock (generally supporting the Japanese fisheries, and the United States fishery in the central Pacific Ocean and in the area north of lat. 40'N and east of long. 140'W). Otolith data, however, indicated much faster growth than is shown by the tag returns. Growth rates of tagged albacore, on the other hand, are generally consistent with historical length frequency statistics and the assumed 1-year interval adjacent length-frequency modes.

Daily increment formation has been validated for albacore larger than 51 cm fork length by tetracycline-tagging experiments, so the whole counts on otoliths were expected to provide accurate age estimates. However, for the whole otolith preparations, daily increments on older albacore may have been undercounted, especially those deposited during the first 2 years of life. As a result, ages may have been underestimated, and growth rates based on the otolith data overestimated.

Otolith increment counts for albacore younger than 1.5 years old were assumed to be unbiased; they were used to estimate mean fork length at first birthday. This result (35-38 cm fork length at 1 year) was combined with the tag return statistics to estimate growth models for the two groups of albacore

Assuming these composite models are correct, spawning seasons for the south and north albacore are estimated to peak roughly 6 months apart, with north fish spawning primarily in the summer and south albacore in winter (with a fair amount of overlap).

These results hinge on several critical assumptions, which require further investigation. In particular, increment counts on whole otoliths should be compared with counts taken on other preparations (e.g., various types of sections). Variations in otolith microstructure should also be studied. Increment width patterns and other features may provide useful additional tests of stock structure hypotheses.

Albacore Fishery Advisory Operations

The La Jolla Laboratory continued to provide albacore fishery advisory information during 1987. Fishery Biologist Ron Dotson prepared a daily albacore broadcast each weekday from July 6 through October 2, 1987, for a total of 64 reports. Information for the broadcasts is taken from fishing vessels' radio reports, conversations with commercial and sport fishermen, State fisheries agencies, fish buyers in coastal ports, port samplers, and others dealing in fisheries-related businesses.

The reports, which are one to two minutes long, were taped over the phone by five commercial radio stations for broadcasting evenings and mornings over AM and FM bands. A hard copy was also transmitted to radio station WWD for transmission twice daily over two single side-band channels. In response to a request by the Canadian Department of Fisheries, a hard copy of the daily broadcast was sent to them via FAX and broadcast by their fisheries department over SSB radio.

In addition to the foregoing, an Albacore Bulletin which summarized albacore fishing conditions, weather and sea surface temperature information and marketing conditions on the U.S. West Coast was written and printed every 15 days. Seven Bulletins were written and distributed during the albacore season in 1987 to a mailing list of 800, most connected in some way with the fishery.

SOUTH PACIFIC ALBACORE

Fishing Assessed in South Pacific

Oceanographers Michael Laurs and Ken Bliss and Fishery Biologists Jerry Wetherall and Robert Nishimoto have completed an analysis of exploratory trolling fishing for albacore in the South Pacific. Seven U.S. fishing vessels conducted exploratory trolling fishing for albacore and made related scientific observations in the central South Pacific from January through April 1987. In addition to the U.S. fishing vessels, SWFC scientists aboard the NOAA Ship Townsend Cromwell conducted an oceanographic and troll fishing survey in conjunction with the fishing vessels' operations. Research vessels from New Zealand and France also participated in the albacore exploration and research investigation.

The vessels conducted exploratory fishing for albacore using standard U.S. commercial troll fishing methods. All the vessels were equipped with sea surface temperature gauges and fish sounders, and some had chromascopes to aid in locating potentially favorable fishing areas. Apart from troll fishing for albacore, fishermen also conducted albacore tag and release operations and made oceanographic observations in cooperation with SWFC scientists.

Fishing success was high in the area between 36-41'S, 135-1553W where catch rates were greater than 250 fish on 55% of the boat-days, and more than 500 fish on 33% of the boat-days. There were eight boat-days, nearly 4%, when the catch per boat was over 1,000 fish. The largest catch made in one day was 1,241 fish by the fishing vessel Defiance. Some fishing captains said that albacore fishing was the best they had ever experienced at any time or place.

The sizes of the albacore tuna caught ranged between 4 and 60 pounds, with 11-to-13 pound fish and 18-to-24 pound fish predominating. The overall average weight of the albacore caught by all boats for all trips was 16.4 pounds.

