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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
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DIRECTOR'S REPORT

TO THE

TWENTY-EIGHTH TUNA CONFERENCE

ON

TUNA AND TUNA-RELATED ACTIVITIES

AT THE

SOUTHWEST FISHERIES CENTER

La Jolla, California

FOR THE PERIOD

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INTRODUCTION

Since 1971, responsibility for tuna research in the National Marine Fisheries Service (NMFS), the federal fisheries agency in the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, has been mainly centered within the Southwest Fisheries Center and its laboratories in Honolulu, Hawaii and La Jolla, California.

At the Honolulu Laboratory, the research program emphasizes monitoring and assessment of the skipjack tuna resources of the central and western Pacific, assistance in the development of skipjack tuna fisheries in the Indo-Pacific and efforts to determine the influence of the environment on the ecology of tunas. Other research on tunas at the Honolulu Laboratory includes assessment of the South Pacific and North Pacific albacore populations, and recreational fisheries research, principally the sport fishery for billfishes.

At the La Jolla Laboratory, the staff of the Oceanic Fisheries Resources Division utilizes world-wide sources of data on tunas and billfishes to conduct scientific and economic studies in support of the U.S. commitment to the International Commission for the Conservation of Atlantic Tunas, provides technical advice for U.S. Commissioners on the Inter-American Tropical Tuna Commission, assists industry in arriving at optimal tuna fishery management strategies, and, in implementation of the provisions of the Marine Mammal Protection Act of 1972, provides data and recommendations on the status of porpoise populations associated with the tuna fishery of the eastern tropical Pacific.

The staff of the Coastal Fisheries Resources Division at the La Jolla Laboratory conducts biological research on North Pacific albacore directed toward fishery prediction and operates a fishery forecasting/advisory service for the albacore tuna fishery off the Pacific west coast.

It should be noted that in addition to the above responsibilities, fishery scientists at both the Honolulu and La Jolla Laboratories are now involved in the preparation of a preliminary management plan for billfishes/sharks in connection with the implementation of the Fishery Conservation and Management Act (FCMA) of 1976. This Act, considered to be the most significant fisheries legislation in the Nation's 200-year history, became effective in March 1977 and extended U.S. jurisdiction over offshore fisheries within 200 miles of its coast and possessions. "Highly migratory species," further defined in the Act as "species of tuna which, in the course of their life cycle, spawn and migrate over great distances in waters of the ocean" are excluded from the fishery management authority provided in the FCMA. Although billfishes and sharks range far outside the 200-mile boundaries, these species are, however, included within the purview of the FCMA. The NMFS, in anticipation of requests from foreign countries for permission to fish for Pacific billfish in the Fishery Conservation Zone (FCZ) seaward of Hawaii, American Samoa, Guam and the U.S. west coast, is preparing a preliminary management plan for Pacific billfishes, specifying restrictions on the take, possession and retention of billfishes by foreign fishermen fishing in the FCZ seaward of the mainland west coast, Hawaii, Guam and American Samoa.

NORTH PACIFIC - ALBACORE

NMFS-AFRF Cooperative Albacore Research Studies

The National Marine Fisheries Service (NMFS), La Jolla Laboratory and the American Fishermen's Research Foundation (AFRF) have cooperated on albacore research studies during the 1971 through 1977 albacore seasons. These cooperative studies were designed to obtain information to expand the fishery in space and time and to obtain information on large-scale and small-scale migratory patterns of albacore and the marine environmental factors that may affect them.

The cooperative efforts have resulted in a number of findings mutually beneficial to the albacore fishing industry and fishery scientists. Results of the studies indicate that commercial quantities of albacore can be found far offshore and earlier than the usual fishing season. Also, much has been learned about the migratory patterns of albacore, growth of albacore and relationships between the distribution and availability of albacore and oceanic features.

An informal report was prepared by Dr. R. Michael Laurs and his staff in the Albacore Fisheries Investigation program at the La Jolla Laboratory summarizing results of the cooperative NMFS-AFRF albacore research studies carried out in 1976.

Cooperative NMFS-AFRF Early Season Offshore Studies, 1976

Four vessels on charter to AFRF and the NOAA research vessel, David Starr Jordan, participated in the 1976 early season survey operations. The objectives for the 1976 survey differed in emphasis from earlier ones in which broadscale surveys demonstrated the association of albacore with the Transition Zone and its frontal boundaries. This year effort was concentrated on detailed analyses of the ocean fronts of the Transition Zone in an attempt to better understand the reasons for this association.

Catches made by AFRF charter vessels during the early-season offshore survey were only moderate. Overall, the catch record for 1976 was poor in relation to the catch per boat in June 1972, 1973, and 1974. The basic difference occurred in the day-to-day changes in the catches. A single day of good catches was generally followed by a day of poor or no catch, and no centers of persistent catch occurred as in 1972 and 1973. In 1974, there were also no large persistent centers of catch, but much larger catches were made and good catches were maintained as the vessels moved shoreward daily, apparently following the albacore movement.

The best catches of the charter vessels were centered 1) immediately south of the Subtropic Front and occurred in the second week of June and 2) within the Transition Zone (TZ) waters. These findings match those from the earlier surveys in 1972, 1973 and 1974. In 1973, the earliest catches of consequence were south of, and very close to, the Subtropic Front. In all these earlier years, the major catches were taken within the Transition Zone in June. During June 1976 the Transition Zone was found to be narrow, the fronts well developed.

Most of the fishing effort expended by the Jordan, was in the TZ and in the vicinity of the Subtropic Front. Out of 11 fishing periods in the TZ, modest catches were made on two and small catches were made on five. Effort north and south of the TZ produced negligible or no catches.

Albacore Scouting, 1976 Season

The scouting activities of the charter vessels during the 1976 seasons produced several significant findings. There were a number of times when the charter vessels located fish in areas away from where fleets of boats were operating and directed them to fish. The charter boats also found no commercial concentrations of albacore in several large areas, even after considerable search. These findings, communicated to the fleet, were an important contribution in that it saved search time and effort. Scouting was unproductive in many areas outside of Guadalupe Island to the San Juan Seamount, and in a number of regions beyond about 200 miles off the coast. Scouting operations are also being conducted during the 1977 season with three vessels chartered to the AFRF participating.

Joint NMFS-AFRF Albacore Tagging Study

Albacore tagging operations have been conducted by vessels chartered by AFRF for the early season offshore surveys; the within-season scouting surveys and by independent commercial vessels. The objectives of the joint NMFS-AFRF tagging study are to examine the migration patterns of North Pacific albacore and to obtain information on growth and mortality for use in population studies. Over 10,000 fish have been tagged and released since the start of the joint albacore tagging study. Over 600 recoveries have been made of tagged albacore.

Results of the tagging program have provided considerable new information on albacore migration patterns, stock structure, and growth (findings described later in this report). Based on tagged albacore release and recovery data, Dr. Laurs has provisionally concluded that:

1) More than one group of fish make up the U.S. albacore fishery with fish which comprise the fishery north of about 38°N (off the Pacific Northwest) being separate from those which make up the fishery south of 38°N (off California).

2) During a given season, the amount of exchange of fish between the northern and southern groups is small.

3) The northern group of fish make trans-Pacific migrations between the eastern and western North Pacific resulting in an exchange of fish between the northern area of the U.S. fishery and the Japanese livebait, and at least part of the longline, fisheries.

4) The southern group of fish appear to have a different migration scheme from the northern group of fish.

5) Only a small proportion of the southern group of fish appear to migrate between the eastern and western Pacific.

6) While it is not known where the majority of the southern group of fish migrate, it is presumed that they migrate between the eastern and central North Pacific.

7) The amount of exchange of fish between the southern area of the U.S. fishery and the Japanese livebait fishery does not appear to be large.

Considerable further analysis will be required to confirm these speculations.

Exploratory Fishing/Research Activities Carried Out in Western Pacific

Jig vessels chartered in 1976-77 by the AFRF and the Pacific Tuna Development Foundation (PTDF) to conduct exploratory fishing/research activities in the central and western Pacific worked cooperatively with the staff of the Albacore Fishery Investigation at the La Jolla Laboratory. Only modest catches were made by the two vessels on charter in 1976. Based on oceanographic observations made by the vessels, and other data, oceanographic conditions in the western North Pacific were much different during 1976 than they have been during the past several years. These differences have been attributed largely to changes in the patterns of the Kuroshio Current. The variation in oceanographic conditions apparently had marked influence on the migratory patterns of albacore in 1976 in the western North Pacific resulting in, among other factors, an apparent low availability of albacore in the Emperor Seamount chain during late May through July 1976 and consequently reduced catches by U.S. albacore jig vessels. Sections of the vertical distribution of temperature determined from bathythermograph observations and albacore catches made by U.S. albacore trolling vessels showed that the vertical ocean thermal structure was similar in 1975 for the area north of the Hawaiian Island chain to the region just east of the Emperor Seamount; however, marked differences between the two years are evident in the vicinity of the Emperor Seamount, where most fishing took place. Evidence indicates that albacore did not migrate through the Emperor Seamount area in substantial numbers until several months later than has occurred in recent years and after the charter AFRF-PTDF vessels had terminated their activities.

