

A REVIEW OF THE UNITED STATES SCIENTIFIC RESEARCH ON THE BIOLOGY AND
THE STATUS OF BLUEFIN TUNA STOCKS AND OF THE BLUEFIN TUNA FISHERIES

by

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SUMMARY

Results of the biological research and quantitative investigations by the U.S. Atlantic Bluefin Tuna Program during 1977 are summarized and combined with those of previous years to assess present projects and future research needs on the status of the U.S. bluefin tuna fisheries and of the stock(s) they exploit.

RESUME

Dans le présent document, les résultats de la recherche biologique et des études quantitatives effectuées par le "U.S. Atlantic Bluefin Tuna Program" en 1977 sont résumés, puis combinés avec ceux des années précédentes, dans le but d'évaluer les projets actuels et la recherche nécessaire à l'avenir quant à l'état des pêcheries américaines de thon rouge et du stock, ou stocks, qu'elles exploitent.

RESUMEN

Los resultados de la investigación biológica y estudios cuantitativos efectuados bajo el "Atlantic Bluefin Tuna Program" de Estados Unidos durante el año 1977, se resumen y combinan con los de años anteriores, con el fin de evaluar los proyectos en curso, así como la necesidad de investigar en el futuro sobre la situación de las pesquerías de atún de Estados Unidos y del stock (o stocks) que explota.

INTRODUCTION

The Atlantic Bluefin Tuna Program of the U.S. National Marine Fisheries Service continued its research on the life history and fisheries, as they relate to the management, of the North Atlantic bluefin tuna, Thunnus thynnus. Much of this research effort was in direct response to the recommendations of the Standing Committee on Research and Statistics (SCRS) of the International Commission for the Conservation of Atlantic Tunas (ICCAT) at the 1975 and 1976 meetings in Madrid.

REVIEW OF RESEARCH

The main recommendations of the SCRS for United States participation in bluefin tuna research and a brief summary of the Atlantic Bluefin Tuna Program's responses to them, follows.

- 1) Prepare a table on age structure. Many man-months of research were devoted in 1976 and 1977 to an analysis of sequential markings on otoliths and vertebrae to accurately determine age, especially in the older and more difficult to age fish. Preliminary results of this long-term study are presented in several working documents submitted to the SCRS.
- 2) Prepare an updated cohort analysis. The 1976 cohort analysis using 1973 and earlier data was extensively revised to include 1974 and 1975 data, particularly the data on longline catches in the Gulf of Mexico, which have not been used before in the U.S. cohort analyses. This newly revised cohort analysis is submitted to the SCRS as a working document.
- 3) Prepare a yield-per-recruit analysis. As part of the revised cohort analysis, an updated yield-per-recruit analysis is submitted to the SCRS.
- 4) Prepare production model and fishing-effort analyses. These and similar analyses have not yet been performed due to understaffing during nearly all of 1977 and to the time needed to prepare the cohort and the yield recruit analyses. However, these analyses are planned for completion in 1978.

Specific research projects of the Atlantic Bluefin Tuna Program, with a brief summary of results, are outlined below.

Age Determination (research by F. Berry and D. Lee)

Research efforts that began in late 1975 on solving the immense difficulties and intricacies of how to definitively determine age in bluefin tuna, despite their exceptionally small otoliths and much ringed vertebral cones, has continued with progressively better results, even though the problem is still far from solved. Proper age determination is, of course, a necessity to further refinements in the cohort analyses that provide our estimates of population numbers by individual year classes.

The study and analysis of otoliths is not yet complete, but the interpretation and correspondence of otolith bands with vertebral rings has become satisfactory on many specimens to an assigned age of 10 years, while the numerous bands on the otoliths of many large bluefin are hypothesized to be in part subannular. Using length and weight frequencies (that separate

most bluefin samples by month for ages 0 through 5) and stained vertebrae (a series of measurements and described interpretations of stained rings and elevated ridges) allow us to assign ages of bluefin from 0 through 10 years. The resolution of ages of older bluefin will probably result only from more detailed studies of otoliths and vertebrae from the same fish, and such studies in the Program are continuing.