The survey area during the mid-January through mid-

February period was characterized by sea surface temperatures ranging from 62 to 70'F, mixed-layer depths to the top of the thermocline ranging from about 100 to 150 feet, and thermocline gradients ranging from about 3 to 8'F. The northern boundary of the Subtropical Convergence Zone (STCZ) was found between about 37'30' to 39'30'S in the region of about 155'W and appeared to bend southwestward west of 155'W. Fishing success experienced by the Cromwell and the fishing vessels was related to variations in the locations and strength of oceanic boundaries associated with the STCZ.

Weather conditions while the boats were traveling from California to Papeete and to the fishing grounds were generally good with light to moderate trade winds and relatively calm seas. One of the fishing vessels, the Red Baron, encountered some rough weather for a few days while traveling to the fishing grounds from Honolulu. Weather conditions overall were fair to good on the fishing grounds and boats lost only a few days of fishing because the were forced to drift.

The catches of albacore were sold in Papeete and averaged approximately $1,300 per short ton. Small amounts of fish were rejected by the buyer in Papeete because they were badly misshapen, broken or split and judged to be of inferior quality.

Laurs, Bliss, Wetherall, and Nishimoto conclude that prospects for establishing a U.S. troll fishery on albacore in the South Pacific appear to be excellent based on the experiences of the vessels that conducted exploratory trolling explorations. The high catch rates, high total catches and relatively good weather conditions, combined with the infrastructure in the South Pacific for selling catches and supporting vessel needs, indicate that it is economically feasible for U.S. albacore fishing vessels to operate there. They caution, however, that substantially more fishery exploration, especially in the area west of about 155'W, and knowledge of the migratory patterns and biology of the South Pacific albacore population are required to successfully develop a viable U.S. albacore surface fishery in the South Pacific. Delivering a high-quality product to the albacore fish buyers and canneries will be most important.

A detailed assessment of albacore fishing in the South Pacific can be found in SWFC Administrative Report LJ-87-22, "South Pacific albacore fishery exploration conducted by U.S. jig boats during early 1987" by R. Michael Laurs, Ken Bliss, Jerry Wetherall, and Bob Nishimoto.

South Pacific Albacore Research Plan is Prepared

During 1987, scientists at the SWFC, Honolulu Laboratory, took the lead in preparing a cooperative plan for South Pacific albacore research. The plan outlines the research needs and strategies for improving capabilities in stock assessment, fishery monitoring, fishery development, analysis of fishery interactions, and modeling of stock and yield dynamics. Also contributing to the plan were albacore biologists from the La Jolla Laboratory and the New Zealand Ministry of Agriculture and Fisheries. The plan will be released as a Southwest Fisheries Center Administrative Report.

Cooperative South Pacific Albacore Tagging Program

The Southwest Fisheries Center continued a lead role in a cooperative South Pacific albacore tagging program. Albacore tagging operations were conducted on a coordinated, informal basis in 1986 by SWFC scientists on board the R/V Townsend Cromwell albacore research cruise, by New Zealand scientists on board the R/V Kaharoa, and by U.S. fishermen conducting albacore exploratory fishing. A cooperative South Pacific albacore tagging program with standardized methods was recommended and adopted at the First South Pacific Albacore Workshop held in Auckland, New Zealand in June, 1986. Albacore tagging operations were conducted in 1988 by cooperating U.S. fishermen with equipment and training provided by SWFC scientists and by New Zealand fishery scientists. A summary of the number of South Pacific albacore that have been tagged and released is given in Table 3 below.

Table 3. Summary of South Pacific albacore tagged and recovered during 1986-1988.

Vessel	1986	1987	1988	Total
U.S. fishing vessels	702	456	447 (1,247)	1,633 (2,453)
R/V Cromwell	21	425	na	446
R/V Kaharoa	138	178	624	940
N.Z. fishing vessels	na	70	na	70
R/V Coriolis	na	190	na	190
TOTAL	861	1,319	1,071 (1,871)	3,551 (4,051)

The numbers in parenthesis indicate tags that were distributed to U.S. fishermen fishing in the South Pacific this year who have not yet returned to the U.S. At this time it is not known for certain if all the tags were used.

The first tagged albacore recoveries ever made in the South Pacific occurred in 1987. Two albacore, which were tagged by Captain Carroll Hoeppner on the U.S. F/V Day Star, one released in 1986 and the other in 1987, were recovered by Taiwanese and Korean longline fishing vessels. Both tag recoveries were made several hundred miles east of the release locations after being at liberty for 2 and 13 months. Information on the dates and locations where the fish were released and where they were recovered is given in the Table 4 below. This is the first direct information on albacore migration in the South Pacific.