Two vessels were also chartered for operations in the central and western Pacific in 1977. These vessels made only small to modest catches during May and June, but enjoyed excellent fishing during July and both vessels caught full loads (about 45 tons each). Although analysis of oceanographic data is still underway, it appears that ocean conditions in 1977 was similar to those observed in 1976.

North Pacific Albacore Workshop Held in Japan

The second in a series of North Pacific albacore workshops was held at the Far Seas Fisheries Research Laboratory (FSFRL), Shimizu, Japan, on May 17 and 18, 1977. These workshops are the result of an informal agreement between the Southwest Fisheries Center (SWFC) and FSFRL to promote and accelerate joint research on the North Pacific albacore stock. The objectives of the first workshop were to produce a preliminary assessment of the status of the stock, with respect to standard equilibrium yield and yield-per-recruit criteria, to identify weaknesses in the preliminary assessments, and to recommend specific areas for further cooperative study.

The participants at the second workshop briefly reviewed the proceedings of the first workshop and decided that they would concentrate on reviewing the results of research on problems identified in the previous workshop rather than repeat the assessment of the status of the stock. The participants included more than 25 scientists from about seven different agencies and laboratories. Dr. Shou Morita, FSFRL, was selected chairman of the workshop and Mr. Susumu Kume, FSFRL, and Dr. Gary Sakagawa, SWFC, were appointed rapporteurs. The meetings were conducted in Japanese and English and interpreters were available to translate the proceedings.

Presentations of seven studies on the North Pacific albacore stocks were made during the workshop. Dr. Jerry Wetherall, Leader of the North Pacific Albacore Population Dynamics Task at the Honolulu Laboratory, SWFC, reported on the results of a comparative albacore growth study based on tagging data (Laurs and Wetherall. 1977. Estimates of growth rates for North Pacific albacore, Thunnus alalunga (Bonnaterre), based on an analysis of tag returns. SWFC Admin. Rep. 10H). A difference in growth rate was described for albacore recaptured off Japan compared with albacore recaptured south of lat 38°N in the eastern North Pacific. The use of tetracycline to mark the otoliths of tagged fish was mentioned as a method being considered by U.S. scientists for studying albacore growth and stock structure.

Dr. Wetherall also reported on a study comparing methods to estimate age-specific fishing mortality from catch-at-age (Wetherall and Yong. 1977. Comparison of methods for estimating age-specific fishing mortality rates from catch-at-age data. SWFC Admin. Rep. 9H). Described in this study is a simple nonlinear regression method to estimate parameters of a general age-specific mortality model. This method, and a least square technique devised by Doubleday were compared with the standard Gulland-Murphy cohort analysis. It was provisionally concluded that Doubleday's method was not very robust and

was not likely to work well for the North Pacific albacore. It was suggested that the regression procedure developed in the present study can establish a reasonably accurate estimate of the average fishing mortality rate, F, over a cohort's life. If so, the method may be useful in sorting through the vectors of age-specific F computed in the usual Gulland-Murphy cohort analysis, based on different initial F values, and in choosing the most appropriate one.

Dr. Michael Laurs, leader of the Albacore Fisheries Investigation program at the La Jolla Laboratory, discussed the stock structure and migratory pattern of albacore in the eastern North Pacific. Dr. Laurs hypothesizes that there are two groups of albacore that enter the U.S. fishery. One group enters into the area off southern California and then migrates northward along the coast to the northern boundary of the fishing ground, and the other group enters the northern fishing ground directly.

The Japanese scientists discussed problems concerning cohort analysis, results of Japanese albacore tagging experiments, and the Japanese pole-and-line fishery for albacore during the fall of 1976.

The Japanese delegation accepted an invitation to participate in a third workshop to be held in Honolulu in June 1978. The workshop participants agreed to exchange data on a more timely basis; Dr. Wetherall and Dr. Morita will be data correspondents. Finally, it was also agreed that basic fishery data, such as CPUE, effort, catch and age composition will be appended to future workshop reports.

Studies on Physiology of Albacore Tuna

Experiments to measure physiological and biochemical responses in live albacore and evaluate life-support systems for transporting and maintaining live albacore were conducted on cruises aboard the NOAA research vessel, David Starr Jordan, in July 1976 and August 1977. Under the direction of Dr. Michael Laurs, research activities were conducted in collaboration with scientists from Scripps Medical Research Clinic, University of California, San Diego School of Medicine, Mercy Hospital and the La Jolla Laboratory.

Studies were made to define and characterize the histological and functional aspects of the major cellular elements of the albacore's circulatory, hemoporetic and immune systems including experiments to examine the basic parameters by which these various blood cell types may be recognized and the effects of anesthetic and prolonged maintenance of albacore in holding tanks on the ability of the cells to behave normally. In addition the functional systems which allow the albacore to respond immunologically to foreign materials was examined. The cardiovascular system of the albacore was also studied including vascular anatomy, assessment of relative blood flow to the red and white muscle and various organs of the fish, measurement of blood pressure at various sites of the cardiovascular system and study of the vascular system associated with the rete mirabile of the "heat exchangers."

Hematological studies, measurement of blood volume and determination of selected enzymes and lactic acid in the serum of albacore were also conducted. Measurements were also made of arterial blood gas tension of carbon dioxide and oxygen and pH to investigate the acid-base relationships in the albacore.

These studies have contributed considerable information and knowledge about the life functions of the albacore and are being used to assist in understanding causal factors involved in albacore-oceanographic/environmental relationships.

Albacore Fishery-Advisory Activities

The La Jolla Laboratory continued albacore fishery-advisory activities during the 1976-1977 albacore fishing season. Advisory products, as in past years, included a seasonal forecast for the fishery, bi-weekly albacore fish bulletins issued in conjunction with 15-day sea-surface temperature charts, daily broadcasts of albacore fishing information transmitted over marine radio bands to the fleet at sea, and transmission of weekly charts of sea-surface temperature via radio facsimile.

CENTRAL PACIFIC SKIPJACK

Experimental Ecology of Tunas

The Experimental Ecology of Tunas Task, led by Dr. Andrew Dizon, is concerned with the determination of the responses of tunas to various ecological parameters and to determine how the tuna's energy is utilized. Distribution of tunas in the ocean can be understood and predicted by observing their responses to environmental changes in controlled experiments in the laboratory, and models of biomass can be built upon energy requirements of the exploited tuna populations.

Last year, experiments were started at the Honolulu Laboratory to determine the responses of tunas to olfactory cues. Specifically, these experiments were conceived to determine the feasibility of attempting to separate yellowfin tuna, Thunnus albacares, from their association with porpoises by chemosensory behavioral modification. Bioassays of the effects of prey scents on the swimming and feeding behavior of captive tuna were continued during the current year. Responses have been observed to a variety of seawater rinses from prey organisms, porpoise excreta, and chemically altered natural odors. Videotape equipment was acquired which allows rapid and immediate review of test sessions that would not be possible with movie film. Data collection consequently progressed at a rapid rate.

Tests with various extracts of a prey species, nehu, Stolephorus purpureus, were conducted. The devolatilized portions of nehu stock solutions were separated by protonated column to yield two fractions, one containing mainly

amino acids and amines and the other containing most likely long chain lipids, polysaccharides and uncharged particles. The amino acid fraction was analyzed by thin-layer and gas chromatography which indicated that the main amino acids present in the fraction were tryptophan and a metabolic product of tryptophan, kynurenine. Smaller amounts of isoleucine and leucine were present and other amino acids occurred in trace amounts. Preliminary analysis of the data seem to indicate that amino acids and amines may be the prime constituents of the stimulatory fraction and not the long chain lipids and mucopolysaccharides.

Experiments to determine body temperature and activity patterns of tuna under controlled temperature regimes continued this year. Tests conducted on kawakawa, Euthynnus affinis, as reported last year, indicated that these fish maintained an excess body temperature of about 3°C at 20°, 25°, and 30°C temperature regimes; no thermoregulation was indicated. Tests conducted this year by Dr. Dizon and Mr. Richard Brill, graduate student, Department of Physiology, University of Hawaii, have provided the first definitive laboratory evidence of physiological thermoregulation in fish. In the experimental procedure, the test animals, yellowfin tuna, were exposed to a water temperature schedule of 25°, 20°, 30°, 20° and 25°C for 12-h periods at each treatment temperature. Deep red muscle temperatures were measured on the free-swimming fish by a temperature sensitive ultrasonic transmitter and swim speed was continuously recorded over the 60-h experimental period.

The experimental data indicated that as the temperature of the test water increased, the excess deep body temperature decreased. The excess body temperature of a yellowfin tuna weighing about 6 kg was about 2.4°C above the water temperature in the tests at 20°C; at 30°C water temperatures the excess was only about 0.6°C. At 25°C the excess was intermediate between that at 20° and 30°C.