The most important results of the studies to date are: 1) that western North Atlantic bluefin tuna grow faster and have greater variability of size range within each age group than recent estimates or calculations had opined or pronounced, and 2) because there is an overlap in size ranges of ages 1 through 10, an age assignment based on size alone is not without significant possibility of error.

An Atlantic Bluefin Tuna Ageing Workshop was held in New York City at the American Museum of Natural History in March 1977 (F. Berry, Convenor). An invitation to participate in this Workshop was sent through the Secretariat to all ICCAT member nations. Represented and participating were scientists from Canada, Morocco, Spain, and the United States. A working document has been submitted to the SCRS on the events and results of the Workshop (J. Hunt and P. Cahn, Editors). One of the papers in that document covers an analysis of vertebral techniques and variations by F. Berry. An additional working document has been submitted separately by this Program to the SCRS on ageing analyses of vertebrae and otoliths by F. Berry and D. Lee.

New techniques continue to be developed on preparation, observation and analyses of vertebrae and otoliths for ageing.

A contract to the Graduate School of Oceanography, University of Rhode Island, to test the feasibility of otolith and vertebral analyses by low-profile surface analyzers remains to be completed.

Sport Fishing Survey (research by F. Berry, P. Cahn, M. Holliday, and T. Boswell)

Coverage of the extensive and complicated sport fishery between North Carolina and Rhode Island was greatly improved and expanded during this third year of the survey through a contract with C.W. Post College of

Long Island University and by the cooperation with the Northeast Fisheries Center of the National Marine Fisheries Service. A detailed documentation of the hundreds of landings of the many thousands of private, party, and charter boats was prepared. The number of fish species surveyed for catch, effort, and size data was expanded to include all tunas and mackerels, billfishes, and sharks. For bluefin tuna, catches of school tuna in Virginia increased over 1975-1976, but remained relatively low in New Jersey and New York. Catches of giant tuna increased off New York (Montauk) and Rhode Island. To date bluefin tuna are being caught from New Jersey to Rhode Island. Biological sampling of bluefin tuna parts was reinstated in 1977, and valuable data were obtained for ageing, maturity, and other studies. A working document by F. Berry, P. Cahn, M. Holliday and T. Boswell on the sport fishery for school bluefin tuna has been submitted to the SCRS.

Biodynamics of Gulf of Mexico Atlantic Bluefin Tuna Spawning Populations
(research by F. Berry)

An analysis based primarily on as yet limited biological and catch data on Japanese longline vessels on the spawning grounds in the northern Gulf of Mexico from February through June 1977 has been prepared. Age estimates, maturity state, and size changes during the season are some of the aspects considered. This research was made possible through the generous cooperation of the Japanese Government and the captains and crews of several Japanese longline vessels in the Gulf of Mexico. A working document by F. Berry on this biodynamic data has been submitted to the SCRS.

Ichthyoplankton Sampling and Experimental Longlining in the Gulf of Mexico
(Research by R. Baglin, W. Richards, and I. Potthoff)

A cruise on the FRV Oregon II was conducted in the Gulf of Mexico, Yucatan Channel, and Straits of Florida from 29 April to 25 May 1977. The main objectives were to collect ichthyoplankton for tuna, billfish and dolphin (fish) distribution and population studies, and to obtain ripe bluefin tuna gonads for fecundity studies, as available.

Fifteen longline sets, averaging about 580 hooks, were made during the cruise period. On the longline, no giant bluefin were caught. However, several species of sharks and billfish were taken. Seven white marlin, one blue marlin, one blackfin tuna, and fourteen sharks were tagged and released.

There were 48 bongo and neuston tows and one stepped deep neuston net tow to 450 fathoms. Large numbers of bluefin tuna larvae were collected, primarily along the 1000 fathom curve. In general, the distributions of bluefin tuna larvae were found to be similar to those in previous years. An analysis of this ichthyoplankton data by W. Richards and I. Potthoff, has been submitted as a working document to the SCRS.

