SOUTHWEST FISHERIES CENTER

NATIONAL MARINE FISHERIES SERVICE
SOUTHWEST FISHERIES CENTER
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MAY 1984

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

For The Period
MAY 1, 1983 To APRIL 30, 1984

ADMINISTRATIVE REPORT LJ-84-15

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INTRODUCTION

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

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

Under the leadership of Richard Shomura, Director, tuna research at the Honolulu Laboratory includes studies on the behavior, energetics, physiology and sensory biology of tropical tunas, South Pacific albacore and other tuna populations of the central and western Pacific and recreational fisheries research, principally the sportfishery for billfishes. Research results are important in the development of management plans by the Western Pacific Regional Fishery Management Council, the development of international policy on tuna and billfish management by the U.S. Department of State and the Department of Commerce, and for the evaluation of fishing potentials and exploitation strategies by the U.S. tuna industry.

At the La Jolla Laboratory, the staff of the Oceanic Fisheries Resources Division under the leadership of Dr. Gary Sakagawa provides basic fishery analysis and management advice on tunas and billfishes to U.S. Commissioners serving on international fisheries bodies, and conducts studies on the status of dolphin involved in the tuna purse seine fishery of the eastern tropical Pacific. The staff of the Coastal Fisheries Resources Division, led by Dr. Reuben Lasker, also conducts studies on the distribution, availability and migration patterns of North Pacific albacore and associated environmental influences in the eastern North Pacific. Results of these studies are a key source of information and advice for U.S. representatives to international tuna management organizations, the International Commission for the Conservation of Atlantic tunas, fisheries scientists, administrators, and the U.S. tuna industry.

During the past year, major oceanographic events, shifts in the location of fishing areas, market economics, trade balances, and escalating labor costs have forced significant and possibly long-lasting changes in the world tuna picture. The American consumer, cannery worker, businessman, and taxpayer all have a vital stake in the continued vitality and maintenance of tuna fisheries, and in the conservation of tuna resources, domestically and world-wide. Although the U.S. produces only about 12% of the total world tuna production, it consumes close to 40% of the global catch. The total annual

retail value of tuna fisheries (in the form of canned products of U.S. catches and foreign (whole) fish imports for canning) has been estimated at $1.75 billion in 1983. This value, which is based on a living renewable resource, can be threatened by overfishing and uncontrolled and unrestricted exploitation, by the pursuit of small, short-term gains at the expense of long-term conservation of the resources, by the complexities of demographics, and by the vagaries of market demands on a global scale.

The tuna stocks and fisheries of the world are inextricably linked by principles of nature and the biological responses of the tuna resources to fishing, as well as by the realities of international economics. Thus, the success of the tuna fisheries of Japan, Korea, and Taiwan is of interest and long-range concern to the U.S. as well.

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

The report which follows is not intended as a comprehensive presentation of the Southwest Fisheries Center's research on tuna and tuna-related activities but rather as an informal account of major on-going activities. The information was compiled by Lillian Vlymen and Jean Michalski, Technical Writer/Editors, from material supplied by the Center's scientific staff at the Honolulu and La Jolla Laboratories.

Izadore Barrett

Izadore Barrett, Director
NMFS Southwest Fisheries Center

May, 1984
La Jolla, California

IN SUPPORT OF EXISTING INTERNATIONAL AGREEMENTS

RESEARCH ON ATLANTIC TROPICAL TUNAS AT THE SOUTHWEST FISHERIES CENTER

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

During 1982-1983, noteworthy research activities on Atlantic tuna at the La Jolla Laboratory included participation in the ICCAT-sponsored International Skipjack Year Program (ISYP) conference in Tenerife Island, Spain; collection of biological and fishery data from U.S. fisheries; and completion of analyses for stock assessment of yellowfin and skipjack tuna for the 1983 Standing Committee on Research and Statistics (SCRS) meeting.

Research in support of ICCAT's International Skipjack Year Program was presented by Center scientists at the ICCAT-sponsored conference, June 20-30, held in Tenerife Island, Spain. At the conference, SWFC scientists presented six papers dealing with biological research, stock assessment research, and fishery evaluation.

The 1982 catch of tuna and tuna-like fish by U.S. fishermen was monitored and reported to ICCAT. Catches of U.S. and Venezuelan yellowfin and skipjack tunas were sampled for length frequency. Foreign-caught Atlantic tunas transshipped to Puerto Rico were sampled for length frequency and species composition. Number of fish sampled was 5,783 yellowfin tuna, 2,173 skipjack tuna, 1,094 bigeye tuna, and 100 albacore. These activities are continuing this year (see page 10).

Center scientists have completed stock assessments on yellowfin and skipjack tunas. For yellowfin and skipjack tuna stocks, assessment results with respect to data and analysis techniques were examined critically.

The Fisheries*

United States commercial catches of Atlantic tunas and tuna-like species total approximately 14,500 metric tons (mt) in 1982 (Table 1). This was a

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*Prepared by staff members of the Southwest Fisheries Center, La Jolla, California, and the Southeast Fisheries Center, Miami, Florida.

Table 1. Catch and landing (metric tons) of Atlantic tunas and tuna-like fishes by American fishermen, 1967-82.[1]

Year	Bluefin	Yellowfin[2,3]	Albacore	Bigeye[2]	Little tunny	Skipjack[2]	Bonito	Swordfish	Spanish mackerel	King mackerel	Unclassified	Total
1967	2,320	1,136	0	0	7	493	22	474	3,577	2,767	10	10,806
1968	807	5,941	0	18	6	3,314	43	274	5,342	2,813	2	18,560
1969	1,226	18,791	0	148	7	4,849	98	171	4,952	2,814	1	33,057
1970	3,327	9,029	0	195	158	11,752	83	287	5,506	3,050	-	33,387
1971	3,169	3,764	0	544	5	16,224	90	35	4,713	2,571	50	31,165
1972	2,138	12,342	10	212	212	12,290	24	246	4,863	2,213	-	34,550
1973	1,294	3,590	0	113	20	21,246	261	406	4,437	2,710	-	34,077
1974	1,857	5,621	13	865	51	19,973	92	1,125	4,990	4,747	1	39,335
1975	2.823	14,335	1	67	67	7,567	117	1,700	5,288	3,095	19	35,079
1976	1,931	2,252	0	28	5	2,285	23	1,429	6,385	4,053	30	18,421
1977	1,956	7,208	2	331	53	6,179	268	912	5,453	3,837	71	26,270
1978	1,852	9,747	9	248	113	8,492	224	3,039	3,310	2,507	31	29,572
1979[4]	2,297	3,182	11	212	12	3,102	502	3,405	2,926	2,204	11	17,864
1980[4]	1,505	2,118	21	202	88	3,589	195	3,535	5,429	3,192	513	20,387
1981[4]	1,526	1,866	54	152	97	5,373	333	2,074	2,748	3,368	200	17,791
1982[4]	689	883	126	377	87	731	209	3746	3747	3713	250	14,558

[1]Estimated catch is for bluefin tuna, yellowfin tuna, albacore, bigeye tuna, skipjack tuna and little tunny. Landing is for all other species. Sport catches are not included except for bluefin tuna.

[2]Includes catches of purse seiners flying the flags of Bermuda, Netherlands Antilles, Nicaragua and Panama.

[3]Includes small quantities of bigeye tuna prior to 1975.

[4]Preliminary.

decrease of about 20% from the 1981 catch. This decrease was due to lower catches of skipjack, yellowfin, and bigeye tunas.

During 1982, U.S. vessels fishing for Atlantic tropical tunas operated under a minimum size regulation of 3.2 kg for yellowfin and bigeye tunas with a 3% allowance by weight per boat landing. U.S. vessels fishing for bluefin tuna operated under a minimum size regulation of 6.4 kg and catch limitation.

Tropical Tunas

United States commercial catches of Atlantic tropical tuna species (yellowfin, skipjack and bigeye) totaled about 2,000 mt in 1982, substantially lower than in 1981. This was due primarily to much reduced skipjack tuna catches.

Two large U.S. purse seiners participated in the Atlantic tropical tuna fishery in 1982. They caught 636 mt of yellowfin tuna, 79 mt of skipjack tuna and 345 mt of bigeye tuna in the eastern Atlantic; and 82 mt of yellowfin tuna and 6 mt of skipjack tuna in the western Atlantic. Five smaller U.S. purse seiners, fishing primarily for bluefin tuna, took about 646 mt of skipjack tuna off the U.S. east coast.

In 1982, the estimated number of undersized (less than 3.2 kg) Atlantic yellowfin tuna in the landings of the U.S. fleet was approximately 2% of the total number landed. No Atlantic bigeye tuna were sampled from the U.S. fleet's landings. Through September of 1983, no large U.S. purse seiner has participated in the tropical Atlantic tuna fishery. U.S. imports of Atlantic tunas through July 1983 are 38,489 mt: 24,756 mt of eastern Atlantic skipjack tuna, 9,236 mt of western Atlantic skipjack tuna, 2,212 mt of eastern Atlantic yellowfin tuna, 1,786 mt of western Atlantic yellowfin tuna, and 505 mt of western Atlantic bigeye tuna. There was no reported catch of eastern Atlantic bigeye tuna.

Temperate Tunas and Billfishes

Bluefin tuna catches by U.S. vessels operating in the Atlantic in 1982 amounted to 684 mt. The catch by various gears was purse seine, 202 mt; hand gear, 134 mt; harpoon, 80 mt; rod and reel, 200 mt; and longline, 68 mt.

Catches of Atlantic albacore tuna totaled 126 mt, slightly more than in recent years. Atlantic billfish taken by recreational fishermen amounted to about 700 mt in 1982. Swordfish catches, primarily by longline gear are estimated to be 3,746 mt in 1982, up 45% from 1981. Through September 1983 U.S. catches of bluefin tuna totaled 1,342 mt. The 1983 U.S. catch limit is set at 1,387 mt.

INTERNATIONAL COMMISSION FOR THE CONSERVATION OF ATLANTIC TUNAS

SWFC Scientists Participate in 14th Regular Meeting of ICCAT/SCRS

From October 31 through November 9, 1983, the Standing Committee on Research and Statistics (SCRS) of the International Commission for the Conservation of Atlantic Tunas (ICCAT) held its 14th regular meeting in Madrid, Spain, to determine the status of tuna and billfish stocks covered under the ICCAT Convention. The U.S. scientific delegation to this meeting was headed by Dr. Gary Sakagawa, Chief of the Oceanic Fisheries Resources Division and consisted of NMFS scientists from the SWFC and SEFC (Southeast Fisheries Center). Drs. Norman Bartoo and Pierre Kleiber were the other SWFC scientists in the delegation.

SWFC scientists participated in all sessions of the SCRS and chaired a number of important discussion groups: Dr. Bartoo served as rapporteur for the skipjack status of stock report and convener of the Working Group on SCRS Organization. Dr. Kleiber served as rapporteur for the multispecies Interaction-tropical tunas report. Dr. Sakagawa served as rapporteur for the Multispecies Interaction-Temperate Tunas report, convener of the Skipjack Subcommittee and substitute convener of the Statistics Subcommittee. Eight working documents prepared by the tuna research team at the La Jolla Laboratory were presented by the SWFC scientists to the SCRS.

Au, D. Comparison of recent changes in the space-time patterns of fishing by FISM and Spanish fleets in the eastern Atlantic.

Coan, A. L., and N. W. Bartoo. Effects of sample size on the accuracy of length-frequency sampling of tunas transshipped to Puerto Rico.