Heat production in a swimming fish is related to approximately the cube of velocity. Although the yellowfin tuna increased its swim speed by approximately 20%, its body temperature excess decreased by 500%. Also, in two 25°C temperature treatments 36 h apart, the body temperature was virtually the same while the swim speeds were significantly different. Clearly, then, the yellowfin tuna was able to regulate body temperature excesses independently of activity. It is suggested that this is strong evidence of a true, albeit primitive, physiological thermoregulatory response.

To study the energy requirements of skipjack tuna, Katsuwonus pelamis, researchers in the Task set a goal to determine respiration rate at velocities greater than two lengths sec^{-1}. Captive fish will not spontaneously swim at a rate greater than this for any length of time and persuading them to swim faster in the small volumes of water necessary for respiration measurements seemed like an insurmountable problem. Two approaches were tried to solve the problem. Kawakawa, skipjack tuna, and small yellowfin tuna maintain hydrostatis equilibrium with lift generated by their pectoral fins (and other structures). The magnitude of the lift is a function of their velocity through the water. Faster swimming generates more lift and hydrostatis equilibrium is reached at the point when lift cancels tendency to sink. Increased density thus requires increased speeds to prevent the fish from sinking to the bottom of the tank.

The density of kawakawa was increased by feeding them plastic encapsulated lead weights. Stomach volume is sufficient to increase speeds required for hydrostatis equilibrium by four times. Using a 200 g slug of lead it was possible to double the swim speed of a 40-cm kawakawa; the fish still fed actively and except for the fast swimming and the continuously extended pectoral fins they seemed otherwise normal.

The contradictory requirements for large volumes of water for fast swimming and the small volumes necessary for effective measurements of respiration were solved by use of a 10-in. diameter polyethylene tube kept open by about 1 ft. of head pressure. The fish adapted well to the tube and swam continuously for 24 h without undue ill effects. A working model using heavier gauge vinyl-tubing and an indoor tank to prevent algae growth are now being built.

Work Begun on Fish Aggregating-Object Project

Tunas and other pelagic fishes have long been known to be attracted to floating objects, and good catches of these fishes have been experienced by commercial and sport fishermen around such objects as drifting logs, rafts, and other flotsam of various sizes and shapes. Pole-and-line fishing records in the Japanese fishery indicate that skipjack tuna can be caught from around drifting logs, even in the absence of surface signs of schools. Unfortunately, such objects are encountered in quantities only in certain areas, such as in New Guinea and Japanese waters, where sea surface current conditions are ideal. In the greater part of the ocean, however, drifting objects are few and far between and the chance of encounters with them are relatively rare.

In addition to areas where established commercial skipjack tuna fisheries exist there are vast areas where fishing on a commercial scale is not being done even though skipjack tuna are known to occur in abundance. This is particularly true of the central and parts of the western equatorial Pacific. It is anticipated that anchoring man-made floating objects in easily accessible areas would benefit island states in the central and western equatorial Pacific.

To determine the usefulness of floating objects in attracting and aggregating skipjack tuna and other fishes in the central and western equatorial Pacific waters, a project was initiated to anchor such devices in Hawaiian waters. The project is under the leadership of Fishery Biologist Walter Matsumoto and is being undertaken jointly by the Honolulu Laboratory and the Pacific Tuna Development Foundation (PTDF).

Floating objects were anchored in early May 1977 at four different locations in waters between 100 and 540 fathoms deep near Oahu, Hawaii. Object A was anchored approximately 7 miles southwest of Diamond Head at lat. 21°12'N, long. 157°55'W; object B was placed approximately 15 miles south of Koko Head at lat. 20°01'N, long. 157°45'W; object C, 25 miles south of Koko Head, off the southwest tip of Penguin Bank at lat. 20°51'N, long. 157° 45'W; and object D, at lat. 19°19'N, long. 157°11'W.

The following are the results of the experiment as of July 21, 1977:

a. Monitoring records show that one small bird flock (12 birds) was seen at A on two visits; one flock (20 birds) at B on four visits; and one flock (40-50 birds) at D on two visits. All sightings have been within 4 miles of the objects.

b. On 10 visits each to A and B, and 9 visits to C (totals include visits by sport trolling boats) no skipjack tuna were taken near the buoys and no skipjack tuna school has been reported from the vicinity of the buoys.

c. To date no skipjack tuna boat has fished near the buoys. Skipjack tuna have been running on the windward side of Oahu and that is where the fleet has been concentrating.

d. Catches of wahoo, Acanthocybium solandri, and mahimahi, Coryphaena hippurus, have been fairly good, particularly at buoys A and B. Most of the catches (10 out of 15 wahoo and 23 out of 46 mahimahi) had been taken on 8 days at buoy A in the last 2 weeks in June. One boat had a high of 11 mahimahi and another took 4 two days prior to the loss of the buoy.

e. The side benefits of the floating objects are evident from the catches of wahoo and mahimahi. The sport fishermen are quite enthusiastic about the project and some have remarked that the floating objects assured them of catches even on days when they were no catches made in their normal trolling areas.

Otoliths Used to Study the Age and Growth of Tunas

A manuscript, "Age and growth of skipjack tuna, Katsuwonus pelamis, and yellowfin tuna, Thunnus albacares, as indicated by daily growth increments of sagittae," by J. Uchiyama and P. Struhsaker was completed in late 1976 and is presently undergoing review by outside reviewers.

Fishery Biologist James Uchiyama has been receiving otolith samples from various species of tunas from varying locales. Otoliths from skipjack tuna 33-80 cm long from the Atlantic Ocean have been processed and mounted in preparation for reading. He has also processed for reading, otoliths of skipjack tuna from the western equatorial Pacific, juvenile albacore (Thunnus alalunga) otoliths sent by Dr. Michael Laurs of the La Jolla Laboratory and otoliths from juvenile mahimahi (Coryphaena hippurus).

Based on data from otolith readings on 13 albacore specimens, a preliminary growth model using the von Bertalanffy growth function was obtained. The parameters for the growth model are: L_∞ = 142 cm; K = 0.24; and T_0 = -0.38. The data were made available to Dr. Wetherall for his use during the North Pacific albacore workshop held in May 1977 in Japan.

Two temporary, part-time biological technicians were hired during the year to assist in processing the increasing backlog of otoliths. The two technicians have successfully completed a training and orientation period and have started work reading otoliths. Also, an experiment to determine the variability of readings among readers and between readings has commenced. The experiment was suggested by Dr. Gary Sakagawa, SWFC, La Jolla. In this experiment otoliths from three specimens of widely different ages will be selected. Each reader will then read the otoliths, randomly, until each reader has read each otolith sample three times. Once the variability experiment has been completed quick-reading of otoliths, i.e., reading each otolith only once, will commence. At present, a time-consuming system of making at least several readings on an otolith to determine the age of a fish is being used.

CENTRAL PACIFIC - BAITFISH

Baitfish Transport Project

It was noted in last year's Director's Report to the Tuna Conference that the baitfish transport system to transport northern anchovy, Engraulis mordax, from California to Hawaii had been modified to include: (1) using a bait barge to receive the bait directly from the dealer at the baiting grounds in San Francisco Bay; (2) holding the anchovy in the bait barge for a period of time; (3) transferring the anchovy into two portable circular steel tanks of 2,500-gallon capacity each by lowering the tanks into the bait barge and guiding the anchovy into the tanks; (4) transporting the tanks on a flatbed via commercial roll-on/roll-off freighters; (5) hauling the flatbed with the tanks from the Honolulu terminal to a nearby distribution site. The plans were that after delivery of several trial loads under this system the project would be evaluated and a decision would be made whether to proceed into pilot scale studies. However, after encountering many problems during the latter part of 1976, a decision was made to postpone the trial shipments until the spring of 1977. At this writing, problems with the availability of anchovy in San Francisco Bay are hindering the project and the trial shipments are still not forthcoming.

In the meantime a contract was entered with the California baitboat Pacific Trojan to transport to Honolulu a small load of northern anchovy for skipjack tuna fishing trials. The Pacific Trojan arrived in Honolulu in June 1977 with a load of approximately 400 scoops (3.6 kg or 8 lb per scoop) of northern anchovy. The bait was tested on field trials on board the Hawaiian skipjack tuna boat Lehua.

Fishing trials commenced on June 14 and continued through June 18. During this period the Lehua fished 18 schools using anchovy, one school using nehu (Stolephorus purpureus) and one school using a combination of anchovy and nehu. In general the Lehua's catch using anchovy as bait compared favorably with the catches of the other boats in the fleet which used nehu only as bait during the same period.