Bluefin Tuna Oceanography (research by F. Williams and M. Roffer)

A contracted pilot study was undertaken by the Rosenstiel School of

Marine and Atmospheric Science, University of Miami, to evaluate the feasibility of attempting a larger investigation on the correlations of physical and chemical oceanographic parameters with bluefin tuna catch statistics and biological data to assess historical changes in bluefin tuna distribution, abundance, and availability. Hopefully, such studies will lead to better predictability of bluefin tuna availability in the western Atlantic fisheries. The results of the pilot study, as reported by F. Williams and M. Roffer in a working document submitted to the SCRS, have been encouraging enough to warrant further pursuit.

Bluefin Tuna Parasitology (research by V. Walters)

One avenue of research seeking to determine the degree of distinctiveness of the eastern versus western Atlantic members of the Atlantic bluefin tuna populations is the study of the relative distinctiveness of the varieties of external and internal parasites from specimens of bluefin tuna from both sides of the Atlantic. The parasitic fauna of bluefin tuna from the eastern Atlantic and Mediterranean are relatively well-known in comparison to the paucity of published information for the western Atlantic. The parasite collecting program in the western Atlantic, begun by F. Berry in 1976, has led to an initial analysis of these parasites in a contracted report by V. Walters submitted as a working document to the SCRS, which discusses the composition, occurrence, and abundance of parasites obtained from several hundred school and giant bluefin tuna taken in the U.S. fisheries.

This research on bluefin tuna parasitology will continue with a comparison between western and eastern Atlantic faunas, as an aid to stock identification. Hopefully, this project will also lead to a better understanding of recently noted internal abnormalities of some giant bluefin tuna landed in New England.

Stomach Contents (research by M. Holliday)

A study was started in 1976 to collect stomach contents on a time-as-available basis from both school and giant bluefin tuna obtained from the U.S. fisheries. Both gross (for easiest means of identification of major groups of organisms being consumed) and microscopic (to identify certain digested remains) analyses of the recovered stomach contents are being made to better understand the variety of food items eaten by bluefin tuna. This information on prey organisms may lead, in conjunction with the oceanographic studies described earlier, to a firmer basis for predictability of the joint occurrence of bluefin tuna and its forage fishes and invertebrates.

Aerial Surveys (research by L. Rivas for Bahamas and by R. Baglin and B. Freeman for New England)

Aerial surveys for giant bluefin tuna migrating north in the Straits of Florida past the western side of the Bahamas were conducted in 1974, 1975, and 1976. Flights back and forth over a 1-mile tract, including a portion

of the main sport fishing grounds where giants are seen and caught, were flown for about 1-hour each day (weather permitting) during May and early June. The numbers of giants counted per hour were extrapolated for the 24-hour day and for a 50-day period encompassing the assumed typical length of the main migration in this region. These extrapolations indicate that the following minimal numbers of giants migrated past the narrow Bimini-Cat Cay tract on and over the edge of the western Bahamian banks: about 100,000 in 1974, 9,000 in 1975, and 25,000 in 1976, with the low numbers counted in 1975 possibly due, at least in part, to weather conditions leading to poor visibility. A working document by L. Rivas discussing these matters has been submitted to the SCRS.

A decision was made to shift the aerial survey in 1977 to New England as a feasibility study on the difficulties that would be encountered in attempting to survey the occurrence and relative abundance of schools of migratory and feeding giants in the vastly greater spaces of Cape Cod Bay and the Gulf of Maine. These waters are less clear and there are more often inappropriate weather conditions than had been our good fortune in the limited migratory region of clear water and usually fair weather in a 1-mile tract off the western Bahamas. The New England aerial surveys began during June with flights up to 70 miles offshore, in an attempt to detect a northward movement of giant bluefin. However, no such migration was detected. The survey continued from July through October with inshore flights from Cape Cod (Massachusetts) to Grand Manan (Maine) close to the Canadian border. Giants were sighted during each month of the survey, especially in the area of the Stellwagen Bank between Cape Cod and Cape Ann, Massachusetts. The aerial survey is being closely coordinated with a color-coded-streamer tagging program in conjunction with the Northeast Regional Office of the National Marine Fisheries Service. This year's data will be analyzed in the near future and a working document on it submitted to the SCRS in 1978.