Coan, A. L., and T. C. Foster. Differences between length frequency samples taken in Puerto Rico and other sampling sources, 1979-1981.

Foster, T., and E. Holzapfel. Size and species compositions of Atlantic tunas from imports landed in Puerto Rico during 1982.

Kleiber, P. Analysis of ISYP skipjack tagging results using the methods of the South Pacific Commission Skipjack Programme.

Kleiber, P., and W. Parks. An example of the use of micro-computers for population assessment: investigation of the effect of uncertainty in catch data on results of cohort analysis.

Rinaldo, R. G. Analysis of Atlantic yellowfin tuna cohort statistics.

Rinaldo, R. and P. Kleiber. Evaluation of a method for determining minimum and maximum recruitment using cohort and yield per recruit analyses.

The findings on the status of tuna stocks of the SCRS can be summarized as follows:

Yellowfin tuna.--For the eastern stock, the stock appears to be fully exploited. Catch is high, consisting of large numbers of small fish and at the level of MSY, 107,000-114,000 mt with current exploitation patterns. Fishing effort, however, appears to be in excess of that required to yield MSY; consequently, the SCRS warned that if these trends continue, stringent regulations will be necessary to maintain maximum productivity.

Skipjack tuna.--Data primarily collected during ICCAT's International Skipjack Year Program served as the basis for the assessment. The stocks appear to be underexploited and can withstand additional fishing pressure which will produce additional yield.

Bigeye tuna.--The Atlantic stocks are currently being fished at or close to their MSY levels (32,900-74,100 mt for the north stock of 23,700-49,200 mt for the south stocks) with existing exploitation patterns. The SCRS, therefore, concluded that increased fishing effort is unlikely to generate increases in sustainable yield.

Albacore.--For the north stock, exploitation is at a moderate level with the catch and effort currently below the levels for MSY. The SCRS noted that increases in fishing effort would probably result in increase in sustainable yield. The south stock, on the other hand, appears to be exploited at or beyond the MSY level. The Committee warned that if the surface fishery for albacore in the south Atlantic develops into a major fishery, the sustainable yield is likely to decrease owing to the smaller sizes of fish that are caught by the surface fishery.

Bluefin tuna.--The SCRS was unable to reach a consensus on the current state of the Atlantic bluefin tuna stocks. It noted that ongoing analyses that are scheduled for completion in 1984 will serve as the basis for a thorough status of stocks determination in 1984.

Other highlights of the meeting included presentation of the final report of ICCAT's International Skipjack Year Program by Dr. Sakagawa, who was involved in supervising the Program since its inception in 1979 and the appointment of Dr. Bartoo as convener of the Subcommittee on Statistics for the next two years.

INTERNATIONAL SKIPJACK YEAR PROGRAM OF THE ICCAT

A four-year research program to obtain information for assessing the condition of the Atlantic skipjack tuna, Katsuwonus pelamis, population, and for developing plans for the rational exploitation of the resource was initiated by the International Commission for the Conservation of Atlantic Tunas (ICCAT) in 1979. In the ensuing years Center scientists continued their active involvement in the program, culminating in a "wrap-up" conference, June 20-30, 1983, in Tenerife in the Canary Islands. Participants included Drs. David Au, Andrew Dizon, John Graves, Pierre Kleiber, and Gary Sakagawa of the Southwest Fisheries Center.

The Conference was held at a new oceanographic institute on the island of Tenerife in the city of Santa Cruz. The Instituto Español de Oceanografia hosted delegates from Benin, Brazil, Canada, Cape Verde, Cuba, France, Gabon, Ivory Coast, Japan, Korea, Portugal, Senegal, South Africa, Spain, and U.S., as well as observers from ICCAT (the sponsoring group), the Fisheries Committee for the Eastern Central Atlantic, and the South Pacific Commission (SPC). Dr. P.E.K. Symons (ICCAT) chaired the meeting and Dr. Brian Rothschild, University of Maryland, and Dr. Robert Kearney, SPC, made the keynote addresses.

Papers presented by the U.S. delegates assisted in directing the thinking towards the idea that skipjack are a single, widespread stock of high productivity. Rapid growth, early maturity, and a short life-span characterize these opportunistic tunas.

Dr. Au presented a paper, "The spawning schedule of skipjack tuna from southeastern Brazil as determined from histological examination of ovaries, with notes on spawning in the Caribbean," authored by himself and Dr. Stephen R. Goldberg. The manuscript describes work in which a total of 996 skipjack tuna ovaries (961 from Brazil and 35 from the Caribbean) were examined to determine their reproductive condition. Brazilian fish were sampled from November 1981 to July 1982 from the coastal area south of Cabo Frio between 22° and 28°S latitude. Caribbean samples were obtained during June, August, and September 1981. A portion of the Brazilian population was in spawning condition in November and this condition continued through March. Ovaries obtained during May-July were regressed. Minimum length of sexually mature females was 510 mm and the minimum gonad index of spawning fish was 30. Skipjack are multiple batch spawners and histologically mature ovaries represent a wide range of gonad indexes, including ripening and recently spawned conditions.

Regression analyses revealed significant positive correlations between egg number and body length, body weight, and ovary weight. For skipjack tuna measuring 510-720 mm fork length and 2600-9650 g body weight, the average fecundity was estimated at 385,937 $\pm$ 75,169 eggs.

Dr. Au also asked the question, "Are skipjack tuna population dynamics quantitatively different from that of other tropical tunas?" in a paper which he authored. The manuscript compares population features of skipjack, yellowfin, and bigeye tunas and seeks an explanation for the erratic nature of skipjack catch statistics. The most notable feature of skipjack appears to be its wide-ranging behavior. This is related to a feeding strategy evolved to efficiently exploit an oceanic environment characterized by relatively low productivity. The high activity levels are associated with higher metabolic rates, higher natural mortality rates, and higher growth rates, and an earlier age of reproductive maturity, relative to other tunas. The resulting production/biomass ratio is high and the age structure simple, so that recruitment success and movement-related availability of cohorts dominate the catches. At the same time the widespread population of adults tends to protect the stocks from recruitment overfishing.

Dr. Andrew Dizon presented a manuscript authored by Lisa Ankenbrandt, Biological Aid, titled, "Food habits of bait-caught skipjack tuna from the southwestern Atlantic Ocean." The paper describes the analysis of food habits from 1041 adult skipjack tuna caught off southern Brazil. Ankenbrandt was particularly interested in whether juvenile skipjack tuna were utilized as forage. Changes in diet were also examined by season and by size of the predator.

No juvenile skipjack tuna were found in any of the stomach contents. While Auxis thazard and Scomber japonicus represented the major scombrid prey items, Euphausia similas and Maurolicus meuellei provided the bulk of the diet items throughout the entire season and size range of the sample.

Dr. John Graves presented, "The mitochondrial DNA genetic structure of skipjack tuna populations and its management implications" by Graves and Dizon. The investigators used restriction enzyme analysis of mitochondrial DNA (mtDNA) to determine the genetic basis of the population structure of skipjack tuna from the eastern and western Atlantic and Pacific Oceans. No significant genetic differentiation was detected between fish from different ocean basins although sufficient within-sample variation was detected. These results are consistent with the lack of morphological and electrophoretic differentiation found in previous studies and strongly suggest a sufficient gene flow between ocean basins exists to prevent genetic differentiation. Although the probability of any particular skipjack tuna school interchanging or even crossing ocean basins is probably small, management decisions must be made which consider such genetic evidence.

Dr. Gary Sakagawa described, "Some recent changes in the Atlantic skipjack tuna fisheries" in a paper authored by himself and Atilio Coan, Statistician. ICCAT's International Skipjack Year Program (ISYP) was instrumental in drawing attention to the presence of the underutilized resource of skipjack tuna in the Atlantic Ocean and in encouraging increased exploration and exploitation of the resource. Fisheries statistics for the period 1979 and after 1978, when the 4 year ISYP was in effect, demonstrate that the fisheries for skipjack tuna have undergone expansion and changes.

The Atlantic catch of skipjack tuna, for example, increased from an average of 91,300 metric tons in 1975-78 to an average of 118,300 metric tons in 1979-82.

Dr. Sakagawa also discussed the "Skipjack fisheries in the western Atlantic." Fishery information on skipjack tuna in the western Atlantic Ocean shows that the fish are caught throughout the area on a range of gear types from the artisanal to the advanced. Areas in the Gulf of Mexico, Caribbean Sea, and off northeastern and southeastern Brazil appear promising for further skipjack fishery development. It appears that production from the region will not increase appreciably in the near-term without employment of more efficient methods for locating schools or for catching available schools. Sakagawa suggests fish aggregating devices as a possible technique for concentrating schools and catching them more efficiently.

Much discussion centered on the results obtained by the French delegation's analysis of tagging data. These data showed extensive movements of fish along the African coast with area-specific growth and attrition rates. On the basis of these data and from analysis of catch statistics, the French scientists proposed the term "black hole" (sink) to explain the sizeable segment of large fish (greater than 53 cm) of the exploited stock that moves offshore, thus becoming unavailable to the fishery, but which may function as the "cryptic nursery" (source) for recruits, as they describe it. In the discussion that ensued, the conference participants felt that it was impossible to distinguish between high mortality rates, changes in behavior which render them unavailable to the gear, or emigration (The French hypothesis).

The meeting concluded with consideration of research goals posed by the ISYP organizers. The delegates approved wording to the effect that skipjack catches could be increased, with due caution for the juvenile yellowfin and bigeye by catch in the coastal fisheries, and that more intensive sampling and studies be conducted in certain poorly known areas, particularly those of the western Atlantic.

RESULTS OF SAMPLING OF 1983 ATLANTIC TUNA CATCH

Foreign-caught Atlantic tunas transshipped to Puerto Rico are sampled routinely for biological information by biological technician Eugene Holzapfel. Data on fork length, weight and species composition of catches are collected. Results of Holzapfel's sampling during the period January 1, 1983, to December 1, 1983, are as follows:

Species	# of samples	# of fish sampled	Tonnage sampled (MT)
Yellowfin			
Purse seine	28	1857	689.8
Baitboat	28	2245	439.8
Longline	1	71	1.1
Unknown	15	1170	191.8
Skipjack			
Purse seine	13	657	5106.8
Baitboat	18	912	1791.6
Unknown	3	151	151.7
Bigeye			
Purse seine	22	731	341.2
Baitboat	2	69	1.0
Unknown	7	193	52.6
Albacore			
Longline	5	250	1463.5
Unknown	3	150	938.2
Blackfin			
Baitboat	2	100	13.3
Bullet tuna			
Purse seine	1	50	180.3

Holzapfel also obtained two yellowfin length frequency samples from transshipments of catches by French seiners fishing in the Indian Ocean.

During the period of January 1 to December 31, 1983, twenty-six size composition samples were collected for the Multispecies Data Management and Fisheries Monitoring Program by the Inter-American Tropical Tuna Commission. These data were collected from seven foreign purse seiners that fished in the Caribbean Sea and transshipped their catches to Puerto Rico. A summary of these data follows:

Species	Trips sampled	# of samples	# of fish sampled
Yellowfin	7	10	500
Skipjack	7	9	452
Blackfin	4	4	119

Bigeye	2	2	6
Albacore	1	1	18

1983 U. S. TUNA TRADE SUMMARY

U.S. tuna industry performance during 1983 was highlighted by increased domestically-caught cannery receipts of albacore and tropical tuna, an increase in the light meat tuna pack and increased purchases of tuna products by U.S. consumer. However, marked improvement in these areas was not realized without some significant changes in the industry's structure and operations. Some of these changes can be traced back to the late 1970's and early 1980's when rising production costs, particularly for fuel, led to record high prices at the ex-vessel, wholesale and retail levels. Higher prices, especially relative to meat and poultry prices, increased consumer resistance to purchases of canned tuna resulting in an accumulation of canned tuna inventories. To stimulate consumption, the U.S. tuna industry initiated price reductions in mid-1980 and prices at all levels have declined since. This action together with overall improvements in the U.S. economy during the past year has enhanced canned tuna sales and done much toward restoring U.S. canned tuna production to its historic average.