Research Assistant Thomas Kazama and Dr. Stanley Swerdloff, PTDF, who served as observers during the trials noted that the anchovy tended to sound and disperse when chummed. The captain of the Lehua tried a variety of fishing tactics to counter this behavior of the anchovy. Tactics such as chumming larger quantities of anchovy, stunning the anchovy before chumming, stopping the vessel or doubling back on the school, did not improve the catch rate. The observers noted only a few "surface breaks" during chumming, suggesting that the skipjack tuna were primarily feeding on the anchovy below the surface. However, reports from other vessels during the same period indicated that the skipjack tuna schools were also responding poorly to nehu.

Detailed results of the fishing trials are included in Administrative Report No. 11H, 1977.

CENTRAL PACIFIC - BILLFISHES

Meeting Held in Japan to Plan Billfish Workshop

An informal meeting was held at the Far Seas Fisheries Research Laboratory, Shimizu, Japan, in May 1977 to discuss objectives, data exchange and work assignments for the Billfish Stock Assessment Workshop that is scheduled to be held in Honolulu in December 1977. Present at the meeting were J. Wetherall and G. Sakagawa of the U.S.A. and S. Ueyanagi, S. Hayasi, M. Honma, S. Kikawa, S. Kume, S. Mito, P. Miyake, Z. Suzuki, Y. Tadokoro, and T. Yonemori from Japan.

It was agreed that the purpose of the billfish workshop will be to produce a report containing a scientific assessment of the status of billfish stocks in the Pacific and Atlantic Oceans, including a summary of appropriate background information, supporting analyses and recommendations for improvement in billfish stock assessments. Specifically, the workshop will focus on: (1) a description and evaluation of data bases; (2) an overview of commercial and recreational billfish fisheries; (3) a review of available population parameter estimates for billfishes; (4) a species-by-species, stock-by-stock assessment of the present status of Pacific and Atlantic billfishes, based on production model analysis and other standard methods; and (5) recommendations for correcting deficiencies in data collection practices and for revising stock analyses. The workshop is being sponsored by the National Marine Fisheries Service, the Western Pacific Regional Fishery Management Council, and the South Atlantic Regional Fishery Management Council, and the convenor is Mr. Richard Shomura, Director of the Honolulu Laboratory.

CENTRAL PACIFIC - RECREATIONAL FISHES

Recreational Fishing Research for Marlins and Yellowfin Tuna

Kailua-Kona, Hawaii, is one of the most important recreational fishing areas in the State of Hawaii. Last year, a contract was entered into with Research Associates of Honolulu, Hawaii to evaluate the socio-economic importance of the recreational fishery for marlins and yellowfin tuna (Thunnus albacares) to the community of Kailua-Kona. Mr. Heeny Yuen, Leader of the Recreational Fisheries Task, reports that Research Associates recently completed a report for Module I, "A study of bio-economics and optimal management for utilization of Pacific billfish." Module I gives profiles on small boat owners and charter boat owners in Kailua-Kona and also descriptions of various aspects of the activities of small boat and charter boat owners. Briefly, it was determined that an average Kailua-Kona small boat owner is a male about 45 years old who owns a 19-ft boat for which he paid $5,650 and which he owned for less than 5 years. His boat is used primarily for fishing and the annual overall expenses related to fishing and ownership of his boat averaged $4,740. His yearly catch of all species amounted to 4,141 pounds; yellowfin tuna and wahoo (Acanthocybium solandri) are the most important species in his catch.

The profile of charter boat operators indicated that the average charter boat operator is a male just over 40 years of age who has been in the charter business about 5 years. His boat is 38 ft. long and was purchased at a cost of about $63,000. His total gross earning from all sources is $30,140 per year, and interestingly, his total yearly expenditures exceeded his income by about $1,336. Blue marlin, Makaira nigricans, and yellowfin tuna are the most important species in his catch.

One of the aims of the Recreational Fisheries Task is to devise a Pacific-wide data collection system for recreational fisheries. Mr. Yuen had an opportunity to examine historical catch records maintained by the fishing clubs in New Zealand when he participated in the 5th Annual Bay of Islands Billfish Tournament in March 1977. He obtained size data on striped marlin dating back to World War II from the records maintained by the Bay of Islands Swordfish Club.

At the tournament Mr. Yuen examined all the fish caught by the tournament participants and also worked on other cooperative projects with fishery biologists in New Zealand. He also conducted a workshop on the identification of billfishes and tunas which was attended by about 100 persons.

SOUTH PACIFIC - ALBACORE

South Pacific Albacore Fishery

The Resource Monitoring and Assessment Task, under the leadership of Dr. Robert Skillman, continued to monitor the status of the South Pacific albacore

fishery based at American Samoa. Quarterly summarizations of catch and effort statistics, including final statistics for 1975 and preliminary statistics for 1976, were completed. The final statistics confirmed earlier indications that 1975 was the worst year in the history of the South Pacific albacore fishery not only for total albacore caught but also for CPUE in numbers of albacore caught per 100 hooks fished. The 1975 winter peak in CPUE never materialized, possibly because less fishing effort was expended in the southern areas of the fishery as vessels attempted to save on fuel costs. The preliminary statistics for 1976 indicate that the situation has improved and that the usual low for February was not as severe and that the winter peak approached that of 2 years ago.

EASTERN PACIFIC - YELLOWFIN, SKIPJACK

Marine Weather Data Acquisition System Updated

The staff of the Real-Time Fishery Systems Tasks at the La Jolla Laboratory produces monthly and bi-monthly publication entitled, "Fishing Information." In addition, weekly radio facsimile (FAX) charts for broadcasts to the tropical tuna fleet from radio station WWD in La Jolla are prepared by the staff and by the National Weather Service. Both of these projects depend on marine weather observation from merchant ships and fishing vessels for input data.

Presently, some 20,000 marine weather observations are received each month at the La Jolla Laboratory via a 100-word-per-minute teletype line. These observations are punched on paper tape and then placed on computer cards. The resulting card deck is then hand-edited before being processed on the Burroughs 6700 computer of the University of California, San Diego.

In May 1977, permission was obtained to update and automate this data system. A new system was designed and equipment purchases initiated. The new system will employ a 1200-wpm teletype and dedicated micro-processor to collect, edit and store marine weather data on magnetic tape. At frequent intervals, the data will be further edited using a CRT terminal and semi-processed before entry into the Burroughs 6700 computer for more complicated processing. The transfer of the data to and from the Burroughs will be facilitated by a dedicated telephone line.

To date all of the hardware for the new system has been purchased and installed at the La Jolla Laboratory. A contract has been awarded for the development of the necessary system software, and the computer programs needed for the new system are currently under development. It is expected that the system will be fully operational by December 31, 1977.

Aside from the obvious savings in labor costs associated with the new system, other benefits are expected from the new system. These include: 1) more rapid and efficient data processing, 2) retrieval of more marine weather data for the Pacific that are currently being lost by time constraints on the 100-wpm teletype line, and 3) increased capability of collecting marine weather data from all parts of the world.

FAX Program

The Cooperative Tropical Tuna Advisory Program or FAX (for radio facsimile) program of the La Jolla Laboratory has been in existence since 1971. To date, more than 10,500 marine weather and 2,000 XBT observations were collected from tuna purse seiners via radio station WWD, an NMFS-licensed station, that participate in the program. The data provided by the fishermen have been the backbone of an ongoing investigation into the effects of the marine environment on the distribution of tropical tunas. In exchange the fishermen receive FAX charts of environmental conditions on a daily basis (except weekends) for the fishing area in the eastern tropical Pacific.

Unfortunately, data reporting rates by cooperating tuna purse seiners have dropped steadily since 1975 when the fleet contributed 2839 marine weather and 546 XBT observations. Current reporting rates are down by more than 50% for both weather and XBT observations from the 1975 figures. This has occurred despite an increase in services (specifically more frequently FAX transmissions) by WWD to the cooperating vessels.

This failure on the part of the vessels is of increasing concern to the staff. This concern was expressed in a February 1977 letter to the managing owners of cooperative vessels by Mr. Izadore Barrett, Center Director, in which Mr. Barrett requested that the cooperating vessels transmit daily environmental information as specified in the cooperative agreement, and he pledged continued and better FAX services from the Center.

As part of the Center's continued efforts of improving the FAX services, members of the Tuna Resources program at the La Jolla Laboratory have instituted procedures to improve the data flow from the cooperating vessels. First, they have developed an automated system for monitoring the FAX program. Information including names, addresses and telephone numbers of boat owners, data reporting rates for cooperating vessels, serial numbers of government-owned equipment aboard the vessels and equipment maintenance records are stored in a computer file. These data are updated monthly and reports of reporting rates by cooperating purse seiners are prepared. These reports are used by the staff to rapidly identify vessels that fail to submit observations. In addition, the data are used to prepare a monthly report for each participating boat owner on the number of observations submitted by each of his vessels. This report also contains current information about the FAX program and serves to keep the owner informed about the program and the reporting "track record" of his vessels.