Table 4. Recoveries made of tagged South Pacific albacore.

Tag no.	Date	Lat. (S)	Long. (W)	Size (cm)	Date	Lat. (S)	Long. (W)	Size
A01473	2/28/87	39'43'	151'04'	64	4/27/87	38'23'	145'38'	
R03362	3/09/86	40'20'	145'50'	78	4/16/87	38'23'	133'45'	86

HAWAII'S TUNA FISHERIES

Hawaiian Tuna Fishery Data Analyzed

Data collected on Hawaii's tuna fisheries by the Honolulu Laboratory and the State of Hawaii Division of Aquatic Resources through 1987 were analyzed to document the expansion of fisheries for yellowfin and bigeye tunas and the decline of the fishery for skipjack tuna. Attempts to use longline trips as a unit of effort for stock assessment of yellowfin and bigeye tunas have indicated a need for additional information on effort. In 1988, information volunteered by longline fishermen on their operations was collected by Chris Boggs, SWFC, Honolulu. In exchange, fishermen were provided with information, upon request, on El Nino, ocean temperatures, past locations of seasonal high catch rates, and publications regarding vertical distribution and fishing techniques.

Sampling Program for Tuna Initiated at Honolulu Auction

Biological sampling of tuna at the Honolulu auction was initiated to increase contact and information flow between fishermen and National Marine Fisheries Service personnel. Morphometric measurements for yellowfin tuna, stratified by season, gear (surface vs. longline), and area (from nearshore

Hawaiian Islands to Palmyra Island) were collected under the direction of Fishery Biologist Chris Boggs, SWFC, Honolulu. Techniques were calibrated against those of the Inter-American Tropical Tuna Commission (IATTC) so that results can be compared with the IATTC Pacific-wide "snapshot" samples collected in February and March 1987. The objective is to determine whether identifiable groups of yellowfin tuna differ in their distribution and availability.

1987 Hawaiian Skipjack Tuna Fishing Forecasted

A model that predicts the catch of large (>15 lb) aku (skipjack tuna, Katsuwonus pelamis) per unit of fishing effort by the Hawaiian domestic pole-and-line fishery has been used by Chris Boggs to forecast an average of 2,000 lb of large aku per standard day fished in 1987, and 2,200 lb of large aku per day fished in 1988. The availability of large aku is economically more important than the availability of other sizes, and the availability of large aku seems to be more highly correlated with environmental changes.

The forecast is best stated in relative terms because economic factors (especially the closure of the local cannery) have caused radical reductions in the effort expended during a day of fishing. In relative terms, the forecasts for 1987 and 1988 were that fishing conditions should be similar to what they were like in 1986. Or stated another way, more large aku should be available to Hawaii fishermen than there were in 1974 through 1983.

The model is an update of attempts that started at the Honolulu Laboratory during the 1960's and 1970's to predict the total annual catch. Using data through 1978, Operations Research Analyst Roy Mendelssohn of the Pacific Fisheries Environmental Group reworked and improved this approach in 1986 (Southwest Fisheries Center Administrative Report H-86-13C). Since then, the decline in the capacity of the fishing fleet has made prediction of total catch from this model a problem. Recent catch and effort data compiled by Biological Technician Bert S. Kikkawa and Fishery Biologist Robert A. Skillman (NOAA-TM-NMFS-SWFC-72) and data on the size distribution of catches in recent years were used to fit a model that predicts the average annual catch rate of large aku.

The prediction of catch rate is based on the north-south movement of sea-surface temperature isotherms east of the Hawaiian Islands (at long. 140'W) during January through April of the current year and 1 and 4 years previously. High catch rates are predicted when the 20'C sea-surface temperature isotherm is relatively farther north in April than in January for 2 consecutive years. This model explained 68% of the variance in annual catch rates of large aku from 1960 through 1983. The relative proportion of other sizes (<15 lb) of aku in the catch was also predicted from isotherm movements. The forecast for 1987 was that large aku will would comprise 48% of the catch, and the forecast for 1988 was that 44% of the catch would be large aku.

Assuming the same level of effort would be expended in 1987 as in 1986 the total catch was predicted to be about 2 million pounds in 1987. The actual catches in 1987 were higher than predicted, due to a very large catch of medium sized aku. The total pole-and-line baitboat catch estimated by the State of Hawaii was 3.1 million pounds, but catch rates were only about 1,000 pounds of large aku per boat per day.