To accommodate wholesale price reductions and improve inventory positions, production at California canneries was cut back severely beginning in 1982 with the closure of one major cannery and significant contractions in the remaining operations through 1983. Adverse conditions in the processing sector of the U.S. tuna industry at the end of 1981 filtered downward to U.S. tuna fishermen in the form of substantially lower ex-vessel tuna prices and difficulties and delays in selling their catches. Furthermore, canneries were anxious to divest themselves of interests they held in tropical tuna vessels and to cut back their financial support to independently owned vessels. Under these circumstances many vessels were unable to participate in the fisheries. In addition to weakened ex-vessel markets, U.S. tropical tuna fishermen faced continued uncertainty in terms of access to traditional eastern Pacific fishing grounds, decreased availability of tropical tuna resources in the eastern Pacific attributable to El Niño and increased competition from foreign fishermen. These factors, together with potentially more abundant tropical tuna resources to be found in the western Pacific Ocean, contributed to a reduction in the number of active U.S. tropical tuna vessels and a re-deployment of most large U.S. purse seiners to the western Pacific in 1983.

The U.S. industry has also expressed considerable alarm over the recent influx of canned tuna imports. The market share of imports has more than doubled in recent years from 6% in 1977 to 14% in 1982. In terms of total volume, U.S. imports of canned tuna increased 136% between 1978 and 1983 (72% from 1981 to 1983), an annual average rate of 19%. On the other hand, during this same period imports of raw tuna decreased almost 43%, a significant shift

in U.S. tuna imports from raw to finished product, representing a loss in terms of value added to U.S. processors. This implies a real cost-revenue squeeze for U.S. processors as they compete with foreign processors for inputs of raw tuna driving up production costs, and compete with foreign processors to maintain their share of domestic retail sales, putting downward pressure on prices they receive. Domestic wholesale prices fell to low levels in 1983, and discounts of up to $9.00 per case were also being offered; nonetheless, import prices were still $3.00 to $5.00 per case below domestic prices. These low prices together with a strong U.S. dollar abroad have made foreign produced canned tuna very attractive to U.S. importers since early 1982. Furthermore, since the ad valorem duties on canned tuna imports are determined by their price, the lower the price of imported canned tuna, the lower the customs duty. With regard to canned imports, the most significant occurrence affecting the tuna industry in 1983 was the exclusion of canned tuna packed in American Samoa from being counted against the quota on imports of canned tuna not in oil. It is estimated that one third of the annual quota in recent years had been filled by canned tuna processed in American Samoa. In effect, the American Samoa exclusion allows foreign countries to export that much more canned tuna not in oil under the lower tariff duty rate. To a great extent this accounts for the large increase in foreign produced canned imports in 1983.

The U.S. tuna industry has brought attention to the import situation by seeking revisions to the tariff structure for tuna imports not in oil. It also petitioned for a countervailing duty being placed on imported canned tuna from the Philippines. If foreign competition grows more intense it is likely that the U.S. industry will pursue other means available to protect itself as it adjusts to a new international order in tuna harvesting and processing.

On another front, the U.S. tuna industry recently responded to the changing tastes and preferences of U.S. consumers by introducing a line of low-sodium (low-salt) canned tuna products. While it may be premature to judge the popularity of the low-sodium tuna products among growing numbers of health and nutritional conscious consumers, the line has experienced wide-ranging acceptance in terms of retail distribution. More important perhaps, this product innovation suggests a willingness on the part of the U.S. tuna industry to look ahead and assume a greater degree of risk to assure future growth in an increasingly competitive market for the U.S. consumer's food dollar.

Table 1. U.S. tuna cannery receipts (short tons) by receiving site and ocean of origin, 1982-83.

	Domestically-Caught			Imports			Total		
	1982	1983	%CHG	1982	1983	%CHG	1982	1983	%CHG
Site									
California	140,850	134,658	-4	56,397	51,481	-9	197,247	186,139	-6
Am.Samoa/HI	42,388	79,240	87	41,180	35,983	-13	83,568	115,223	38
Puerto Rico	44,918	71,656	60	174,913	159,031	-9	219,831	230,687	5
Total	228,156	285,554	25	272,490	246,495	-10	500,646	532,049	6
Ocean									
E. Atlantic	-	21	100	78,552	55,911	-29	78,552	55,932	-29
W. Atlantic	115	77	-33	41,306	40,643	-2	41,421	40,720	-2
E. Pacific	159,618	115,303	-28	31,164	12,237	-61	190,782	127,540	-33
W. Pacific	68,423	170,153	149	102,086	118,663	16	170,509	288,816	69
Indian	-	-	-	19,382	19,041	-2	19,382	19,041	-2
Total	228,156	285,554	25	272,490	246,495	-10	500,646	532,049	6

Source: NOAA, NMFS, Statistics and Market News, Southwest Region.

Table 2. U.S. production of canned tuna (thousand standard cases) by processing site, 1982-83.

Site	White Meat 1982	White Meat 1983	White Meat %CHG	Light Meat 1982	Light Meat 1983	Light Meat %CHG	Total 1982	Total 1983	Total %CHG
California	954.4	781.1	-18	9,427.4	9,190.5	-3	10,197.4	9,971.5	-2
Am.Samoa/Hi	1,537.2	911.9	-41	3,004.2	5,482.3	82	4,541.5	6,394.3	41
Puerto Rico	3,529.1	3,412.2	-3	8,635.1	8,604.1	-	12,164.2	12,016.3	-1
Total	6,020.7	5,105.2	-15	21,066.7	23,276.9	11	27,087.4	28,382.1	5

Source: NOAA, NMFS, Statistics and Market News, Southwest Region.

IN SUPPORT OF POSSIBLE FUTURE INTERNATIONAL AGREEMENTS

NORTH PACIFIC ALBACORE

Constituents Participate in Albacore Workshop Hosted by SWFC and SWR

A Workshop on the future of the North Pacific albacore fishery was held at the Southwest Fisheries Center in La Jolla, June 1 and 2, sponsored by the Center and the Southwest Regional Office. Participants in the workshop represented a variety of perspectives but shared a common interest in the albacore resource and fishery.

According to David Mackett, Co-Facilitator for the Workshop, "The purposes of the workshop were to benefit both NMFS and the participants. NMFS hoped to gain valuable information about what interested people hoped to see happen in the North Pacific albacore fishery over the next decade. NMFS could then use this information in making program plans consistent with and supportive of the participant's goals for the fishery. It was also intended that the participants, through their involvement in the Workshop, would gain a sense of having contributed in a meaningful and useful way toward the improvement of their government and toward creating the future they desire for an important and valuable fishery."

The Workshop participants generated and organized 23 desirable goals and objectives for the North Pacific albacore fishery to 1993. From the results of organizing or structuring the objectives four major clusters of objectives were identified: Fishery Development, Alternative Products, Research and Fishery/Government Partnership. On the basis of their own experience and insights, the participants identified future desirable trends and events that if realized would help achieve the objectives in each of the four clusters. About 120 such trends and events were identified.

The joint SWFC/SWR Task Force for Planning the albacore program, chaired by Richard Parrish, subsequently met to organize this information for facilitating the Strategic Planning phase.

Workshop on Strategic Planning for the NMFS Program for North Pacific Albacore Research and Management Held at SWFC

Headed by Assistant Administrator for Fisheries William Gordon, a blue-ribbon group of participants from NMFS, Washington, DC, the Northwest and Alaska Fisheries Center, Northwest Region, and the Southwest Region and Center met at the Southwest Fisheries Center in La Jolla, California, January 18 and 19, 1984 to consider and select the strategic options that will guide the planning and further development of the Service's research and management program.

The options were developed from the futures-oriented deliberations of a constituent group meeting at the Southwest Fisheries Center in June 1983, and from analyses conducted by a task force of scientists and managers from the Southwest Region and Center. The options were arrayed for the participants into 14 separate categories, each of which represented a dimension thought necessary for the design of a comprehensive program (e.g., Fishery Development, Fishery Management, New Product Development, Product Quality, Financial Assistance, Data Systems, Research, etc. Participants then discussed the options within each category and selected those most appropriate for guiding the NMFS program.

The options encompassed the entire spectrum of important considerations from citizen participation in planning and operations through continuance of the present level of data collection to the establishment, if ultimately required, of a new international framework for management of the Pacific albacore fisheries. The report of the meeting and the NMFS Strategic Plan for the Albacore Program were prepared by Richard Parrish and David Mackett and is available as Administrative Report Number LJ-84-09, "The Strategic plan for the NMFS's North Pacific Albacore Fishery Program."

SWFC and American Fishermen's Research Foundation Continue Investigation to Develop Winter U.S. Albacore Longline Fishery

The U.S. albacore fishery has traditionally operated during summer and fall months, usually within a few hundred miles of the North American coast. In some years the fishery extends as far south as central Baja California, Mexico, and as far north as northern British Columbia, Canada. In recent years U.S. fishermen have also begun to fish for albacore near the dateline and eastward during early spring and summer months.

The NMFS is participating in a study with the American Fishermen's Research Foundation (AFRF) to evaluate the potential for establishing a U.S. longline fishery on North Pacific albacore during winter months in eastern North Pacific waters.

This study is being conducted cooperatively between the National Marine Fisheries Service, Southwest Fisheries Center (SWFC) in La Jolla, California, and the U.S. albacore fishing industry's American Fishermen's Research Foundation (AFRF). Saltonstall-Kennedy funds managed by the NMFS Southwest Regional Office in Terminal Island, California, and awarded to the AFRF were used to defray fuel expenses of the vessels. The operational aspects of the study were carried on by the AFRF and managed by the Western Fishboat Owner's Association (WFOA), a west coast association of fishermen. Fishery scientists at the SWFC under the direction of Dr. R. Michael Laurs planned the study and worked with the AFRF and WFOA to organize it. In addition, the SWFC provided scientific equipment. Fishery scientists were aboard the subsidized fishing vessels to make scientific observations and to keep detailed records related to the fishing operations and catch.

An area several hundred miles off the coast of southern California and extending to the longitudes of about the Hawaiian Islands was selected for the overall study. The purposes of the field operations have been: 1) to conduct exploratory fishing using longline fishing methods to determine if sufficient catches of albacore can be made to support an expansion of the U.S. fishery, 2) to make scientific observations to determine oceanographic conditions that may influence albacore distribution and catchability in the area, and 3) to collect scientific data for albacore biology and fishery studies. The scientific observations included: a) vertical temperature profiles and surface ocean temperature measurements, (b) albacore tagging for migration and stock structure studies, (c) collection of detailed records on fish catch, amount of gear fished, modifications made to fishing gear and fishing tactics, and size composition of tuna caught, and (d) experiments to measure the depth distribution of longline gear during a set.