Another procedure that has been initiated to increase the flow of environmental data is through the assistance of porpoise observers and gear technicians. Porpoise observers and gear technicians are being assigned to many of the U.S. purse seiners that fish in the eastern tropical Pacific Ocean. Many times the observers are assigned to cooperating FAX boats. These observers could assist in taking marine weather and XBT observations and in transmitting the information to WWD. In September, a pilot project was undertaken by Forrest Miller, Inter-American Tropical Tuna Commission and Mark Sweeney of the La Jolla Laboratory to train six observers to collect environmental data on cooperating FAX boats. These instructions included training in operation of the ship's radio facsimile recorder and XBT recorder as well as instruction in the encoding of marine weather and XBT observations and radio telephone protocol. Of the six observers trained, five are scheduled to accompany FAX and/or XBT-equipped seiners. Plans are being made to train all observers and gear technicians in procedures for collecting and transmitting environmental data at sea.

Fishing Information

The publication, "Fishing Information" is designed to provide timely environmental information on the North Pacific and the eastern tropical Pacific Ocean to the fishing industry and fishery scientists. The monthly and bi-weekly charts of sea surface temperature (SST), SST anomaly, barometric pressure and wind fields, ocean thermal structure and narrative text are edited by Fishery Biologist James Renner of the La Jolla Laboratory and have been published at this laboratory since 1960.

Regulations of the Congressional Joint Committee on Printing and Binding require annual verification of all mailing lists maintained for the purpose of free distribution of government publications. Because of recent restrictions placed on the number of recipients for this free publication it was decided to reduce the mailing list from about 2000 subscribers to 750. Subscribers responding to the annual verification notice in the spring of 1977 were given "first-come, first-served" priority until the maximum number was reached. All subsequent respondents were notified and placed on a waiting list until such time as there is a vacancy.

The preparation of "Fishing Information" requires the acquisition, processing, editing and analysis of more than 20,000 marine weather observations each month. These observations are currently received on a teletype reperforator unit and then punched on cards prior to computer analysis. To increase the efficiency of this system, work is now in progress to phase out the reperforator-punched card data storage and replace it with direct, on-line computer storage capability.

Mathematical Model for Analysis of Tagging Data

Tagging is a fundamental tool used in research on the dynamics of tuna populations. Results from tagging experiments, however, are frequently difficult to interpret because they are strongly linked to where the fish are tagged, to behavior of the tagged fish and to the distribution of fishing (recovery) effort. One method of investigating the effects of these variables on tagging results is with mathematical models.

Dr. Takeo Ishii of the University of Tokyo used this approach and developed a mathematical model to better describe migration and population dynamics parameters for yellowfin tuna (Thunnus albacares) from tag returns. His model utilizes information on recaptures, fishing intensity, release sites and transfer patterns among areas. The model has been tested with data from the eastern tropical Pacific and is being further refined. This work was sponsored by NMFS' La Jolla Laboratory through contract to the Inter-American Tropical Tuna Commission.

Participation in Meetings of the Inter-American Tropical Tuna Commission (IATTC)

The IATTC held its 33rd meeting in Managua, Nicaragua, during October 11-14, 1976. Dr. William W. Fox, Jr., Chief of the Oceanic Fisheries Resources Division at the La Jolla Laboratory attended that meeting and served as scientific advisor to the U.S. Commissioners.

Major issues discussed at the meeting included the yellowfin tuna catch quota for 1977 and the tuna-porpoise problem. Through negotiations, the member countries agreed to a total catch limit of 175,000 short tons of yellowfin tuna from the Commission's yellowfin regulatory area for 1977. Certain provisions were adopted that provided for decrease or increase up to 210,000 tons of this catch limit depending on appraisals by the Director of Investigation of the fishery and status of the stocks during the 1977 season.

The member countries also agreed that the Commission's staff would undertake a comprehensive technical review of information pretaining to the tuna-porpoise problem and prepare a detailed proposal for porpoise research by the Commission, for consideration at a July meeting.

In July 1977, the 34th IATTC meeting was held in San Diego, California to discuss the Commission's findings concerning the tuna-porpoise problem. Mr. Izadore Barrett, Center Director, and Dr. Fox attended the meeting as scientific advisors. The Commissioners received the report and after much discussion accepted the findings and authorized the Director of Investigations to prepare a budget for research by the Commission on tuna-porpoise related problems.

Analysis of Flotsam Associated with Tuna Sets from the Eastern Tropical Pacific

Tuna fishing records for flotsam associated tuna (skipjack and yellowfin tuna) in the eastern tropical Pacific were examined by Oceanographer Paul Greenblatt at the La Jolla Laboratory. Mr. Greenblatt discovered that the number of sets made on floating objects has increased dramatically since 1971. The catch per set of tuna associated with flotsam has also increased markedly since 1967.

Correlation analysis of the number of sets occurring in an area indicates that unassociated tuna and flotsam associated tuna are related. Analysis of length-frequency data indicated that, on a single set basis, tuna fork length is more variable on sets associated with flotsam and porpoise than with unassociated school fish sets. Results of these analyses support the idea that both flotsam and porpoise aggregate tuna. In addition, Mr. Greenblatt concluded that if the rivers of Central America are the major source of flotsam, then the average current patterns adequately describe the observed distribution of flotsam associated sets in the eastern tropical Pacific.

EASTERN PACIFIC -- PORPOISE/TUNA INTERACTION

Porpoise/Tuna Interaction Program at the La Jolla Laboratory

The SWFC Porpoise/Tuna Interaction Program at the La Jolla Laboratory has three basic objectives: 1) develop methods and technology to reduce porpoise mortality incidental to yellowfin tuna purse seine fishing, 2) determine the status of the porpoise stocks, and 3) monitor the incidental porpoise mortality resulting from U.S. purse seine fishing. The program consists of four components: a) mortality reduction technology, b) general biology and behavior, c) stock assessment, and d) quantitative analysis and data management. A summary of the past year's conclusions and results of research efforts are as follows.

Data have been analyzed and preliminary results prepared concerning the large-scale federal government/industry cooperative gear experiment which began last fall. These tests, conducted aboard 20 purse seiners, were designed to compare the Fine Mesh Medina Panel and the Bold Contender Apron system to conventional fishing gear to determine the most effective design in reducing porpoise mortality during fishing operations. The Bold Contender system produced a statistically significant reduction in mortality rates compared to both the Fine Mesh Medina Panel and conventional systems.

Other gear-oriented research included testing 1) a torque-balanced anti-rollup purse block aboard a chartered purse seiner, 2) Guillen snap-links for quick release of the net from the purse cable, 3) the use of speedboats to hold the net open and prevent collapse, 4) the use of a rubber raft as a porpoise observation-and-rescue platform, 5) the use of face masks and snorkel for surface observations from the raft, and 6) the use of floodlights and spotlights during sets around sundown.

The performance of the U.S. fleet in 1977 will be monitored during the course of about 100 fishing trips with NMFS observers aboard. Observations thus far show that the species composition of the kill has not changed significantly from last year. The fleet's overall performance shows continuous improvement in releasing porpoise alive. A calculation made in August 1977 for the first 7 months of 1977 shows a 65 percent reduction in the kill of porpoise from last year which is comparable to 67 percent reduction between 1976 and 1975. The reduction in 1977 is primarily attributed to extended periods in port and a late start in the fishing season. However, the fleet's kill rate is continuing to improve as well. Recent calculations, for the first 7 months of 1977 show that the kill per porpoise set fell from 14.0 in 1976 to 3.13 in 1977, a reduction of 77.6 percent. This gives an overall decline in kill per set from 1973 to 1977 of 84 percent. Full analyses of these radioed-in results must await availability of the comprehensive data after the cruises are completed.

Biological research concentrated primarily on life history studies of the most important involved porpoise stocks. A contract was awarded to NUC to do life history studies on Delphinus delphis. Spotter (Stenella attenuata) and spinner (S. longirostris) porpoise, collected from an area southwest of the Galapagos Islands, are being analyzed to see whether these animals are from a different stock than those found further north. No determination has yet been made on these animals. Porpoise age determination studies are continuing with two contracts awarded, one to cut a large sample of porpoise teeth for calculation of mortality rates and another to analyze racemization of porpoise eye protein.

A porpoise population stock assessment survey of the eastern tropical Pacific was conducted this spring utilizing the NOAA ships David Starr Jordan and Townsend Cromwell and two different long range aircraft. The aircraft surveyed areas up to 1,000 miles from shore while the vessels covered the inside areas between Central and South America and 150°W. The survey data, collected from over 46,618 linear nautical miles, will be evaluated by an ad hoc committee made up of representatives from the Marine Mammal Commission, tuna industry, SWFC and universities before any final analyses are performed.

Excluding stock assessment cruises, other seagoing research projects included: a porpoise behavior study aboard the chartered tuna seiner Elizabeth C.J. designed to analyze porpoise behavior related to different phases of the seining operation, and a ground truth survey aboard the NOAA ship Surveyor, aimed at comparing shipboard estimates of school size to helicopter observer estimates and photographic counts. An observer aboard the NOAA ship Oceanographer rode on two trips to the equator and 125°W to collect additional porpoise distribution data. In addition, several gear technicians made trips aboard tuna seiners to analyze new fishing gear or techniques.