Looking at the data for recent years more closely, it was found that since the cannery located in Honolulu closed in 1984, the patern of effort has shifted, such that relatively more effort is expended in what used to be the "off" season. During the traditional season, when large aku are usually most available, a quota system is used to avoid flooding the market and lowering prices.

The forecast was adjusted in 1988 to take this market force into account. It was assumed that total effort (days fished) would remain similar to 1986 and 1987, but that landings would never exceed 300,000 pounds per month, which was around the level of high catch months in recent years. With this correction the 1988 forecast came to 1,200 pounds of large aku per standard day fished, with an estimate for total 1988 landings of 3 million lbs.

Time-series data on sea-surface temperature, salinity, and density measured at Koko Head on Oahu were also reexamined in forecasting aku abundance (all sizes): higher-than-average summer and autumn temperatures were found to precede 5 of the 6 worst years between 1960 and 1983. Higher-than-average tempera- tures were also observed in the summer and autumn of 1986.

In May of 1987 and again in 1988, a flyer summarizing the forecast and the Koko Head sea-surface temperature data was mailed to the Hawaii tuna industry and other participants in the 1986 aku workshop and strategic planning sessions held to examine the future of Hawaii's aku (skipjack tuna) industry.

Tuna Fishery Monitoring Activities at the Honolulu Laboratory

Much of the tuna research at the Honolulu Laboratory centered on tuna fisheries monitoring activities. Several reports representing previous economic research were prepared in

1987. Because a large portion of the data used for these reports is confidential, many of the research results are not released to the public. Plans for 1988 include transferring the American Samoa sampling program to the NMFS Southwest Region and instituting a Honolulu longline tuna fishery monitoring system.

The five areas of tuna research in 1987 are summarized below:

1) American Samoa tuna monitoring program.

Foreign albacore longline fishery--Data were collected by Fishery Biologist Gordon Yamasaki on size frequencies of albacore, yellowfin, bigeye, and skipjack tunas, total catch and effort (in hooks) and cannery off-loadings. Longline gear technology was also surveyed. Data have been collected since the 1960's. The program is voluntary and the data are classified as confidential.

Western Pacific tuna purse seine fishery--Data were collected on size frequencies of skipjack, yellowfin, and bigeye tunas by boat well. Landings by general area fished were also collected, as were cannery off-loadings and transshipments. This program also was voluntary.

The American Samoa station also collected data on size frequencies from landings by the U.S. albacore trolling fleet, which has fished in the South Pacific over the past 2 years.

Under the 1987 South Pacific Tuna Treaty, U.S. tuna purse seiners fishing the central and western Pacific will be required to file logbooks. The National Marine Fisheries Service's Southwest Region will take over the American Samoa tuna monitoring program sometime in 1988, but until then, the voluntary data are being collected by the Fishery Management Research Program.

A confidential report on the purse seine fishery was completed in 1987, and a public report on the longline fishery is near completion. The longline report utilizes a computerized mapping program produced by Dr. Jerry L. Fuqua.

2) Hawaii wholesale market monitoring program.

Data were collected from a limited number of sites on tuna (and other species) sold through wholesale markets. These data included the number, size, volume, and price as well as information on source and distribution. Data on tuna were first collected under the new monitoring program in 1987, although data from earlier years (1960's and 1970's) are also available. Tuna data for Hawaii will be reported later in 1988 by Christofer Boggs and Samuel Pooley.

3) Western Pacific Fishery Information Network.

Dave Hamm, Manager of the Western Pacific Fishery Information Network at Honolulu, compiled fisheries data, including local tuna catches, from American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands (CNMI). Data also included tuna transshipments (U.S. and foreign distant-water catches) from Guam and the CNMI. The statistics for 1979-86 have been compiled and are available as administrative reports.

4) Honolulu skipjack tuna sampling.

Landings of skipjack tuna by the pole-and-line tuna fleet were monitored by Ray Sumida, Honolulu Laboratory, on a regular basis at Kewalo Basin, Oahu. This sampling has been conducted intermittently for the past 25 years. The data have been used for a variety of purposes related to pelagic and economic research.

5) Koko Head ocean sampling.