The first study, conducted in January-February 1981, investigated possibilities of expanding the U.S. albacore fishery to operate outside traditional summer and fall seasons using longline fishing methods. The results of the first study showed that it was feasible for U.S. fishing vessels in the 50- to 80-foot size-class to longline for albacore during the winter months. A limited quantity of gear was deployed with subsequent small catches in 1981; however, the catch rates were sufficiently high to suggest that a profitable winter albacore fishery could be developed. The second study, conducted in January-February 1982, was designed to expand upon the 1981 finding. The amount of gear deployed was increased to reflect potential commercial efforts and a fishing strategy was proposed based upon associations of catch and subsurface thermal structure found in the first survey.

The third study conducted in late 1982 was designed to evaluate distribution and catch rates in November-December. Five chartered fishing vessels with fishery biologists Ron Dotson and Bob Nishimoto and biological technician Dimitry Abramenkoff on board conducted exploratory operations for albacore tuna in an area approximately 1000 to 2000 miles west of Pt. Arguello, California, during November-December 1982. A total of 96 longline sets was made on the survey. Each of the vessels typically set 800 to 1400 hooks at targeted depths of 250 to 300 feet in and about the thermocline. A total of 51,377 pounds of albacore and 2,783 pounds of bigeye and yellowfin tuna was caught. Approximately one-third of the total albacore landings (by weight) were fish taken on trolling gear (mostly in transit to the longline fishing areas). Individually, the vessel landings ranged from 8,276 to 14,255 pounds of all tunas combined. Daily longline catches ranged from 0 to 84 albacore per vessel. The mean catch rate of albacore for all vessels was about 1.5 fish/100 hooks (1.6 if other tunas are included). The average catch rate among vessels ranged from about 1.0 to 2.9 albacore/100 hooks.

There was a significant loss of fish due to tangled gangions and/or lost hooks by some vessels. The loss of fish due to tangled gangions, approximately 20% of one vessel's catch, is believed to have resulted from the use of "fixed" gangion type of longline gear. Vessels using snap-on gangions with swivels experienced only about a 5% fish loss due to tangles. The fish loss due to lost hooks, 25 and 29% of the catch for two vessels, was traced to slightly oversized nicropress sleeves used in attaching hooks to the gangions

which allowed the monofilament nylon gangion material to pull out and the hook to be lost.

Experiments showed that higher catch rates were made using 400 pound test monofilament nylon line for main line than 1/4-inch polypropylene line. The mean catch rate for 17 sets (1085 hooks) using monofilament nylon was 4.2 fish/100 hooks and for 17 sets (9363 hooks) using polypropylene was 2.6 fish/100 hooks.

Measurements of the amount of sag in the longline gear after it has been set showed that there may be considerable sag in the main line--as much as 25% of the main line length between floats. Because of the excessive sag, it is believed that the majority of the hooks on most sets fished below the targeted depth of the thermocline where it has been recently shown that albacore generally reside.

In order to investigate further the potential for catching albacore by longlining, an albacore commercial fishing vessel on a S-K fuel subsidy conducted longline fishing operations during November-December 1983. The vessel made 17 sets in an area 1250 miles west of Point Arguello, California. The number of hooks varied from 540 to 1712 hooks per set at targeted depths of 250 feet in and about the thermocline. A total of 25,000 pounds of albacore tuna and 3,000 pounds of bigeye was caught by the vessel. A few scattered albacore were also caught by trolling while the vessel was in transit to the longlining area. The daily longline catch ranged from 10 to 171 albacore per set with a mean catch rate of 6.73 albacore per 100 hooks, and 6.99 tuna per 100 hooks when bigeye were included.

The vessel used monofilament nylon for both mainline and gangion construction. It used short gangions of 5 feet and set 16 hooks per basket of gear. An analysis of set and haul rates shows that using the shorter gear a complete set of 1500 hooks would take 13 hours and 21 minutes, while standard Asian gear would take 28 hours and 45 minutes.

The mean catch rate of 6.99 tuna per 100 hooks on this vessel was higher than the catch rate for any former charter vessel and also exceeds the highest rates published by the Japanese for this area and season. Experiments last year had shown that uses of this type of mainline resulted in a 62% increase in catch rate over nylon or polypropylene mainline.

Analysis of fish distribution along the mainline indicates that the vessel was setting the line above and within the thermocline. Using sag estimates of 20% of basket length, the gear was fishing from 156 to 350 feet in depth, around a thermocline depth estimated to begin at 250 feet. Winds in excess of 20 knots were encountered during one-third of the survey period. The inclement weather conditions reduced the fishing effort of the vessel by reducing the number of hooks per set in rough weather.

1983 U.S. Albacore Fishery Landings Higher than Last Year

The preliminary estimated catch for the 1983 U.S. albacore fishery is between 10,500 and 11,000 tons. While this total is about 30% below the ten-year average of 15,675 tons, it is about 40% higher than the catch landed in 1982, which was about 7,650 tons. Several factors contributed to the increased catch in 1983, including oceanographic conditions, in part associated with the El Niño, relatively good weather, especially off central and northern California, and a more stable market for fish-buying by processors.

Albacore arrived in waters south of Pt. Conception, California, about one month earlier than usual, and fair catches were made until the end of July. After July, catches dropped to virtually nil for the remainder of the season owing to very warm upper layer ocean temperatures and deep thermocline conditions associated with the El Niño. While oceanographic conditions related to the El Niño were detrimental to albacore fishing south of Pt. Conception and in much of the Pacific Northwest, the El Niño was in part responsible for the best albacore fishing in a number of years off central and northern California. Water conditions were favorable, oceanic fronts important for the aggregation of albacore were close to shore, and weather conditions were generally good resulting in the best fishing conditions and catch rates for several seasons between Pt. Conception and Eureka, California. In coastal waters off much of Oregon and Washington, except for brief periods in local areas, e.g., off the Columbia River, Newport, Coos Bay, etc., albacore catches were generally low owing in large part to the lack of upwelling fronts to concentrate fish. Some of the best albacore fishing during the 1983 season occurred about 1,000 miles off northern Oregon, where a large fleet of boats made high catches for a number of weeks during August to late September. There was relatively good fishing in coastal waters off British Columbia for brief periods in the latter part of the season, as is usually the case.

The albacore fishing this year accurately reflected the albacore forecast prepared by Dr. Laurs and his staff at the SWFC's La Jolla Laboratory, in early June prior to the start of the 1983 season. In addition to the seasonal forecast, albacore fish bulletins detailing fishery information were issued biweekly by the investigations Staff.

Daily albacore fishing broadcasts were also made during the 1983 fish season, as they have been since 1967. In all 72 broadcasts were made this year over 9 radio stations, twice daily by Ron Dotson, Fishery Biologist, who prepared the broadcasts, based on information gathered from contacts with fishermen, fish buyers, fish processors and State agency personnel.

Development of the North Pacific Albacore Model

At the La Jolla Laboratory, Dr. Pierre Kleiber, Mr. Earl Weber, and Miss Susan Chivers are developing the North Pacific albacore model which is a

simulation model incorporating recruitment, growth of albacore among a set of subareas in the North Pacific, natural mortality, and harvest by three different major fishing fleets--Japanese baitboats, longliners (mostly Japanese), gillnetters and U.S. jig boats (includes some U.S. baitboats).

The population in this albacore model is divided into length categories instead of age categories which brings the predictions of the model more in line with the observed fishery data, which are catch at length. For a first cut, Kleiber, Weber, and Chivers divided the population into 10 cm fork length categories, beginning at 35 cm. (Albacore start becoming vulnerable to the fishery at around 35 cm). The seventh and largest size category includes fish 95 cm or larger. Few fish larger than 105 cm are caught.

Observed catch and effort data by month and monthly 1 cm interval size frequencies in the catch are available for three fleets (baitboats, longliners, and jigboats) for the years 1970 through 1977. For this model, the catches in the 10 cm categories described above have been calculated for each fleet and month from January 1970 through December 1977.

For comparison with the observed catch data, the model predicts catch for each size category and for each fleet as a function of time, which can be one month or multiple thereof. For larger time intervals the observed catch data must be aggregated into corresponding intervals. Catch of a particular size by a particular fleet is assumed to be proportional to the number of fish at large of that size and to the effort expanded by that fleet. The proportionality constants, "catchabilities," vary according to fleet and fish size.

In the model, fish graduate from one size category to the next according to the growth rate at the size which separates the two categories. The proportion graduating out of a size category per unit time is the growth rate (cm per unit time) divided by the width of the size category (10 cm in this case).

Fish are lost by natural mortality as well as by harvest and by graduation to larger size categories. The proportion dying "naturally" per unit time, M, is thought to be around 0.2 per year. No information about variation in M with size is known.

At year's end, the modelers had a non-environmentally driven version of the model working on a new 16-bit microcomputer using test data and hope to test the model further with the input of real albacore data on recruitment, growth, migration, mortality, and harvest.

The long term goal is to use the albacore model to investigate such questions as the degree of interaction among different fishing fleets. They also plan to integrate the albacore model with an economic model of the fishery to predict the possible effects of various fishery development and management decisions.

Experimental Verification of Daily Increment Formation on Albacore Otoliths

In many teleostean fishes the age of an individual may be estimated by counting the number of growth rings or marks deposited on scales, otoliths, or other calcified structures, and then dividing this result by the frequency of ring formation. Successful application of the method requires the development of criteria for identifying and interpreting the marks and experimental verification of their assumed frequencies. In tunas both problems are the subject of active research.

Dr. Michael Laurs and Robert Nishimoto of the La Jolla Laboratory and Dr. Jerry Wetherall of the Honolulu Laboratory recently completed an experiment which confirms the daily formation of increments on the sagittal otoliths of North Pacific albacore. The results are based on 106 fish which had been tagged, released, and recaptured up to 1,142 days later. The tagging was part of the joint NMFS/American Fishermen's Research Foundation tagging program. The smallest fish was 51 cm FL at release, the largest was 97 cm FL at recapture. The frequency of the fine increments on albacore otoliths was judged by placing a flourescent tetracycline marker on the growing edge of the otoliths at the time of tagging, and observing the number of new increments deposited on recaptured fish during the known period of liberty.

The researchers concluded that identifiable increments are deposited through some process with a daily rhythm. They also found that actual counts of "daily" marks on albacore sagittae may underestimate true age by about 5% due to systematic undercounting, erosion of marginal increments during sample preparation, or interruption of the ring formation process.

Age and Growth of North Pacific Albacore Determined from Tag Returns and Daily Increments on Otoliths

Despite extensive research using hard parts, length-frequency data and tag recapture statistics, biologists have been unable to determine the absolute age-length relationship of North Pacific albacore. Dr. Michael Laurs and Robert Nishimoto of the La Jolla Laboratory and Dr. Jerry Wetherall and James Uchiyama of the Honolulu Laboratory are investigating the albacore age-length relationship by the analysis of daily increments on sagittal otoliths and tag recapture statistics. They conclude that North Pacific albacore have an expected length of 35-38 cm at an age of one year, but that growth rates of older albacore differ between two hypothesized subpopulations.

In the present work, the SWFC researchers estimated the absolute ages of a sample of albacore by counting verified "daily" increments on sagittal otoliths. The frequency of the aging increments was established experimentally by tetracycline injection experiments. They then combined this information with tag recapture statistics on other fish to estimate parameters of the von Bertalanffy growth function and computed expected lengths at various ages for two groups of albacore. One consists of those fish

supporting the albacore fisheries in the eastern Pacific south of latitude 40°N, which they call the "south stock." The other is the albacore contributing to fisheries in the central and western Pacific and the eastern Pacific north of latitude 40°N (the so-called "north stock").

The estimated growth curves were used to interpret accumulated length-frequency data for albacore caught in the eastern Pacific by U.S. jig boats. In particular, inferences were made concerning birthdate distributions. If the growth models are correct, this analysis suggests that the hypothesized "north" and "south" subpopulations have birthdate distributions centered approximately 6 months apart.