A Porpoise Tagging Workshop was held at the La Jolla Laboratory, May 4-5, 1977 to review the state-of-the-art and tag designs in preparation for a large-scale tagging program in FY 1978. A contract is being let to design the gear necessary to hold the porpoise for this operation. Tests of a satellite-linked transmitter and antenna system were conducted using a live porpoise in a tank; results look encouraging.

The La Jolla Laboratory hosted a workshop February 28 to March 2, 1977 to review the status of research related to the porpoise/tuna problem with emphasis on mortality reduction. A later meeting, with SWFC personnel and Porpoise Rescue Foundation respresentatives, discussed future gear research, including a dedicated vessel for the fall of 1977. Results of last year's workshop on stock assessment have been completed. A major result of the workshop was that the eastern spinner porpoise was considered below its optimum sustainable population and therefore was classified as depleted.

EASTERN PACIFIC - BILLFISHES AND OTHER MARINE GAME FISH

Cooperative Marine Game Fish Tagging Program - 1976 Results

In May 1977, an annual report covering the results of the "Cooperative Marine Gamefish Tagging Program" and the "Pacific Billfish Angler Survey" was issued by the Southwest Fisheries Center.

In 1976 the number of billfish reported tagged by having tag cards received by the Southwest Fisheries Center, La Jolla, California by December 31, 1976 was 1,341, slightly more than reported tagged in 1975 (1,307).

The total number of fish tagged by the program in 1976, which includes billfish, roosterfish, dolphin, yellowtail and other species such as sharks, wahoo, and sturgeon, was 1,673.

Of the number of billfish tagged by cooperating marine anglers, striped marlin (Tetrapturus audax) accounted for 626 or 46% of the total tagging. Black marlin (Makaira indica) with 520 being tagged accounted for 39%. Sailfish (Istiophorus platypterus) accounted for 170 of the tagging total (13%) and 25 blue marlin (Makaira nigricans) for 2%.

A breakdown of billfish tagging by species and geographic area for 1975 and 1976 for ports having tagging recorded in 1976 follows:

	1975	1976	Number increase or decrease
Striped marlin			
Southern California, USA	16	58	+42
Baja California, Mexico	647	568	-79
Black marlin			
Queensland, Australia	433	516	+83
Baja California, Mexico	1	2	+ 1
Panama	1	2	+ 1

	1975	1976	Number increase or decrease
Blue marlin			
Baja California, Mexico	16	23	+ 7
Hawaiian Islands, USA	2	2	0
Sailfish			
Baja California, Mexico	87	23	+42
Manzanillo, Mexico	1	4	+ 3
Guaymas, Kino Bay, Mexico	6	9	+ 3
Mazatlan, Mexico	12	12	0
Acapulco, Mexico	61	3	-58
Panama	6	2	- 4
Queensland, Australia	0	11	+11

New tag return posters in the Japanese and Korean languages were distributed in Japan and Korea during the past year in cooperation with the Far Seas Laboratory, Shimuzu, Japan and an increased number of recoveries are being obtained from Japanese longline vessels. For example, the number of black marlin tag recoveries reported in 1977 is now 10.

Recoveries reported to the Southwest Fisheries Center in 1976 (January 1 to December 31, 1976) totaled 21 fish.

From tagging off Queensland, Australia, eight black marlin were recovered. In the eastern Pacific recoveries included six striped marlin, two roosterfish, and one yellowtail tagged off Baja California, Mexico. Additional recoveries off Australia were of a barracuda and a whaler shark. Off New Zealand a mako shark was recaptured, and off southern California a diver-tagged black sea bass was recovered.

Pacific International Billfish Angler Survey

Since 1969, the National Marine Fisheries Service has conducted, in cooperation with big-game angling clubs throughout the Pacific, an annual angler catch-effort survey of billfishing. This survey in the Pacific is the only oceanwide survey that attempts to measure the sportfish catch and effort trends for billfishing. Knowledge of the catch trends of billfish anglers in the many fishing locations throughout the Pacific, is of importance in the management of the billfish resources relative to the needs of the marine recreational fisheries.

In 1975, fishing for striped marlin was less productive off southern California than in 1974, and the fishing off Baja California, Mexico was at about the same catch rate as observed in 1974.

The sailfish catch rate dropped substantially off Acapulco which usually has a higher rate than any other port in Mexico. However, it remained approximately the same at Manzanillo.

The black marlin catch rate off Australia was down slightly from the 1974 level, and is down considerably from the high catch levels observed in 1971 and 1973.

The blue marlin catch rate showed a substantial increase off Hawaii in 1975.

ATLANTIC TUNAS

Participation in ICCAT Meetings

The Tuna Resources program of the La Jolla Laboratory is responsible for providing scientific advice on Atlantic tunas to United States Commissioners of the International Commission for the Conservation of Atlantic Tunas (ICCAT) and for participating in activities of the Standing Committee on Research and Statistics (SCRS) of ICCAT. Dr. Brian Rothschild, chairman of the SCRS and formerly of the SWFC, and Dr. Gary Sakagawa and Mr. Atilio Coan of the La Jolla Laboratory traveled to Madrid, Spain to participate in the annual ICCAT meetings during November 10-22, 1976. The scientists presented their findings of research conducted at the La Jolla Laboratory, participated in discussion on appraisal of the state of the Atlantic tuna stocks and advised the U.S. Commissions on scientific matters. Nine papers, containing research results of the La Jolla group were presented and from which the SCRS drew much information for appraising the state of the tuna fisheries and the Atlantic tuna stocks. The SCRS appraisal is as follows:

Yellowfin tuna. The 1975 catch was a record high of about 117,000 MT and the 1976 catch is expected to be even higher, 124,600 MT, despite a decrease in the total carrying capacity of the fleet owing to reduced participation by U.S. fishermen. Fishing effort, however, is expected to equal that of 1975.

Much of the increase in catch in 1975 and 1976 resulted from offshore expansion of the fishery into non-traditional fishing areas (off Sierra Leone and the Ivory Coast). Production model analysis reconfirmed previous year's conclusions that the equilibrium yield curve is flattopped and further increases in fishing effort would produce a negligible increase in equilibrium yield.

The amount of undersized fish (less than 3.2 kg) in the surface catch captured much of the attention of the scientists, who estimated that it amounted to 37% in number of the total 1975 surface catch. While the amount was less than that caught in 1974, the Committee felt that 1975 was an unusual year and in 1976 the catch of undersized fish will increase and be close to the 1974 figure of 54% as a result of increased fishing by Tema-based baitboats.

The Committee also discussed the problem of identification of small yellowfin and bigeye tuna and the deliberate false reporting of catches of undersized yellowfin tuna as bigeye tuna. This problem has an impact on the SCRS's assessment of the condition of the stock as well as on the quality of the management advice.

Skipjack tuna. The 1975 catch of skipjack tuna was 60,000 MT, approximately half of the 1974 yield owing to poor availability of fish in the Angola and Annobon sectors. While the catch in 1976 is estimated to also be low, 40,000-50,000 MT, the cause is due to a shift of fishing effort onto yellowfin tuna rather than to low abundance or poor availability.

The Committee concluded that the current fishery is highly dependent on only one or two year-classes that fluctuate widely in availability; the growth rate of skipjack and apparent natural mortality rate are high and therefore, a minimum size limit for skipjack will not increase the yield-per-recruit.

The Committee noted that the skipjack resource is considered large and available for development by many countries, yet not much is known about the exact potential yield. A 3-year intensive research program on skipjack tuna, which would culminate in an "International Skipjack Year" was proposed by the Committee to learn more about the resource.

Bigeye tuna. The bigeye tuna catch steadily increased since 1965, but in 1975 the increase appeared to have halted. The catch was 52,600 MT, about the same as in 1974. Because of the "mis-identification" problem with yellowfin tuna, the Committee was hesitant to comment on the exact recent trends in bigeye tuna catches.

The scientists agreed that the increase in catch in recent years was primarily due to the surface fishery and possibly, a large number of small fish are being removed. They also voiced concern over the possible detrimental effect that the yellowfin tuna minimum-size regulation has on the long-term yield of bigeye tuna. Small bigeye tuna and yellowfin tuna are caught by the surface fishery and fishermen cannot differentiate the species before a set is made. Fishermen probably set on undersized fish because there is a tolerance limit for incidental catches of undersized yellowfin tuna. The scientists did not recommend a particular action, except for studies to determine the affect of the increased surface catch and the yellowfin minimum size on the yield of bigeye tuna.

Albacore. The overall albacore catch has been decreasing since 1972 and the average age of fish in the catch has increased slightly. Cohort analyses indicated that recruitment in recent years has been on the decline.

Revised production model analyses indicated a maximum equilibrium yield of 46,500-55,000 MT for the northern stock and 30,000 MT for the southern stock. The Committee recommended that caution should be exercised in increasing fishery effort on the albacore stocks.