Data were collected twice weekly on water temperature, salinity, and weather conditions at a point on the southern shore of Oahu. The data have been used in models predicting the relative availability of skipjack tuna in Hawaii's waters. The sampling program will be summarized by Research Assistant Russell Ito later in 1988.

TUNA DATA BASES DEVELOPED

Al Coan, Statistician, and Aaron Weinfield, Computer Programmer at the La Jolla Laboratory have created two new data systems for tuna researchers. The first data system contains yearly catch data by FAO areas for tuna and tuna-like fishes, billfishes and sharks from the Indian, Pacific and Atlantic Oceans. The source of the data is the FAO Yearbook of Fishery Statistics, supplied by Dick Schween of NMFS in Washington, D.C. Some of the data have been modified to include gear designations obtained from Indo-Pacific Tuna Development and Management Programme Data Summaries. The system currently contains data for 1970 to 1985 and will be updated yearly. The data are stored on a microcomputer using the commercial data base management package FOXBASE, a compiler for Dbase III programs. ASCII files can also be generated.

The second system contains data for purse seiners fishing in the western Indian Ocean. Data include monthly catches of yellowfin and skipjack tunas, fishing effort in days fishing and number of vessels and catch-per-unit effort. The data source is the Seychelles Fishing Authority Tuna Bulletin. The system currently contains data for 1983 through the second quarter of 1987 and new data will be added as they are received. The data are stored on a microcomputer using the commercial package LOTUS, and can be transferred to ASCII files.

TUNA BEHAVIOR AND PHYSIOLOGY

Small-scale, limited range fisheries in the proximity of tropical Pacific islands often experience abrupt changes in tuna availability. During the past year, much of the research activity of the staff of the Pelagic Ecosystem program at the Honolulu Laboratory has focused on the dynamics of tuna and tuna fisheries around the Pacific Islands. Other research has examined the behavior of tuna in response to physical variables that affect their distribution worldwide.

Physiological Responses to Changes in Ambient Oxygen Concentrations

A 3-year series of experiments into the physiological abilities of skipjack tuna and yellowfin tuna to withstand low ambient oxygen was completed recently by Peter Bushnell, a graduate student at the University of Hawaii, and Richard Brill, of the Honolulu Laboratory. The overall research objective was to determine the effects of ambient oxygen concentrations on tuna movements, available habitat, and gear vulnerability.

Analysis of the data from these experiments is still in progress, but results to date have shown both species to be sensitive to changes of less than 0.3 parts per million in ambient oxygen content. In other words, yellowfin and skipjack tunas are much more sensitive to changes in ambient oxygen levels than had previously been thought. Both species respond to lowered ambient oxygen by increasing swimming speed and ventilation volume while reducing heart rate. These physiological adjustments are made in an apparent attempt to provide the tissues with adequate oxygen.

Preliminary analyses of recently completed experiments also indicate that these responses are only effective in maintaining oxygen delivery down to ambient oxygen levels of approximately 4 parts per million. When ambient oxygen falls below this level, oxygen delivery to the tissues is impaired in both tuna species. Combining oceanographic data with these newly acquired physiological data implies that oxygen availability limits yellowfin and skipjack tunas to the upper 200 m of the water column in much of the tropical Pacific.

Tuna Tracking Continues off the Islands of Oahu and Hawaii

The tuna tracking project, using depth-sensitive, ultrasonic transmitters, concentrated on three new aspects: (1) tracking skipjack tuna associated with fish aggregating devices (FAD's), (2) tracking large (>50 lbs) yellowfin tuna,. and (3) analyzing the tracking data previously collected on small yellowfin tuna with respect to the amount of time spent at specific depths and temperatures. These efforts were part of a continuing joint program being conducted by Richard Brill and Randolf Chang, Fishery Biologists with the Honolulu Laboratory, and Kim Holland of the University of Hawaii Sea Grant Program. Chris Boggs, SWFC, Honolulu, working with Alvin Katekaru, Marine Resources Chief with the State of Hawaii Division of Aquatic Resources (HDAR), planned the joint NMFS - HDAR project to track large yellowfin tuna associated with small areas of high availability (called "koa") near islands.

The skipjack tuna tracking was conducted off the leeward and windward coasts of Oahu, whereas tracking of large yellowfin tuna was conducted for 2 months aboard the National Marine Fisheries Service's research vessel Kaahele'ale off Kona on the Island of Hawaii. Kona was chosen as the site for tracking large yellowfin tuna because their abundance is usually high in summer in this area. Unfortunately, this past summer was a record low for large yellowfin tuna. In spite of this, two 60-lb and one 75-lb yellowfin tuna were among the fish tracked. The latter, the largest yellowfin tuna so far tracked by any research team, was followed for 50 hours at predominantly deeper depths than were smaller specimens tracked previously.