Research Findings Made Concerning Albacore Using Satellite Imagery and Sonictracking

Drs. R. Michael Laurs and Paul Fiedler, Oceanographers, have recently completed a manuscript for publication dealing with the use of satellite imagery in albacore research studies involving the relationships between albacore and oceanic fronts.

The migration, distribution, availability and vulnerability of albacore to fishing are markedly influenced by oceanographic conditions in the north Pacific, notable hydrographic fronts. For example, albacore fishing grounds in the western Pacific have been linked to oceanic fronts in the region of the Kuroshio Current and Kuroshio Extension waters. Seasonal migration into North American coastal waters is associated with the Transition Zone and its frontal boundaries. Coastal upwelling fronts and fronts at the margin of river plumes influence local concentrations and movements of albacore in U.S. coastal waters. U.S. albacore fishermen traditionally fish in blue, oceanic waters warmer than 15°C and near fronts indicated by temperature or water color "breaks." Fishing grounds are often found associated with undersea topographic features, such as seamounts and banks, which are believed to be sites of local enrichment and food abundance.

Optimum temperature ranges for albacore catch have been determined from commercial or research vessel catches and sea surface temperature measurements. However, documentation of an association between albacore and thermal or color fronts has not been possible owning to the difficulty of obtaining concurrent catch and hydrographic data covering sufficiently large areas.

Since 1978 earth-orbiting satellites have the ability to rapidly provide data which yield images of sea surface temperature and mark the turbidity and phytoplankton pigment concentration of near-surface waters over large areas of the ocean. Some of these data are used to provide U.S. west coast fishermen with sea surface temperature and ocean color boundary charts. Drs. Laurs and Fiedler found that environmental features observed in satellite infrared and color images of the sea surface define boundaries for albacore aggregations and optimum fishing regions (indicated by daily catch data obtained from logboat records kept by U.S. jig fishermen).

The satellite images and concurrent albacore catch data clearly show that the distribution and availability of albacore are related to oceanic fronts. They also substantiate the conventional wisdom of many fishermen who use temperature and/or color "breaks" to locate areas of potentially productive fishing for albacore. The results show that in nearshore regions off the coast of North America commercially fishable aggregations of albacore are found in warm, blue oceanic waters near temperature and color fronts on the seaward edge of coastal water masses. Relatively intense fronts are favored, such as those associated with persistent upwelling; shoreward intrusions of oceanic water are also particularly favorable sites for albacore aggregation.

The results also show that in offshore waters during late summer commercial concentrations of albacore are found associated with hydrographic boundaries which are marked by color fronts detectable from satellites, but lacking temperature gradients. The availability of albacore in offshore waters appear to be higher in relatively productive waters. The temperature signature denoting the boundaries of the relatively more productive waters, if present earlier, may be lost due to seasonal warming. The color gradient pattern, however, is conserved.

Explanations for the environmental preferences of albacore are changing as new knowledge is acquired. Past studies stressed confinement to a physiologically optimum temperature range or utilization of frontal gradients for thermoregulation. Temperature by itself, however, cannot explain distribution of albacore observed off North America. Recent evidence based on acoustic tracking experiments conducted by Laurs and Dotson in conjunction with vertical temperature measurements show that albacore move vertically through the thermocline and experience temperature changes of 5°C or more in 10-30 minute periods.

Albacore are believed to migrate to exploit the high densities of food organisms available in North American coastal waters. Albacore are opportunistic carnivores and consume northern anchovy, saury, euphausiids, squid, and decapod shrimp off California. Suboptimum temperatures perhaps limit them to the edges of the productive coastal water mass where these organisms are most abundant. However, like all tunas, the albacore is a visual predator. The aggregation of albacore in clear water on the oceanic side of fronts in nearshore areas off North America may reflect an inability to capture large mobile prey efficiently in turbid coastal water and a dependence on food that has migrated or dispersed across the coastal-oceanic boundary. In offshore regions of the eastern north Pacific, the aggregation of albacore in relatively productive waters occurs presumably because relatively higher amounts of food organisms are present, yet the waters are clear enough for the albacore to detect them.

First Joint Albacore and Squid Assessment Cruise Completed

Many of the staff of the Oceanic Fisheries Resources Division at the La Jolla Laboratory participated in an 18-day at-sea sampling cruise aboard the NOAA Ship, David Starr Jordan, which ended September 2, 1983. The major

objectives of the sampling cruise were to sample the albacore population in several different depth strata with gillnets, sample the albacore population with trolled jigs, sample for various squid species, and collect biological data from specimens. Additionally, observations were made of birds and marine mammals along the cruise track.

Operations were conducted off southern and central California, generally in the vicinity of the commercial albacore fisheries. A total of 27 gillnet sets were made at depths ranging from the surface to 212 ft. Samples included squid, skipjack, and yellowfin tunas, bonito, four species of sharks, plus other fishes. No albacore, however, were taken by nets although surface trolling operations produced approximately 130 albacore plus skipjack and yellowfin tunas as well as bonito. Detailed biological data were taken from sampled fish, including gut contents, liver tissue, muscle tissue, otoliths, plus various measurements. Possible changes to sampling nets to improve their effectiveness are being evaluated.

Albacore Chromosome Study Underway

There is a growing body of evidence, including tag and recapture data, growth rate analysis, and difference in size composition of fish caught in the U.S. fishery, which supports the hypothesis that the North Pacific albacore is not a homogenous population but rather that there are at least two substocks. As part of the recent studies on North Pacific albacore stock structure, biochemical studies are being conducted to determine if there are genetic differences in the proposed substocks. These studies include chromosomal analyses conducted by Dr. Frank Ratty and Y.C. Song, a visiting scientist, at San Diego State University in collaboration with Dr. Michael Laurs of the La Jolla Laboratory.

Methods for culturing lymphocytes and separating the chromosomes for chromosomal analysis of albacore have been developed. The chromosome number has been determined (48), the chromosome morphology described and C-banding patterns have been determined. Studies are planned for the summer of 1984 to use multiple banding procedures to provide further information on chromosome characteristics. Chromosome karyotyping will then be used to ascertain if there are genetic differences between the proposed substocks.

Information on North Pacific Albacore Presented to Fishermen

During the past year Dr. R. Michael Laurs gave several presentations on the results of recent albacore research studies to fishermen's groups, including a Board of Directors meeting of the American Fishermens' Association and the general membership meeting of the Western Fishboat Owners Association in Reno, Nevada, in mid-November.

Highlighted in Laurs' talks was new information about the North Pacific albacore resource that was the result of the cooperative NMFS/AFRF albacore tagging program. Approximately 20,000 albacore have been tagged and released since the start of the program during the fall of 1971 and nearly 1,200 tagged

albacore have been recovered after being at liberty a few days to more than 5 years. Laurs discussed the impact of tagging results in the development of the U.S. distant water fishery in the western and central North Pacific, presented information on large-scale and small-scale migration patterns of albacore, explained the hypothesis that at least two substocks of albacore comprise the North Pacific albacore population instead of a single stock as was believed earlier, and provided detailed information on the age and growth of albacore.

SWFC Scientists Travel to Japan to Attend Albacore Workshop

From September 25 through October 1, Drs. Norm Bartoo of the Oceanic Division and Michael Laurs of the Coastal Division, traveled to the Far Seas Fisheries Research Laboratory in Shimizu, Japan, to attend the 8th North Pacific Albacore Workshop. During the workshop, 18 working papers were presented relating to the north Pacific albacore fisheries. All the attendees were Japanese except for the two SWFC scientists; no representatives from Canada or China attended.

In summary, the workshop participants concluded that catch-per-effort in all the major fisheries has shown a general declining trend since the early 1970's, even though total catch has declined some in the last few years. Production model analyses show MSY to be in the 90,000 to 150,000 mt range. The stock is still producing about 75,000 mt per year, although the distribution of the catch between fisheries is changing. The stock appears to be well-exploited. Remaining to be factored into the analyses are some indices of recruitment and effects of possible multiple stocks.

SWFC Scientist Participates in Joint Japanese-U.S. Tuna Research

In March 1984, Dr. Norm Bartoo, Fishery Biologist at the La Jolla Laboratory ended a 2-month joint research study on North Pacific albacore tuna with scientists at the Far Seas Fisheries Research Laboratory (FSFRL) in Shimizu, Japan. The unique research arrangement is a first for Center scientists who have maintained close links with the FSFRL for a number of years through their joint participation in the series of North Pacific Albacore Workshops.

Dr. Bartoo and his Japanese colleagues compiled an up-to-date data base on the North Pacific albacore, combining both U.S. and Japanese fisheries data, and then performed simulation analyses evaluating the adequacy of catch size frequency sampling, the first time a common and corrected data set for North Pacific albacore has been prepared. A production model analysis, including a Monte-Carlo simulation to evaluate the effects of errors in input data was completed and documented in a paper which Dr. Bartoo co-authored with T. Shiohama, FSFRL, to be submitted to the FSFRL fisheries journal.

During his visit Dr. Bartoo presented a talk at the Japan Tuna Conference on the U.S. albacore fishery and a seminar on application of the Monte-Carlo simulation technique to fisheries problems to scientists at the FSFRL. He prepared a manuscript on the U.S. albacore fishery for inclusion in the proceedings of the Japan Tuna Conference and conducted a production model assessment and investigation of longline catch-per-effort adjustment methods for Atlantic bigeye tuna stocks. With co-author S. Kume, Dr. Bartoo prepared a document for the upcoming meeting of the International Commission for the Conservation of Atlantic Tunas.

CENTRAL AND WESTERN PACIFIC SKIPJACK AND YELLOWFIN TUNAS

U.S. Tuna Fishing Effort Increases in the Central and Western Pacific

In 1983 the tuna catch by purse seiners operating in the central and western Pacific continued to increase. Based on several sources it is roughly estimated that more than 130 purse seiners operated in the region in 1983 and caught more than 300,000 metric tons of tuna. Fleets of the U.S. (65 purse seiners) and Japan (32 purse seiners) dominated the fishing activity. Other purse seiners engaged in the fishery included those from Korea, Taiwan, Solomon Islands, Fiji, Indonesia, New Zealand, and the U.S.S.R. The western Pacific purse seine fishery is being conducted in an area bounded by Guam to the north and New Zealand to the south, and Papua New Guinea to the west and Tahiti to the east. The tuna catch is composed primarily of skipjack tuna and lesser amounts of yellowfin tuna. Longline and pole-and-line fisheries are also active in this area. It is estimated that the longline fishery annually takes about 60,000 metric tons of tuna and the pole-and-line fishery about 100,000 metric tons of tuna. Thus, the estimated total catch of tuna in the western tropical Pacific grounds in 1983 probably exceeded 400,000 metric tons. This figure is conservative since it does not include tuna catches made by Philippine fishermen.

In 1982, about 24 American purse seiners participated in the western Pacific tuna fishery and made a total catch that has been estimated to exceed 100,000 metric tons. In 1983, the U.S. fleet was reported to be composed of 65 purse seiners, as noted earlier, which made an estimated catch of 150,000-175,000 metric tons. The participation of American purse seiners can be considered the culmination of earlier experimental purse seine chapters using Saltonstall-Kennedy funds. In the western Pacific fishing grounds American seiners not only set on the traditional "school fish" but also fish found under drifting logs and other flotsam. Projections are that 1984 will be an equally active, if not a more active year, for purse seining in the western Pacific tuna grounds.