Bluefin tuna. The bluefin tuna catch has increased since 1972, amounting to 13,300 MT in 1975. The increase is due to better statistics from the Mediterranean as well as actual increased catches in the Atlantic. Increased catches in 1975 were recorded primarily by longliners (Japanese) and the harpoon-handline-trap fishery (U.S.A.) of the northwestern Atlantic.

The Committee reviewed the effects of the regulations and concluded that the proportion of undersized fish (below 6.4 kg) in the catch apparently declined in 1975, and F is high and has not been maintained at recent levels in many fisheries. The Committee pointed out that (1) the question of the stock structure of the bluefin tuna population is still unsettled, (2) substantial recruitment to the medium- and large-fish fisheries is not forthcoming until some years hence, (3) yield-per-recruit would increase significantly if the average age at first capture was increased, but such a change would result in reallocation of catch among the fisheries, and (4) fishing mortality rates for the fisheries are high.

Import Landings of Atlantic-Caught Tunas Sampled in Puerto Rico

Eugene Holzapfel, a La Jolla Laboratory technician stationed in Puerto Rico, continued to collect biological data from the import landings of Atlantic-caught tunas. The program was initiated in 1975 to fulfill a request from the International Commission for the Conservation of Atlantic Tunas for data on sizes of tunas and species composition in foreign tuna landings transshipped to Puerto Rico. In 1976, approximately 18% (9,971 fish) of the total import landings of Atlantic-caught tunas were measured for fork length. Results indicate that an estimated 89% of the yellowfin sampled are less than 55 cm. In 1976, 107 species composition samples were taken from reported yellowfin tuna landings. These samples indicate that an estimated 21%, by weight, of the reported landings of yellowfin tuna are actually bigeye tuna.

ATLANTIC - BILLFISHES

Task Force for Re-Evaluation of Data on Billfishes and Sharks

In March 1977, the National Marine Fisheries Service established a task force for re-evaluation and analysis of available data concerning billfishes and sharks. The Task Force was composed of J. Wise, NMFS Washington, R. Otto, NMFS, Washington; B. Stone, NMFS, Washington; J. Zuboy, NMFS Southeast Fisheries Center, Miami; G. Beardsley, NMFS Southeast Fisheries Center, Miami, and G. Sakagawa, NMFS Southwest Fisheries Center, La Jolla. The objective of the Task Force was initially very broad but later was narrowed to preparation of an up-to-date assessment of the billfish and shark stocks of the western North Atlantic Ocean.

The Task Force conducted most of its work at the La Jolla Laboratory in order to utilize the tuna/billfish computer data bases and to consult with experts at the La Jolla facility. Analyses performed by the Task Force yielded a wide range of maximum sustainable yields (MSY) for the stocks, depending on the assumptions and analytical models used.

A set of most reasonable estimates was selected on the bases of evaluation of the assumptions and analytical models. The set is as follows:

Stocks	MSY (metric tons)
Blue marlin	5,900
White marlin	1,900
Sailfish	960
Swordfish	5,000
Sharks	41,000

In some years the catch from some of these stocks have exceeded the MSY; however, at current levels of fishing it appears that none of these stocks are being fished at levels beyond MSY. Results of the Task Force's findings are contained in a document prepared by R. Otto in collaboration with J. Zuboy and G. Sakagawa.

OTHER ACTIVITIES IN TUNA RESEARCH AT SWFC

Progress on Development of a Global Tuna Systems Model

The staff of the Tuna Resources program at the La Jolla Laboratory worked with Tetra Tech, Inc., Lafayette, California in developing a Global Tuna Systems Model. Tetra Tech was awarded a NMFS contract to conduct research to develop the model and is expected to deliver final product outputs before October 1977.

The version of the Global Tuna Systems Model that will be available next month has two principal components: a population dynamics module (PDM) and an economic module (EM). The two are interactive and the overall scheme of the model is to describe tuna fisheries as an integrated bioeconomic system. This systems design gives the model the capacity to describe the biological impact of economic or political changes that influence the level and distribution of tuna fishing as well as the capacity to describe the economic impact of changes in the abundance, distribution and availability of tuna. The descriptive capacities of the model are expected to be particularly useful in evaluating the effects of alternative global tuna management schemes and in assessing the possible biological and economic consequences of unilateral decisions with regard to extending national fisheries jurisdiction.

The first major component of the model, the population dynamics module, tracks variations in the population dynamics of the six principal commercial species of tuna in each of four broadly-defined fishing areas (eastern and western Atlantic and the eastern and western Pacific). Variations with respect to the population of each species are described in the PDM with the use of stock-specific parameters associated with reproduction, natural mortality, fishing mortality, and migrations. The input format is presently being modified so that these biological parameters can be re-specified at the discretion of the user. In the present version, the user is also allowed to select from four general models of fish population dynamics including a generalized production model, simple yield model, Leslie matrix model and a Birth-Death Process model. The overall flexibility of the PDM with regard to both model and parameter specification should insure that the description of fish population dynamics in the global tuna systems model can accommodate the needs of most users and can be modified easily as new information becomes available.

Factors that drive the system model are the world catch from each tuna stock and policies that affect the world catch. These factors are dealt with in the EM which has two general sections, one deals with demand relationships and the other with supply or harvest relationships. In the current version of the model, the demand for tuna in each of the principal tuna-consuming nations is expressed as a function of the global price of tuna and national per capita income; it is the aggregate demand for tuna by all nations at a given price which determines the global demand for tuna at that price. The essential component of the EM, however, is a linear programming algorithm which optimizes the level and distribution of international tuna fishing among various fishing areas. It is this optimizing scheme which provides estimates of the level of exploitation of each stock and determines the world supply of tuna.

In the version of the model that has been developed, the linear programming model computes the profit-maximizing allocation of seven national tuna fleets. The user specifies the world ex-vessel price of tuna and the available standing crop of each species in each fishing area and the linear program allocates the international fleet to various fishing areas in a manner which maximizes economic profits subject to a set of biological, technical, and economic constraints. Holding all constraints constant, the linear programming model goes through several iterations using different ex-vessel tuna prices until the world supply of tuna that is generated by the program at a given price is equal to the world demand of tuna at the same price. At this point, the global tuna market is in equilibrium, the optimal harvest of each stock is determined, and the level of fishing mortality is fed back to the PDM to adjust stock size estimates.

The separate components and subroutines contained in the current version of the Global Tuna Systems Model will be of immediate value; however, the PDM and the EM are not yet completely integrated and the overall model will require some further refinements before it can be used to describe the dynamics of the global tuna fisheries system. The PDM is fairly complete and in its current form can be used to describe changes in the abundance and distribution of tuna stocks under a wide range of biological assumptions. This capacity alone can be used to assess the biological implications of many alternative tuna

management decisions. However, the most common types of fishery management tools, quotas, license fees, taxes, etc., enter the model through the parameters and constraints of the EM and this part of the models needs further refinement. In the current version of the model the EM is relatively static and the computer program does not adequately translate changes in the abundance and distribution of tuna into changes in the optimal allocation of fishing. Work is already underway at the La Jolla Laboratory to make the EM of the model more dynamic and more responsive to the dynamic adjustments in the abundance and distribution of tuna which seem to be described adequately by the PDM.

Although the initial development of the Global Tuna Systems Model will be complete in October when the Tetra Tech version of the model is delivered, a number of modifications and refinements will be required before the Model can be evaluated as a tool for fishery management.

SWFC PUBLICATIONS ON TUNA AND TUNA-RELATED ACTIVITIES

OCTOBER 1976 TO SEPTEMBER 1977

PUBLISHED

Barham, Eric G., Warren K. Taguchi, and Stephen B. Reilly. 1977. Porpoise rescue methods in the yellowfin purse seine fishery and the importance of Medina panel mesh size. Mar. Fish. Rev. 39(5): 1-10. (Also MFR Paper No. 1246.)

Introduction of the porpoise releasing method known as "backdown" by Anton Misetich and Manuel Neves and the development of small-mesh porpoise safety panels by Harold Medina raises the question of the optimum mesh size for the panels. Medina panels of relatively standard dimensions hung from 2-inch mesh webbing had been installed in about half the nets of the U.S. tuna purse seine fleet before passage of the Marine Mammal Protection Act. The fishermen believed, and several statistical studies indicated, that use of the panel resulted in lower porpoise mortality. Despite the improved performance, however, porpoises were still being entangled in nets during the backdown process and a recent study indicates that up to 30 percent of porpoise mortality is due to this factor. Using mainly porpoise specimens taken in the fishery, measurements of penetration of porpoise snouts and flippers through mesh openings of 2, 1-7/8, 1-1/2, and 1 inches were made to elucidate the potential reduction in porpoise entanglement that could be expected through use of Medina panel mesh sizes of less than 2 inches. With their jaws closed, the snouts of even the smallest specimen could not penetrate 1-inch mesh, and the average penetration with the jaws open was grossly reduced as were penetrations of pectoral fins. Because of added weight and drag, additions of large sections of small-mesh netting can drastically affect the buoyance and hydrodynamic performance of purse seines. Recent tests of porpoise "aprons" and "chutes" (trapezoidal-shaped sections of webbing appended to Medina panels) promise a means of making small-mesh netting compatible with tuna purse seine performance.