Also during the past year, software was developed to summarize time spent at specific depths and temperatures by previously tracked tunas, small yellowfin tuna and bigeye tuna. Because depth records are available at 10 second intervals, detailed accounts of time at depth and time at temperature data summaries were also compiled for daylight and nighttime, as well as for time spent associated with FAD's and time spent away from FAD's. In brief, bigeye tuna were found at much deeper depths (210-250 m) than were yellowfin tuna (10-100 m, approximately the depths of the upper mixed layer) during the daytime when they were not associated with FAD's. Bigeye tuna were found at much shallower depths (40-100 m) at night than during the day. These depths were, however, greater than for yellowfin tuna, which spent a significant fraction of their time at the surface at night. The FAD's significantly affected the mean swimming depth of bigeye and yellowfin tunas. Bigeye tuna associated with FAD's tended to remain at much shallower depths. Analysis of the data is continuing.

Further activity in the tracking project will concentrate on tracking large yellowfin tuna, FAD-associated skipjack tuna, and mahimahi (dolphinfish). Also, prototype muscle activity and muscle temperature transmitters have been obtained. These will be tested on captive tunas at the Kewalo Research Facility, and similar transmitters eventually will be used on fish in the open ocean.

Tuna Olfaction Examined

Research into the responses of yellowfin tuna to prey odors was restarted this past year at the Kewalo Research Facility by Kim Holland, of the University of Hawaii. Reimar Bruening, also with the University of Hawaii, has become a collaborator on the project, using the state-of-the-art chemical fractionation techniques to characterize the active compounds of prey odors, which previously have been demonstrated to be effective in evoking food search behavior in yellowfin tuna.

Growth Studied in Small Yellowfin Tuna

A cooperative project on validation of daily otolith growth increments in small (<40 cm) yellowfin tuna captured off the Philippines was conducted at the Kewalo Research Facility by Chris Boggs of the Honolulu Laboratory and Lynne Yamanaka, a graduate student from the University of British Columbia. Growth and mortality of these fish are the parameters critical to estimating the impact of vastly increased fishing pressure on small tunas in many Pacific Island areas following the deployment of fish aggregating devices.

BILLFISH RESEARCH

Pacific International Billfish Angler Survey

Since 1969, SWFC Fishery Biologist Jim Squire has conducted an annual survey of catch and and effort in cooperation with the International Game Fish Association, billfish anglers throughout the Pacific and, recently, those in the Indian Ocean. Detailed results of this survey will shortly be published in the NMFS Marine Fisheries Review.

This international survey was developed to provide information on the trend of angler catch rates for billfish. Commercial longliners are active in both oceans, and in some areas, catch considerable numbers of billfish. Catch and effort records are maintained by these fishing vessels and are usually made available to research organizations for analysis. In some areas, analysis of both angler and longline operations have shown that there is an impact on the catch rate of the recreational billfish angler. This is particularly well-documented for such areas as off the southern tip of Baja California, Mexico.

Unfortunately, few recreational billfish fishing fleets maintain detailed logbook records which give information on fishing effort and catch over a long period of time. James Squire, Fishery Biologist at the SWFC laboratory in La Jolla, California who coordinates the program, has requested billfish angler catch and effort data for an annual analysis. The results will be made available to the billfish angling community, and to countries and research groups interested in maintaining a healthy and economically viable recreational billfish fishery.

In 1986, the total number of billfish fishing days reported by billfish anglers who responded to the Survey for the Pacific and Indian Oceans totaled 15,932 days, with 13,711 days of this total reported for fishing in the Pacific Ocean.

Anglers fishing in the Pacific Ocean reported catching 6,949 billfish; in the Indian Ocean they caught 1,473 billfish, for a total of 8,422 billfish. The catch rate average for both the Pacific and Indian Oceans combined was 0.52 billfish per angler day (1.89 days per billfish). For the Pacific the catch rate was 0.51 billfish per angler day (1.97 days per billfish) and for the Indian Ocean the rate was 0.66 billfish per angler day (1.51 fish per angler day). The catch per angler day for 1986 in the Pacific was the same as recorded for 1985 (0.51 fish per angler day). In comparing this to the early years of the Survey (1969- 1972), when the catch rate was 0.55 billfish per angler day, the current catch rate is only slightly less than that observed 15 years ago.