Close Genetic Similarity of Atlantic and Pacific Skipjack Tuna Demonstrated

At the La Jolla Laboratory, Drs. John Graves, S.D. Ferris, and Andrew Dizon have written a paper (in press) which sets forth how they demonstrated the close genetic similarity of Atlantic and Pacific skipjack tuna (Katsuwonus pelamis) with restriction endonuclease analysis of mitochondrial DNA (mtDNA). Their paper, which is the first study of intraspecific mtDNA variation in fishes, presents evidence of possible gene flow between skipjack from the Atlantic and Pacific Oceans, and supports the findings of previous morphological and electrophoretic studies.

Skipjack, the authors note, are strong swimmers and, although definite migration routes have not been demonstrated, many tagged skipjack have been recovered thousands of kilometers from the site of first capture. As skipjack often travel in large schools, the potential exists for significant gene flow between ocean basins.

The authors write, "Genetic differentiation is promoted by reproductive isolation, a physical separation of populations, and a lack of migration between populations. Skipjack tuna do not have discrete spawning areas and larvae are found circumtropically in pelagic waters. Furthermore, seasonal isotherm data indicate that skipjack tuna have the potential to migrate around the Cape of Good Hope. Although it cannot be stated with any certainty just how much migration between ocean basins occurs, or has occurred in recent times, it would appear from the results of this study that there has been sufficient interchange to prevent genetic differentiation.

The techniques developed as a result of the skipjack study will now be applied to an investigation of albacore stock structure. Oceanographer John Graves has begun work on an analysis of albacore mitochondrial DNA. The project is planned in two phases: an investigation of genetic differentiation among albacore from different ocean basins and an analysis of mtDNA variability of albacore taken in the California coastal fishery.

Samples have been obtained from the U.S. Atlantic coast, South Africa, the mid-Pacific and the California coast for the inter-ocean basin study. Samples for the study of variability will be obtained from the 1984 albacore fishery off California. Results from these studies will be used to determine levels of intra-specific differentiation (stock structure) within the fishery.

IN SUPPORT OF DOMESTIC REQUIREMENTS

PACIFIC COOPERATIVE MARINE GAME FISH TAGGING

Record Number of Blue Marlin Tagged in El Niño Year

Under the auspices of the Cooperative Marine Game Fish Tagging Program, fishermen have tagged billfish to help fishery scientists determine the migration patterns and geographic limits of the populations of game fish in the Pacific Ocean. The Tagging Program, which began in 1954, is currently supported by the National Marine Fisheries Service in cooperation with the International Game Fish Association; James Squire, Fishery Biologist at the La Jolla Laboratory, coordinates the program, as he has from its beginning.

A total of 1,214 billfish was tagged in 1983, an increase from 1,002 in 1982. The total included 762 striped marlin (63% of the total), 191 sailfish (16%), 232 blue marlin (19%), 17 black marlin (1%), and 12 marlin of unknown species (1%).

Tagging of blue marlin was at an all-time record in the northeast Pacific, increasing from 2% of the total billfish tagged in 1982 to 19% in 1983. The exceptional numbers of blue marlin about the southern tip of Baja California, Mexico, during the El Niño year of 1983 appeared to be responsible for this increase in number of blue marlin tagged. The effects of the El Niño were also observed in the distribution of striped marlin off southern California. In 1983, 225 marlin were tagged off southern California, an increase from the 40-70 fish tagged in previous years.

Twenty-one billfish tags were returned to the La Jolla Laboratory in 1983, an increase over the 1982 total of 19. The total number of tagged fish included 19 striped marlin, one blue marlin, and one sailfish.

PACIFIC INTERNATIONAL BILLFISH ANGLER SURVEY

The amount of information available on the catch-per-unit effort (catch per angler day) for recreational billfish fishery is small when compared with the information available for the commercial fisheries. To obtain vital data, the Pacific Billfish Angler Survey has been conducted annually since 1969 to determine the trend in billfish catch per angler day for various locations throughout the Pacific. The information derived from this survey is then summarized by geographical area and species caught, and made available to anyone interested in the trend of billfish fishing. These data have been used by governments and organizations in the development of management plans for their billfish fisheries.

Interest in the trend of billfish catch rates in the Pacific has grown as a result of data collected by the Billfish Angler Survey. The declining trends during the 1970's in catch rate for species such as striped marlin and black marlin have concerned many anglers. In some areas of the Pacific, regulations have been implemented in an attempt to reverse these trends, and the angler survey may provide data relative to the future effects of such regulations.

From results of the 1982 billfish angler survey, 9,949 angler days in the Pacific and Indo-Pacific Ocean were reported; the total number of billfish (blue and black marlin, striped marlin, and Pacific sailfish) reported was 5,058. The total of angler days was a decrease of 1,201 from the 1981 total, which was 11,150. The total number of billfish caught in 1982 was an increase of 898 over the 1981 total, which was 4,160. The Pacific-wide billfish catch rate for 1982 was 0.51 billfish per angler day, or 1.96 days per billfish, an improvement over the 1981 rate (0.37 fish/day or 2.68 days/fish).

The 1982 catch rate for striped marlin caught off Baja California was 0.62 fish per day, which was an increase from the 1981 rate of 0.51 fish per day. The 1982 catch rate for striped marlin off southern California was 0.10 fish/day, a decline from the 1981 rate of 0.17 fish per day. The sailfish catch rate for Acapulco was 0.9 fish per day, although important sailfish fishing areas such as Panama recorded 1.1 fish per day and Costa Rica recorded 1.14 fish per day. The 1982 catch rate for black marlin was 0.5 fish per day, similar to the rates observed since 1978. The blue marlin rate was 0.19 fish per day, a slight increase from the 1981 rate.

1972 MARINE MAMMAL PROTECTION ACT

In implementation of the Marine Mammal Protection Act (MMPA) of 1972, the Southwest Fisheries Center conducts a program of research directed toward understanding the abundance and biology of dolphins associated with the purse-seine fishery for tunas in the eastern tropical Pacific Ocean (ETP). The objective of this research is to provide estimates of the status of stocks of these dolphins for use in preparing an environmental impact statement governing the taking of marine mammals associated with the fishery.

In 1983-1984 major activities included the conduct of a series of panels to review the SWFC's research results and the completion of a census of the dolphin populations. Review panel meetings were convened to review the scientific findings of the Center's research program. The panels, composed of experts in the biology of marine mammals and in the analytical techniques used in stock assessment, were from NMFS, other U.S. and international agencies, private consultants, and from academic institutions. The panels reviewed the results of the following research activities at the SWFC:

Research concerning the distribution of dolphins included studies to identify ranges of species, specific stocks or management units, and to discover possible relationships between distribution and environmental conditions. All sighting data were evaluated for accuracy to update previous distributional ranges of the principal species. Tag-return data and geographic variability in morphological characteristics were used to differentiate stocks. A correlation analysis was used to investigate the relationships between distribution of populations and levels of various oceanographic factors.

Research on vital rates for dolphins included studies on age determination and growth, reproduction, and the population dynamics of dolphin populations. Techniques of ageing dolphins using dental layers were improved and the calibration of layers using tetracycline labels described. The precision of age determination was investigated. Studies of reproduction of dolphins included analysis of trends and variability of reproductive rates. Aspects of reproduction of female spotted dolphin and reproductive maturity and seasonality of male spotted dolphin were investigated. Rates of increase in populations of cetaceans in general and the dynamics of population of spotted dolphin in the ETP were reviewed.

Research on abundance of dolphins included investigations dealing with species proportions, sizes of schools of dolphins, estimates of the density of schools, and estimates of abundance of dolphins. Species proportions by geographic area were developed. Techniques to estimate school sizes using aerial photography were evaluated. The effects of various sighting factors on estimates of school size, using sighting data collected aboard tuna and research vessels and from aircrafts, were assessed. The effects of observer ability and technique in sighting dolphins and the reaction of dolphins to the presence of a vessel were also evaluated. The density of schools of dolphin in the ETP was estimated using line-transect methods and the assumptions of the methods tested.

Studies were completed and reviewed on dolphin mortality, including estimation of the numbers of dolphins chased, captured, injured and killed incidental to tuna fishing in the ETP. The effects of factors associated with estimating mortality from observer data, such as the presence of observers aboard a tuna vessel, were also assessed.

In April 1983, the NOAA Ship, David Starr Jordan, completed a 90-day survey of dolphin populations in the ETP. Data on density, size and species composition of schools of dolphin were collected. The area surveyed included waters south of the Galapagos Islands, an area which had not been previously surveyed for dolphins by the Center. This area is approximately the southern boundary of tuna fishing with dolphins in the ETP and roughly the southern boundary of the distributional range for stocks of dolphin involved in the fishery. A total of 343 schools of marine mammals, containing approximately 13,000 animals, was sighted on this survey. During the survey, the Jordan was joined by the NOAA Ship, Surveyor, to investigate reaction of dolphin schools to the presence of a vessel. The experiment demonstrated that dolphin schools only occasionally react to the approach of a survey vessel, prior to their detection by shipboard observers.

Final Pre SOPS (Status of Porpoise Stocks) Meetings Held

During the past year, the staff of the tuna-dolphin program at the Center continued research directed toward a better understanding of the abundance and biology of dolphin associated with the U.S. purse seine fishery for tunas in the eastern tropical Pacific Ocean. The objective of this work is to provide estimates of the status of stocks of these dolphins for use in preparing an Environmental Impact Statement to be issued in conjunction with regulations governing the taking of marine mammals associated with the fishery in 1986 and beyond. Four panels were set up to review papers treating detailed aspects of dolphin biology in the following subject areas: 1) distribution of dolphin in the ETP, 2) vital rates, 3) abundance, and 4) mortality of these dolphin.

As a group of related papers on each of the four topics was completed, meetings of panels were convened to review the scientific merits of the research presented. Panels composed of experts in the biology of marine mammals and in the analytic techniques used were selected from NMFS, other U.S. and international agencies, private research organizations, and from academic institutions.

The following papers were presented at meetings of the Panels:

Distribution of Dolphins in the ETP:

Perrin, W.F., M.D. Scott, G.J. Walker, F.M. Ralston, and D.W.K. Au. Geographical ranges in four dolphins (Stenella spp. and Delphinus delphis) in the eastern tropical Pacific, with an annotated catalog of data sources.

Perrin, W.F., M.D. Scott, G.J. Walker, and V.L. Cass. Review of geographical stocks of tropical dolphins (Stenella spp. and Delphinus delphis) in the eastern Pacific.

Au, D.W.K. and W. Perryman. Dolphin habitats in the eastern tropical Pacific.

Reilly, S.B. Seasonality of dolphin distribution in the eastern tropical Pacific, from tuna vessel relative encounter rates.

Vital Rates of Dolphin Associated with the Tuna Fishery:

Myrick, A.C., Jr., A.A. Hohn, P.A. Sloan, M. Kimura, and D.D. Stanley. Estimating age from teeth of spinner and spotted dolphins (Stenella longirostris and Stenella attenuata).

Myrick, A.C., Jr., E.W. Shallenberger, I. Kang, and D.B. McKay. Calibration of dentinal layers in seven captive Hawaiian spinner dolphins, Stenela longirostris, based on tetracycline labels.

Reilly, S.B., A.A. Hohn, and A.C. Myrick, Jr. Precision of age determination of northern offshore spotted dolphins.

Hohn, A.A., and P.S. Hammond. Growth in the first year of the offshore spotted dolphin, Stenella attenuata, in the eastern tropical Pacific.

Barlow, J. Variability, trends, and biases in spotted dolphin reproductive rates.