Spawning, Age at Maturity and Fecundity Studies (research by R. Baglin)

The intensive work during 1976 on the reproductive cycles of bluefin tuna continues, for data of these matters are of particular importance to increasing refinements of estimations of population numbers based on cohort analyses.

Giant bluefin tuna gonads were collected during May from Japanese longliners in the Gulf of Mexico and from sport-caught fish from the Bahamas, while from June through September gonads were collected from giants taken by the Gulf of Maine handgear fishery. Gonads were also collected from smaller fish (1-6-year-olds) taken by purse seiners during June and July off the Virginia coast and by the sport fish survey. This biological sampling was only possible because of the generous cooperation of the Japanese longliners, American sport fishermen and American commercial fishermen by angling, handgear and purse seines.

Gross examination of giant and small bluefin gonads has been conducted. Of particular interest are some of the gonads from the Gulf of Mexico,

which appear to be approaching a ripe stage, and gonads from small fish from off Virginia, which also appear to be mature. Histological examinations will be conducted to more accurately determine the stage of maturity of fish that have been collected, and valuable information will be obtained on the age at maturity and fecundity at age. It is expected that a working document on these recent findings will be presented to the SCRS in 1978.

Electrophoretic Biochemistry (research by H. Thompson and R. Farragut)

One of the newer approaches to stock identification in bluefin tuna is the use of electrophoresis. The settling out on starch gel of fractions of proteinaceous enzymes from various tissues, such as muscles and liver, can often show differences in subpopulations of the same species, including, in the present case, possible differences between western and eastern Atlantic samples of bluefin tuna. To be relatively sure that the specimens being sampled from the eastern and western Atlantic were spawned in those respective areas, only 0 or 1-year-old fish are used for the analyses.

Although it has been possible to obtain the 70 young school tuna that are necessary for the statistical validation of the sampling from the western Atlantic through the gracious cooperation of American purse seine vessel operators, difficulties have been encountered in obtaining 70 eastern Atlantic 0 or 1-year-olds because of problems of availability and because they must be preserved in ice and air-freighted, still frozen, to the Miami Laboratory. To date, only 17 specimens have been obtained, through the cooperation of the Moroccan Government and J. Mason of the Woods Hole Oceanographic Institution. Extensive arrangements have been made recently with several Spanish and French fisheries colleagues by L. Rivas of this Program to procure the large number of specimens still needed; we are hopeful that such can be accomplished in the near future.

In the interim, the biochemical analyses conducted to date have led to a preliminary report submitted to the SCRS by H. Thompson and R. Farragut describing the techniques and experimental design of the electrophoretic stock identification studies in progress, and discussing the accomplishments and observations of this research. These include the finding that the liver tissue of 1-year-old western Atlantic bluefin tuna has four variable enzyme systems out of the 23 enzymes that were examined.

Models of Annual Life History Cycles (research by L. Rivas)

The life history of the bluefin tuna is immensely complex to us, in large part because it is a highly migratory species of great longevity and wide-ranging distribution that has not yet been adequately investigated. Much remains to be discovered about its habits and way of life and most of what is known is found in widely scattered popular and scientific literature. Thus, we feel that it is advantageous to collate concisely and pictorially as much of this life history data as possible in one article, summarizing what is and is not known about these complex cycles, as an aid to administrators, fishery biologists, and others, interested in the

management of the bluefin tuna resource.

Thus, the available information of the spawning, migratory, feeding, physiological, and ethological cycles of the Atlantic bluefin tuna was extracted from the literature and from unpublished research data. These data were analyzed and summarized by annual cycles for giant, medium, small, and young-of-the-year fish. The results are presented in a working document submitted by L. Rivas to the SCRS.

Natural Mortality Rates (research by L. Rivas)

The natural mortality rates, as opposed to fishing mortality rates, of various classes of bluefin tuna are not precisely known. For giant fish, there is some indication that some post-spawning females may be subject to increased natural mortality during their migration from the Gulf of Mexico breeding grounds to the New England feeding areas. This possibility is under investigation by L. Rivas in consultation with G. Sharp of the Inter American Tropical Tuna Commission, La Jolla, California.