Cooperative Marine Gamefish Tagging Program, 1987

The tagging program which began in the Pacific in 1963 is currently supported by the National Marine Fisheries Service in cooperation with the International Gamefish Association and the Gardiner Foundation. During the past several years, additional support for the tagging program has been contributed by the National Coalition for Marine Conservation. James Squire has coordinated the Pacific program since its beginning.

In 1987, billfish anglers tagged and released 1,570 billfish, an increase of 336 billfish tagged over the number tagged in 1986. In addition, anglers used billfish tags to tag 74 fish and sharks (species other than billfish) for a total number of 1,644 fish tagged. In 1987, 1,150 striped marlin, 254 blue marlin, 26 black marlin,, 125 sailfish, and 11 short-billed spearfish were tagged and released.

A detailed review presenting the results of the tagging program for striped marlin off Baja California, Mexico will be published in the National Marine Fisheries Service publication, Marine Fisheries Review in April, 1988.

Striped Marlin activity patterns in the Southern California Bight

During September 1982, a striped marlin (*Tetrapturus audax*) was tagged with a sonic transmitter and tracked, by SWFC biologists, in waters off southern California, for a period of 24 hours. This was the first time this species has ever been tracked. In 1986 and 1987 an additional 11 striped marlin were tagged with sonic transmitters off southern California, as a joint program of the SWFC and the California Department of Fish and Game. Fishery Biologists Dave Holts (SWFC La Jolla) and Dennis Bedford (DFG, Long Beach) report that of a total of 12 tagged marlin, 8 were successfully followed for periods ranging from 20 to 48 hours.

Two patterns of horizontal movement emerged from these tracks. Five of the eight moved predominantly in one direction after tagging, usually south. All of these travelled considerable distances during the tracking, although the other three marlin remained in the vicinity where they were first captured. Distances traveled ranged from 22 to 60 nautical miles.

Striped marlin off southern California show a very definite preference for warm surface waters. Satellite imagery of sea surface temperatures showed that marlin remain in 19' to 20' F surface water and avoid entering cooler water masses.

In general , movements of all fish slowed during the night. Several fish exhibited behaviour which might be characterized as "sleeping" or at least remaining motionless, just below the surface , for 1 to 4 hours. On two occasions the marlin's tail was actually viewd above the waters surface.

The greatest activity was observed during the late afternoon when some of the marlin displayed a behavior known to fishermen as "tailing" or "breezing". Here the fish swims rapidly downwind and downswell. Not coincidentally, this is also the time when most fish were lost.

Vertical movement tended to be exaggerated and erratic for up to two hours after tagging. Beyond this time, the fish assumed a behavioral pattern which remained consistent throughout the duration of the track. With one exception these fish remained within the top 10 meters of the surface for greater than 85 percent of the tracking time. There are considerable diurnal depth preferences. The combined time spent at various depths for the first four marlin tracked in 1987 indicate these marlin spent 81 percent of the dailight hours in the top 20 m while spending only 36 percent of the nightime hours at those depths. They only spent 14 percent of dailight hours between 20 and 40 m while spending 46 percent of their night time at that depth. Time below 40 m was 5 percent and 20, respectively for day and night hours.

We believe this pattern indicates that the trauma induced by capture and tagging is short lived and tracks of as little as 24 hours faithfully reflect "normal" marlin behavior. Nevertheless, additional tracks of greater duration are desirable. The tracking program will continue for at least two more years.

Tracking Data on Striped Marlin Digitized

Fishery Biologist Richard Brill of the Honolulu Laboratory recently completed digitizing the data on swimming depth of striped marlin, Tetrapturus audax, in support of the joint project conducted by David Holts of the La Jolla Laboratory and Dennis Bedford of the California Department of FIsh and Game on the behavior of swordfish and striped marlin. Holts and Bedford used depth-sensitive, ultrasonic transmitters and an audiotape data recording system to record the horizontal and vertical movements of striped marlin off the California coast. The system is similar to that used in the ongoing tuna tracking project of the Honolulu Laboratory and the University of Hawaii (UH) Sea Grant Program. Meetings between Brill and Holtsin October 1987 determined that digitizing the data tapes at the Honolulu Laboratory via a computer harware and software system developed by Brill over the past several years would be more cost effective than developing a separate system in La Jolla.