Dizon, Andrew E., William H. Neill, and John J. Magnuson. 1977. Rapid compensation of volitional swimming speeds and lethal temperatures in tropical tunas (Scombridae). Environ. Biol. Fish. 2:83-92.

Observations on continuously swimming tunas were used to determine effects of temperature upon volitional locomotory activity and to determine upper and lower lethal temperatures. Experimental subjects were 10 skipjack tuna, Katsuwonus pelamis, 9 kawakawa, Euthynnus affinis, and 3 yellowfin tuna, Thunnus albacares.

Our results: lower and upper lethal temperatures for the euthynnids (K. pelamis and E. affinis) were 15° and 33°C, respectively. Swimming speed for the euthynnids did not decrease with temperature

within most of the zone of thermal tolerance; we observed either temperature independence or increases in speed as the temperature decreased. Yellowfin tuna swam slower as the water temperature decreased, but swimming speed changes lagged behind the water temperature changes. This effect was almost certainly due to the large thermal inertia that is a property of tunas. The lag between swim speed and water temperature was eliminated by utilizing an estimate of red muscle temperature, rather than water temperature, as a covariate. Yellowfin tuna swim speed was best correlated with red muscle temperature rather than ambient water or brain temperatures.

Dotson, Ronald C. 1976. Minimum swimming speed of albacore, Thunnus alalunga. Fish. Bull., U.S. 74(4): 955-960.

Measurements of density and pectoral lifting area of albacore, Thunnus alalunga, were made and compared with those previously described for yellowfin, Thunnus albacares; bigeye tuna, Thunnus obesus; and skipjack tuna, Katsuwonus pelamis. Albacore have densities within the range of yellowfin of similar size. The pectoral lifting area of albacore was always greater than skipjack tuna but similar to yellowfin tuna and bigeye tuna for fish less than 70 cm long. Larger albacore had increasingly larger fins than did the other species.

Minimum speed necessary for hydrostatic equilibrium of albacore was calculated and compared at 50 and 80 cm fork lengths to values calculated for the species above. Albacore minimum speeds were slower than those for skipjack tuna, similar to those of yellowfin tuna, and greater than those of bigeye tuna. Density variations of albacore, attributed to fat content and gas bladder volume, significantly affected estimates of minimum speed. Calculated speeds were slower than those estimated for albacore tracked at sea or estimated from tag returns.

Laurs, R. Michael, William H. Lenarz and Robert N. Nishimoto. 1976. Estimates of rates of tag shedding by North Pacific albacore, Thunnus alalunga. Fish. Bull., U.S. 74(3): 675-678.

A tagging program was begun in 1971, and is continuing, on North Pacific albacore, to examine their migration patterns, to obtain information for use in population studies, and to estimate rates of mortality. Because loss of tags through shedding can cause estimates of mortality to be biased upwards unless corrected for, part of the tagging program in 1972 consisted of an experiment in which 788 albacore were double-tagged to evaluate tag shedding by this species. Immediate (Type I) and Instantaneous (Type II) rates of tag shedding were estimated using data from a double-tagging experiment. Type I shedding was estimated to be about 0.12 and Type II to be between 0.086 and 0.098 on an annual basis. The paper also contains a discussion on the accuracy of the estimates, and a method was developed to estimate possible bias due to fishermen reporting double tag recoveries as single tag recoveries. The possible bias was estimated to be low.

Laurs, Michael R., Heeny S. H. Yuen, and James H. Johnson. 1977. Small-scale movements of albacore, Thunnus alalunga, in relation to ocean features as indicated by ultrasonic tracking and oceanographic sampling. Fish. Bull., U.S. 75:347-355.

Studies with ultransonic tracking techniques and oceanographic sampling demonstrated that oceanographic conditions play an important role in the local concentrations and movements of albacore, Thunnus alalunga, in U.S. coastal waters. Albacore show a tendency to congregate in the vicinity of coastal upwelling fronts, presumably to feed. They move away from the immediate area when upwelling ceases and the upwelling front is no longer present at the surface. The movements of albacore also appear to be related to the distribution of sea surface temperature, with fish spending little time in water with surface temperatures cooler than 15.0°C.

The average swimming speed for three fish tracked between 27.8 and 50 h was 1.6 knots (82.4 cm/s) with each fish exhibiting slightly faster swimming speeds during hours of daylight than during hours of darkness.

Neill, William H., Randolph K. C. Chang, and Andrew E. Dizon. 1976. Magnitude and ecological implications of thermal inertia in skipjack tuna, Katsuwonus pelamis (Linnaeus). Environ. Biol. Fish. 1:61-80.

Heat exchange experiments with sedated and free-swimming skipjack tuna, Katsuwonus pelamis (Linnaeus), yielded the following results: For fish between 0.4 and 3.5 kg in weight (w) - Inertial resistance to cooling and warming were virtually equal over the same span of temperature (18° to 30°C). Thermal inertia of red muscle, white muscle, and brain (in intact, living animals) was proportional to $W^{0.45}$ (i.e., coefficient of temperature change, k, $\propto W^{-0.45}$ for each tissue). White muscle, brain, and ventricular blood equilibrated with a changed environmental temperature about 1.1, 3.3, and 20 times as rapidly as red muscle. The countercurrent heat exchanger was about 95% efficient as a thermal barrier between gills and red muscle; consequently, only about half (30%-80%, depending on W) the total heat transfer between the red muscle and the environment occurred across the gills. Under conditions of thermal equilibrium, the red muscle and white muscle of sedated fish were warmer than the environment by amounts independent of environmental temperature but proportional to $W^{0.58}$ and $W^{0.61}$, respectively; in contrast, the excess temperature of the brain was independent of fish weight but bore a weak, positive relation to environmental temperature. In two free-swimming fish stimulated to violent activity by chasing, the red muscle warmed at rates up to 0.3°C min^{-1}, ultimately attaining temperatures 1.5° and 3.4°C above prechasing equilibrium levels.

Sakagawa, Gary T., Atilio L. Coan, and Eugene P. Holzapfel. 1976. Length composition of yellowfin, skipjack, and bigeye tunas caught in the eastern tropical Atlantic by American purse seiners. NOAA Tech. Rep. NMFS SSRF-702, 22 p.

Sampling and analytical procedures that are used to estimate the size composition of Atlantic tunas caught by American purse seiners in the eastern tropical Atlantic are described. The procedures are based on a stratified, two-stage subsampling model. Estimates indicated that about 0.2 to 1.4 million yellowfin tuna, Thunnus albacares, 1.2 to 12.8 million skipjack tuna, Katsuwonus pelamis, and 0.5 to 41.2 thousand bigeye tuna, T. obesus, were caught annually by the fleet in 1968-74. The dominant age group in most years was 1-year olds for yellowfin and skipjack tuna and 2-year olds for bigeye tuna.

Sharp, Gary D. and Ronald C. Dotson. 1977. Energy for migration in albacore, Thunnus alalunga. Fishery Bulletin, U.S. (Note) 75(2): 447-450.

Skillman, Robert A., and Marian Y. Y. Yong. 1976. Von Bertalanffy growth curves for striped marlin, Tetrapturus audax, and blue marlin Makaira nigricans, in the central North Pacific Ocean. Fish. Bull., U.S. 74:553-566.

The growth of striped marlin, Tetrapturus audax, and blue marlin, Makaira nigricans, was described by fitting von Bertalanffy growth curves (an assumed age model and a length-increment model) to the progression of age-groups, by quarters, through the Hawaiian longline fishery from 1960 to 1970. For striped marlin, the sexes grew at about the same rate and had similar predicted asymptotic maximum fork lengths, 277.4-314.4 cm for males and 288.7-326.2 cm for females. For blue marlin, the sexes grew at about the same rate until 250 cm. Above this length, the growth rate of males declined and an asymptotic maximum length of 298.8-368.0 cm was predicted. For females above 250 cm, the growth continued at a rapid rate, exhibiting little tendency toward an asymptote over the range of ages available to the study.

Steffel, Sherry, Andrew E. Dizon, John J. Magnuson, and William H. Neill. 1976. Temperature discrimination by captive free-swimming tuna, Euthynnus affinis. Trans. Am. Fish. Soc. 105:588-591.

Captive kawakawa, Euthynnus affinis, were instrumentally conditioned to respond to an increase in temperature to determine discrimination abilities. Two fish yielded a discrimination threshold of 0.10°C. Thermal sensitivity of this high-sea pelagic fish is thus no more acute than that of inshore fishes and appears inadequate for direct sensing of weak horizontal temperature gradients at sea.

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