Myrick, A.C., Jr., A.A. Hohn, J. Barlow, and P.A. Sloan. Reproduction in the female spotted dolphin, Stenella attenuata, from the eastern tropical Pacific.

Hohn, A.A., J. Barlow, and S.J. Chivers. Reproductive maturity and seasonality in male spotted dolphins, Stenella attenuata, in the eastern tropical Pacific.

Reilly, S.B., and J. Barlow. Rates of increase in delphinid cetaceans.

Barlow, J. and A. Hohn. Interpreting spotted dolphin age distributions.

Barlow, J. Biological limits on population growth in spotted dolphins.

Goodman, D. Uses of gross annual reproductive rate.

_____. Consideration of age structure in back projection.

Abundance of Dolphin Associated with the Tuna Fishery:

Barlow, J. and R. Holt. Geographic distribution of species proportions for dolphins of the eastern tropical Pacific.

Cologne, J.B., and R.S. Holt. Observer effects in shipboard sighting surveys of dolphin abundance.

Clark, W.G. Analysis of variance of photographic and visual estimates of dolphin school size.

Hewitt, R.P. Reaction of dolphins to a survey vessel.

Holt, R.S. Testing the validity of line transect theory to estimate density of dolphin schools.

Parks, W.W. The effects of various sighting factors on estimates of sizes of dolphin schools in the eastern tropical Pacific Ocean.

Holt, R.S. Estimation of density of dolphin schools in the eastern tropical Pacific Ocean using transect methods.

Cologne, J.B. and R.S. Holt. Observer effects in shipboard sighting surveys.

Polacheck, T. The distribution of searching effort by tuna purse seines in the eastern tropical Pacific.

_____. Analysis of the relationship between the distribution of searching effort, tuna catches and dolphin sightings within individual purse seine cruises.

Holt, R. Estimates of abundance of dolphin stocks taken incidentally in the eastern tropical Pacific yellowfin tuna fishery.

Polacheck, T. Encounter rates with schools of the spotted dolphin (Stenella attenuata) in the eastern tropical Pacific.

Dolphin Mortality:

Lo, N. and T. Smith. Incidental mortality of dolphins killed in the eastern tropical Pacific, 1959 to 1972.

Wahlen, B. and T. Smith. Observer effect on incidental dolphin mortality in the eastern tropical Pacific tuna fishery.

Parks, W.W. Rates, numbers per set, of dolphin chased, captured and injured in connection with the U.S. tropical tuna purse seine fishery in the eastern Pacific Ocean, 1977-1983.

TUNA BEHAVIOR AND PHYSIOLOGY STUDIES

Short-term Movements and Residence Times of Tunas Studied

A study of short-term movements and residence times of tunas around fish aggregating devices (FAD's) in Hawaii by the use of ultrasonic transmitters is being conducted by Dr Kim Holland of the University of Hawaii and NOAA Corps Officer Lt. (jg)J. Scott Ferguson.

Three yellowfin tuna, Thunnus albacares, and one bigeye tuna, T. obesus, were tagged with ultrasonic transmitters and tracked on the Honolulu Laboratory's Kaahele'ale. The first yellowfin tuna tracked was caught in September 1983, near a FAD off Oahu, Hawaii. This fish swam directly offshore for 5 hours and covered a distance of approximately 15 miles. The fish was lost when the directional hydrophone failed.

The second yellowfin tuna was caught near the 91 m (50 fathom) isobath a few miles off the coast of Waianae, Oahu at 9:55 a.m. on October 7. During the initial track, the fish was followed for 26 hours until it was lost directly off Kaena Point. The Kaahele'ale returned to Kaena Point about 12 noon on October 9. The fish was relocated and tracked until the following morning (October 10) when it returned to the vicinity where it was originally caught. After the Kaahele'ale returned to the Waianae Boat Harbor to refuel and exchange crews, a search for the fish was resumed late in the afternoon of October 12. The fish was again relocated near the Kaena Point-Makua vicinity and was tracked until the following morning when it again returned to the inshore area near the 91 m isobath where it was originally caught. The vessel was forced to return to Kewalo Basin on October 13 because of the threat of Hurricane Raymond. An attempt to relocate the fish was made October 19, but the fish had shed the transmitter, which was found near the 109 m (60 fathom) isobath in an area off the coast between Keaau and Kepuli Points.

This very successful mission resulted in three prolonged tracks spanning 6 days. Unprecedented data on yellowfin tuna's horizontal and vertical movements were acquired from the tracks. This yellowfin tuna showed a predictable behavior pattern that allowed it to be repeatedly relocated for days after it was originally caught. The fish appeared to have a definite "home range" that included the inshore 91 m isobath. It made significant excursions offshore (well offshore of the present leeward Oahu FAD locations) but returned to the 91 m isobath area at about the same time every day. Also, rapid dives to over 200 m were recorded. These behavior patterns revealed motor, physiological, and navigational abilities that were previously suspected but undocumented.

The third yellowfin tuna was caught at 7:00 a.m., November 17, immediately adjacent to fish aggregating buoy S which is located off the Waianae coast of Oahu. The fish remained in the vicinity of buoy S for only a short period and then proceeded along a relatively direct course to fish aggregating buoy V, which is located approximately 10 miles north of buoy S. The fish remained in the immediate vicinity of buoy V for approximately 7 hours, until it moved rapidly offshore (west) just before sunset. The fish was followed until approximately 7:00 a.m. the following day when the tag was shed. This track conclusively shows that yellowfin tuna will successively visit fish aggregating buoys that are up to 10 miles apart and that they have the ability to learn buoy locations and directly navigate from one buoy to another.

The bigeye tuna was caught the morning of February 29, 1984, near fish aggregating device S off Oahu. After the fish was released, it proceeded almost due west for the entire duration of the track. The track was terminated when the fish reached a point approximately 27 miles from Oahu. This is the second track of a bigeye tuna. The first track was in 1982 off the Kailua-Kona coast. The swimming depth behavior of this bigeye tuna was almost identical to that of the first bigeye tuna that was tracked. However, at one point this second fish demonstrated one of the most remarkable changes in depth ever recorded for tuna. The fish literally dropped from a depth of approximately 100 m to over 360 m in < 1 min.

Based on this work Dr. Richard Brill completed a manuscript, "Use of ultrasonic telemetry to determine the short-term movements and residence times of tunas around fish aggregating devices," for presentation at the Pacific Congress on Marine Technology. The manuscript includes a description of the tracking vessel, the ultrasonic telemetry, and computerized data analysis systems used for the tracking project. The paper was published in the conference proceedings.

Visiting Scientists Conduct Experiments at the Kewalo Research Facility

Three visiting scientists conducted various studies on the reproduction and physiology of tuna and other fish species at the Kewalo Research Facility (KRF). Dr. Frederick Goetz, Department of Biology, University of Notre Dame, investigated the possibility of using in vitro techniques to obtain mature eggs from the ovaries of recently landed skipjack tuna, Katsuwonus pelamis. The advantage of such a system is that eggs for tuna rearing experiments could be obtained more cheaply and reliably than by the current method, which requires that live skipjack tuna be brought back to the KRF to be spawned. In addition, an in vitro egg maturation system will permit close study of the timing, frequency, and hormonal control of egg maturation and spawning in tunas.

Dr. Goetz developed appropriate culture media, and matured and ovulated skipjack tuna eggs in vitro. These in vitro ovulated eggs were subsequently fertilized and embryo development was observed, but embryo development was not completed to hatching. Modification of the fertilization procedures will most likely enable the production of viable skipjack tuna larvae from in vitro matured eggs.

Dr. Calvin Kaya, Department of Biology Montana State University, developed techniques to induce spawning in manini, Acanthurus triostegus, a small reef species. The objective of the work was to produce fish larvae that could be used as live food for skipjack tuna larvae. Dr. Kaya was able to induce spawning via hormonal injection and to produce viable manini larvae. With the hormonal injection technique, manini larvae can now be produced at times appropriate for feeding skipjack tuna larvae.

Dr. Ian A. Johnston, Department of Physiology and Pharmacology, University of St. Andrews, Scotland, investigated the biomechanics and energetics of isolated muscle fibers taken from tuna. For comparative purposes, muscle fibers from mullet, jacks, and mahimahi were also studied.

Dr. Johnston and Dr. Brill completed a manuscript, "Thermal dependence of contractile properties of single skinned muscle fibers isolated from Antarctic and various Pacific marine fishes including skipjack tuna (Katsuwonus pelamis) and kawakawa (Euthynnus affinis)." The study deals with the maximum contraction velocity, maximum isometric tension, and the effects of temperature on these attributes of single, isolated, skinned, red and white muscle fibers. One of the significant discoveries from this study was that, for the skipjack tuna, the effect of temperature on the maximum contractile

velocity is much greater in red muscle fibers (Q10=3) than in white muscle fibers (Q10=2). However, at the same temperatures, the maximum contractile velocity of white muscle fibers was approximately six times that of red muscle fibers, which is an expected result because red muscle fiber portions of the myotomes are used at sustained swimming speeds and white fiber portions of the myotomes are used for high speed swimming. When the white muscle fiber portions of the myotomes are being used, the slower red muscle fiber would not be able to add any propulsive force to the fish's caudal fin because they would be moved passively by the more rapidly contracting white fibers. However, the 5°-7°C temperature difference that exists between red and white muscle fiber portions of the myotomes in skipjack tuna during bouts of high speed swimming, and the high temperature sensitivity of the contractile velocity of the red muscle fibers mean that the contractile velocities of red and white muscle fibers may be nearly identical during bouts of activity and that both may, therefore, be providing propulsive force to the fish's caudal fin.

In skipjack tuna, 25-30% of the muscle mass is made up of red fibers, compared with 5-10% in non-tuna teleost fish species. Therefore, it is obviously important that both red and white muscle fibers be actively providing propulsive force to the caudal fin when both muscle fiber types are active (e.g., during bouts of high speed swimming). This study provides unique new insights into the selective advantage of tuna's ability to maintain elevated muscle temperatures and into tuna's use of red and white fiber portions of the myotomes at different levels of swimming activity.

Physiological Study of Tunas Completed

As part of a study on lactate metabolism and acid-base regulations in tunas, a manuscript on "In vitro and in vivo acid-base regulation in the skipjack tuna (Katsuwonus pelamis): Effects of temperature change and exhausting exercise," by S.F. Perry, C. Daxboeck, R.W. Brill, P.W. Hochachka, and B. Emmett was completed. This study was designed to elucidate the causes of the conditions known as "burnt tuna" and "honey combing." The former is more prevalent in large yellowfin tuna and the latter in skipjack tuna, but both significantly reduce the commercial value of the fish in which they occur.

The objectives of this study were to determine how skipjack tuna regulate blood acid-base balance after producing high muscle lactate levels during strenuous exercise. The researchers also studied how an appropriate blood pH could be maintained in relation to rapid temperature change. Skipjack tuna (and other tuna species) are unique in that their blood is subjected to 2°-10°C temperature changes with each circuit through vascular countercurrent heat exchangers, or as these fish make rapid ascents or descents in the open ocean.

The study showed that skipjack tuna can somehow rapidly rid themselves of the excess hydrogen ions (created when lactic acid disassociates into lactate and hydrogen ions) and can, therefore, rapidly restore blood acid-base status. Also, it was clearly demonstrated that tuna have developed a unique system to

maintain appropriate blood acid-base status while undergoing rapid temperature changes. "Non-tuna" fish species take up to several days to restore blood acid-base status experiencing a rapid environmental temperature change because they adjust blood pH by regulating blood bicarbonate ion levels, which is a slow process that involves manipulation of an active ion exchange mechanism most likely located in the gills. Skipjack tuna, on the other hand, are able to take up or release (as appropriate) large quantities of hydrogen ions from hemoglobin or possibly other blood proteins. Skipjack tuna do not have to actively change blood bicarbonate ion concentrations to correct acid-base disturbances created by rapid temperature changes. Rather, blood acid-base status is adjusted rapidly by a unique chemical buffer system found in skipjack tuna blood.