The depth data were digitized directly from the audiotape record and then redigitized by a computer graphics tablet. The end result was depth records at about 10 second intervals for the duration of the track. These records were then summarized using a program developed by Brill and by using the XBT data, to provide information on the amount of time spent at various depths and at specific water temperatures during the track. Copies of the software, written for use on IBM or IBM-compatible microcomputers are available from Brill.

A black Marlin, Makaira indica, was tracked for 8 hours in waters off Oahu in October 1977 by Honolulu Laboratory and

University of Hawaii scientists. The shallow swimming behavior observed was similar to the striped marlin tracked of California. The black marlin was lost in the late afternoon, which may have been a result of a late afternoon burst of activity similar to that noted for striped marlin in California.

DEVELOPMENT OF ARCHIVAL TAG PROMOTED FOR TUNA FISH TAGGING

Pierre Kleiber, of the SWFC La Jolla Laboratory, has been monitoring the development of the archival tag for tagging fish. The tags used currently can tell researchers where the fish began and ended its journey, but it tells little about the route the fish took. The archival tag, which is one of the ideas that arose from a series of meetings on tuna movements held at the Southwest Fisheries Center in 1985, would be small enough to be carried by a moderate sized fish (about the size of a skipjack tuna), and would be smart enough to record environmental information that would allow researchers to infer the course the tagged fish followed.

Northwest Marine Technology, Inc. (NWMT) completed a study of the technical feasibility of the tag supported by Small Business Innovations Research, and on the basis of the favorable results of that study, qualified for further support to cover a part of the cost of development and manufacture of prototype tags. However, a market survey was conducted shortly after the technical feasibility study with the result that the archival tag was found to be commercially non-viable at the projected price of approximately $2,000 each. NWMT is therefore unable to continue development of the tag because it would have to look to the market place to recoup its own projected investment in the tag.

Though the tag may not be commercially viable, it is still scientifically and technically viable. Kleiber, assistant contracting officer for the technical feasibility study, has contacted persons who attended the tuna movement meetings or otherwise expressed interest in the archival tag idea. He has received some serious responses, both locally and from abroad, including scientists at the Lowestoft Laboratory in England.

Acting in response to this interest, Kleiber organized a meeting recently in Seattle that was attended by Phil Ekstrom from NWMT, Ron Mitson from the Lowestoft Laboratory, Roger Hill from Wildlife Computers, Kim Holland from the University of Hawaii, Sandy Argue and George Rose from Department of Fisheries and Oceans - Canada, and scientists from the NMFS Northwest and Southwest Centers, to discuss the future of the archival tag. Kim Holland made a video presentation of his work on implanting scaled down versions of the tag in small live tuna. The major recommendation to come from the meeting was that to promote future developments we need to publish papers that showcase the use of data recording tags that now exist. A second major recommendation was that a well documented official appeal for help in tag development should be made to the Ministry of Agriculture, Fisheries, and Food, U.K. This could result in the Lowestoft Laboratory being directed to pursue navigating archival tag development as part of its ongoing program of recording tag development. NWMT is amenable to this development and would share the knowlege they have accumulated so far in developing the archival tag.

TUNA NEWSLETTER NOW ISSUED IN REVISED FORMAT

The Southwest Fisheries Center conducts research on tunas, monitors developments in world tuna fisheries and assesses events that affect the supply of tuna to the U.S. market. In carrying out these activities, information on fisheries and developments of interest to scientists, fishery managers, and tuna fishery constituents is obtained. This information which is not readily available to the public, is distributed to interested parties via the Tuna Newsletter with an active mailing list of 500 subscribers.

The Tuna Newsletter has been produced by the SWFC since 1972. In late 1987, the format and editorial policy of the Tuna Newsletter was revised and publication of issues standardized at four times a year under the direction of a new editor, Fishery Biologist Wes Parks of the La Jolla Laboratory. The new series covers events in the tuna industry worldwide, concentrating on the principal commercial species of tuna (yellowfin, skipjack, bluefin, bigeye, and albacore), Accounts of research in progress and information on trends in world tuna fisheries are featured.

A major addition to the revamped Tuna Newsletter is a regular column featuring the most recent statistics of the U.S. tuna industry compiled and analyzed by staff from the Center and Pat Donley and others of the Statistics and Market News, SWR.

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