Sex Determination (research by M. Lange)

An attempt has been made to quantitatively substantiate previous field testing for sex determination by external examination of the vent. The proportions considered indicate little statistical difference in shape alone.

Size Frequency Per Set of Purse Seiner Catches (research by R. Baglin)

A special effort was made during the 1976 and 1977 purse seine school tuna seasons to obtain more extensive data than had previously been available on the size frequencies of the fish in catches in individual sets of the nets to better ascertain the degree of mixing of the age groups most often encountered in school tuna (ages 1 to 4). Most of the length measurements were taken from fish that were being tagged and released with the assistance of the purse seine vessel captains and crews.

Between the efforts of 1976 and 1977 to record the sizes of fish by individual sets and similar efforts in 1974, 5,601 fish were measured (fork length) from 88 sets from July to September. We have now established, statistically, that 1-year-olds often school together almost exclusively, with little mixing with other age groups. Two and 3-year-olds, however, were frequently found to be mixed, and 4-year-olds were often mixed with 2- and 3-year-old fish. In other words, there is great heterogeneity of mix of ages 2 through 4, while the greatest homogeneity is with age 1. A working document by R. Baglin with the details of this extensive study has been submitted to the SCRS.

Tagging (research by R. Baglin, in conjunction with the Woods Hole Oceanographic Institution)

Five members of the Atlantic Bluefin Tuna Program of the Southeast Fisheries Center and one member of the Woods Hole Oceanographic Institution tagged and released approximately 120 1-year-olds, 1,527 2-year-olds, 8 3-year-olds and 17 4-year-olds, as well as recapturing and re-releasing about 25 bluefin that had already been tagged and released. This tagging was

done with the cooperation and assistance of the captains and crews of the vessels in the U.S. school tuna purse seine fishery under authority of purse seine tagging quotas, after the open purse seine season had been closed.

The Atlantic Bluefin Tuna Program has microfilmed all of the Woods Hole Oceanographic Institution tagging release data since 1954, and approximately 50% of this historical data has been computerized so that it can be far more fully and extensively utilized and analyzed than possible before. This project should be completed in 1978, and research analyzing the masses of data accumulated in recent years by the Southeast Fisheries Center will be used for future working documents to be submitted to the SCRS. In the interim, a working document by R. Baglin, J. Mason, F. Mather and B. Freeman has been submitted to the SCRS updating the tag return data previously reported.

Flank Scars (research by L. Rivas)

The crater-like scars found on the flanks and anal regions of giant bluefins, believed to be caused by a small shark, are found on western Atlantic and northern European specimens, but they are less common on specimens from the Bay of Biscay to the Mediterranean. The significance of this geographical difference in the occurrence of scars and the potential use of it in tracing migrations is being pursued further on a time-as-available basis.

Quantitative Investigations (research by W. Schaaf and L. Rivas)

The current quantitative investigations include cohort and yield-per-recruit analyses and simulation studies predicting the effects of regulating Atlantic bluefin tuna fisheries by various methods on an Atlantic-wide as well as a western-Atlantic-only basis. The present cohort analysis considerably updates the previous analyses submitted to the SCRS by the Atlantic Bluefin Tuna Program, especially by taking into consideration for the first time the extensive longline data from the Gulf of Mexico available through the Fishery Agency of Japan.

In essence, the present cohort analysis was conducted to estimate age-specific fishing mortality rates and population sizes over a 16-year period. Fishing mortality rates (F) estimated for the total Atlantic stock changed significantly in recent years. The population seems unable to sustain the estimated F's and all segments (small, medium, and giant fish) have been declining at about 12% per year. Recruitment at age 1 has remained relatively constant at about 1,000,000. The yield-per-recruit under current fishing rates of about 4.9 kg can be increased to about 13 kg, on a sustainable basis, by setting a size limit equal to 16.6 kg (about age 3) and decreasing mortality rates by one-third. Similar analyses were conducted for a hypothetical western Atlantic stock. All three segments of the population have been declining similarly, in view of similar recent F's. Moderate regulations can increase the Y/R by 103%,