Gill and Vascular Anatomy of Skipjack Tuna Studied

Dr. Richard Brill completed a series of experiments designed to elucidate the fine structure of the gill and general vascular anatomy of skipjack tuna. The work is being done in association with Dr. Ken Olson of the University of Notre Dame. The technique consists of completely filling the fish's circulatory system with a special, low-viscosity plastic. When the plastic hardens, the fish is literally digested away with sodium hydroxide, leaving a detailed replica of the fish's circulatory system. Preliminary examination of the vascular casts revealed several new structures that have previously not been described. These structures are what appear to be small countercurrent heat exchangers serving the white muscle, and complex structures branching off the efferent end of the first gill arch which are probably oxygen or blood pressure receptors.

Physiological Reactions of Tunas to Strenuous Exercise Studied

Dr. Richard Brill and Dr. David Jones of the Department of Zoology, University of British Columbia, have conducted a series of experiments designed to elucidate the physiological reactions of tuna to strenuous exercise. Dr. Brill and Dr. Jones have developed techniques to successfully anesthetize tuna with a water soluble anesthetic, insert catheters into the ventral and dorsal aortas, revive the fish, and return it to a holding tank. They then obtain arterial and venous blood samples from slowly swimming fish. This blood sampling technique permits the determination of normal blood oxygen, carbon dioxide, and pH (acid-base status) of tuna. The ultimate objective of this work is to determine the effects of strenuous exercise which may be relevant to the underlying causes of burnt tuna.

MISCELLANEOUS

SWFC Scientist Invited to Participate in FAO Project in Azores

At the request of FAO, Rome, Italy, Ron Dotson, Fishery Biologist, traveled to the Azores, and Rome, Italy, January 8-22, 1984, to design plans for a proposal to conduct alternative tuna fishing methods in the Azores as an FAO project. He spent 5 days in the Azores, escorted by Dr. Adolfo Lima, Regional Secretary of Agriculture and Fisheries, where he interviewed local fishery scientists and fishermen and examined vessels and facilities. Discussions included the availability of tuna and bait during winter, oceanographic and weather conditions and fishing gear. Scientists at the Universidad dos Azores agreed that they would attempt to conduct bathythermograph sections in prime fishing areas prior to the proposed fishing experiments.

The summary report of his survey visit and proposed project plan were submitted to FAO. The following, excerpted from the project proposal, provides the background and justification:

The Azores tuna fisheries and canning industry has suffered for years from a lack of a year-round supply resources due to a lack of skilled fishermen and adequate technology. The traditional tuna fishery operates from April through late September, when surface fishing success decreases and most of the work force is required to harvest the crops. The technology dominating the Azores tuna operations is pole and line bait fishing. Although the bait resource availability controls, to some degree, the seasonality of the pole and line fishery, changes in oceanographic conditions which reduce the availability of the tunas at the surface and subsequent decreased catches is the primary seasonal control. The Azorean tuna fishery is terminated when the catches for a vessel with a crew of 17 men drop below approximately 1 ton per day. This is coincident with the seasonal deepening of the thermocline in the autumn.

Recent developments in the North Pacific tuna fisheries for albacore and bigeye might be used to extend Azorean tuna fishing operations through much of the rest of the year. Over the past 3 years studies of a modified longline gear combined with fishing area and gear deployment strategies have shown that tuna may be caught effectively in times and areas where surface fishing success is minimal. The modified longline gear requires only 3-4 men to operate efficiently, is designed for vessels of 15-25 m, and is quite competitive when compared to Asian longlining methods which employ 18-25 crew members.

Behavior studies of several species of Thunnus, using ultrasonic tags to map depth distribution and horizontal movement, have shown that these species tend to aggregate around the thermocline and spend little time in surface waters. This is particularly true in the mid-ocean environment when the top of the thermocline is greater than 50 m in depth. By measuring the depth of the thermocline and effectively placing the fishing gear within that zone it is possible to increase longline catches dramatically. Recent tests have also indicated that catches can be further increased by using all monofilament gear rather than the more typical nylon or poly lines.

Using the gear and strategy described above it should be possible to effectively fish for tunas around Azores from autumn to spring. The vessels presently used in the surface fishery are adequately fitted and seaworthy and require only minor modifications to deploy longline gear and employ recent fishing area location techniques. The capability of using fewer crewmen would reduce the number of fish required to make a trip profitable, with catches of 1 ton per day considered sufficient. The probable addition of billfish to the longline catch would also open markets for a new product, with probable sales to mainland countries where these fish command high prices. In addition to longlining, trolling gear will be utilized during running time to supplement longline catches.

The findings from ultrasonic-tagged tuna, experimental albacore longlining, and longline gear development were all derived from past and recent research projects of the Coastal Eastern Pacific Fisheries Environmental Investigations at the La Jolla Laboratory of the Southwest Fisheries Center.

How Much Squid do Tunas Eat?--Food Habits Reviewed

A review of food habits studies of eastern tropical Pacific (ETP) tunas has been completed by biological aid Lisa Ankenbrandt emphasizing information on cephalopod forage and their importance to the predator. Ankenbrandt reports that cephalopods do not appear to be a predominant prey for tunas in the eastern tropical Pacific. Volumetric percentages of prey from all studies consisted of 65.4% fishes, 18.1% crustaceans, and 16.5% cephalopods. The predominant cephalopod families captured by tunas included Ommastrephidae (Ommastrephes bartramii, Dosidicus gigas, and Symplectoteuthis oualaniensis), Loliginidae, Argonautidae, Octopodidae, Onychoteuthidae, and Enoploteuthidae. Ankenbrandt examined variations in the diet, comparing cephalopod importance to that of fishes and crustaceans in terms of volume, numbers and frequency of occurrence. The percentage of squids to octopods was also compared.

The multiplicity of prey indicates that tunas are nonselective feeders and that stomach contents are probably determined by prey availability in any given area. Tunas and other higher trophic level predators could serve as more efficient samplers of fast swimming epipelagic fauna than conventional sampling gear. Comprehensive food investigations of these predators provide an alternative method of assessing cephalopod populations in the eastern tropical Pacific Ocean.

PUBLICATIONS

SWFC PUBLICATIONS ON TUNA AND TUNA-RELATED SUBJECTS

MAY 1, 1983 to APRIL 30, 1984

PUBLISHED

Brill, R.W., K.N. Holland, and J. Scott Ferguson. 1984. Use of ultrasonic telemetry to determine the short-term movements and residence times of tunas around fish aggregating devices. Pacific Congress on Marine Technology, University of Hawaii, Honolulu, April 24-27, 1984.

Brown, M. 1984. Counting dolphins: New answers to an important question. Sea Frontiers 30(2):68-75.

Dotson, R. C. and J. E. Graves. 1984. Biochemical identification of a bluefin tuna establishes a new California size record. Calif. Fish Game 70(1):62-64.

Klevezal', G. A. and A. C. Myrick, Jr. 1984. Marks in tooth dentine of female dolphins (Genus Stenella) as indicators of parturition. J. Mammal. 65(1):103-110.

In decalcified and hematoxylin-stained thin section, teeth of sexually mature female spotted dolphins (Stenella attenuata) often exhibit a deeply dark-stained layer (DSL) at the boundary of one or more of their annual growth layer groups. The authors compared DSL counts, made without reproductive information, to the corresponding reproductive condition in 75 females to test five hypotheses concerning the possible significance of DSLs. They found an exclusive association between DSLs and calving events. The teeth of an Hawaiian spinner dolphin, Stenella longirostris, labeled with tetracycline one month after giving birth to a calf in captivity, contained a dentinal DSL near the label. The number of DSLs in the dentine of a female probably indicates the minimum number of calves born to the female. In future studies DSL counts may be useful in estimating birth frequencies, year-specific birth rates, and calf mortality in odontocetes.

Kuz'min, A. A. and W. F. Perrin. 1983. The main features of the skull formation in dolphins (Cetacea) during the prenatal period. Zool. J. 62:102-112.

Data are provided on skull formation in the killer whale, common dolphin, spotted dolphin and long-snout dolphin during the prenatal period. A marked similarity in the skull development of these species serves as additional evidence of the earlier suggestion on monophyletic origin of toothed whales. The formation of skull vault bones in dolphins and sperm whales is subject to individual and interspecific variation and is similar

to that in the Theromorpha. The origin and formation of the mentomeckelian bone is first described in detail for the toothed whales. The problem of homologization of the skull vault bones in the toothed whales is also discussed.

Laurs, R. M. 1983. The North Pacific albacore--an important visitor to California Current waters. CalCOFI Rep. 24:99-106.

The North Pacific albacore, Thunnus alalunga, is a highly migratory species, valuable to domestic and foreign fisheries. Albacore are found off the west coast of North America from about central Baja California to British Columbia, Canada, from late spring through fall. U.S. fishermen traditionally harvested the resource with surface gear within a few hundred miles of the shore until the mid-1970's, when an increasing number of West Coast- and Hawaiian-based jig vessels began operating from slightly west of the date line eastward across the North Pacific. A U.S. longline subsurface fishery also appears to be developing during winter beyond 1200 miles off southern California. The albacore is also highly sought after along the U.S. west coast by a large number of sportfishermen.

At the present time none of the North Pacific albacore fisheries is under management. Statistics and analysis currently available indicate that the resource is healthy. Recent estimates of MSY range from about 92,000 MT to 166,000 Mt. Since the early 1960's, total catches for all fisheries harvesting albacore in the North Pacific have fluctuated; during the past decade they have ranged from about 70,000 MT to 124,00 MT.

Matsumoto, W. M., R. A. Skillman, and A. E. Dizon. 1984. Synopsis of biological data on skipjack tuna Katsuwonus pelamis. U.S. Dep. Commer., NOAA Tech. Rep., NMFS Circ.-451, 92 p. (FAO Fisheries Synopsis No. 136.)

This synopsis of biological data on skipjack tuna, Katsuwonus pelamis, includes information on nomenclature, taxonomy, morphology, distribution, reproduction, nutrition, growth, behavior, physiology, population structure, exploitation, and management of the species. Over 600 of the more important published and unpublished reports up to 1980, including some published in 1981, were consulted.

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Squire, J. L., Jr. 1983. Weight frequencies for striped marlin, Tetrapturus audax, caught off southern California. Mar. Fish. Rev. 45:63-67.

Yablokov, A. V., W. F. Perrin, and M. V. Mina. 1983. Evaluation of phenetic relations among groups of dolphins using analysis of non-metric cranial variation. Zoologicheskiy Zhurnal 62:1887-1896.

Non-metric variation of 31 characters was studied in 5 samples (185 skulls) of Stenella attenuata and in 2 samples (34 skulls) of S. longirostris from off the Pacific coasts of southern Mexico and Central America. The samples were compared using 15 characters found to be independent of sex and age. An integrative "index of similarity" (Zhivotovskiy, 1982) was calculated. Offshore samples of S. attenuata showed a high degree of similarity and differed sharply from a coastal sample. The two samples of S. longirostris differed more from each other than did any two of the samples of S. attenuata. The discriminative power of the characters is discussed.

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

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

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