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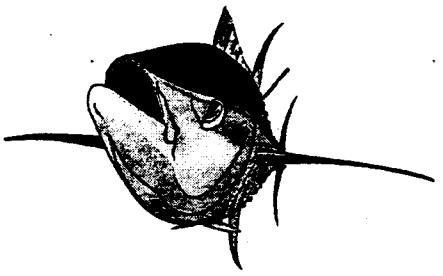
Bigeye Tuna: Five-Year Research Plan
A Prospectus for Coordinated International Research



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Bigeye Tuna: Five-Year Research Plan

A Prospectus for Coordinated International Research

Executive Summary

This Prospectus outlines an ambitious plan to address scientific uncertainties regarding bigeye tuna populations in the Pacific ocean, a resource conservatively estimated to be worth US$1,500,000,000. It envisages a cooperative international research effort that would involve the participation of major tuna research institutions in the Pacific. The Pelagic Fisheries Research Program offers its services as research facilitator and to expand its field research in the United States Exclusive Economic Zone in the central Pacific ocean.

The deployment of 1000 advanced electronic tags on bigeye tuna by 2001 is an integral component of the plan. Large-scale deployment of these encourages further development of advanced electronic tags by actually testing the current generation of tags in the field, enables producers of electronic tags to commit to further research and development, and encourages participation of other research institutions by underwriting a major cost item. The data obtained from these devices will fill major gaps in the understanding of the movements of bigeye tuna at all spatial scales.

The intent of this prospectus is to:

- invite collaboration of scientists from all interested regions and all pertinent disciplines, and
- assist potential collaborators for use in soliciting financial support.

Introduction

Importance of Bigeye

Bigeye tuna have been a primary target of longline fleets since the introduction of the "deep" longline technique by Japanese fishermen in the 1960s. Its importance to Pacific longline fleets has grown in the 1990s as the number of new participants in the longline fleet increases. Viability of these fisheries depend critically on the continued abundance of bigeye tuna and high catch rates. Newly developed fleets in Pacific island states are particularly vulnerable to declines in bigeye catch rates.

Region	Bigeye Catch (mt)[†]
Eastern Pacific Ocean	40,000
Western Pacific Ocean	31,000
Coral Sea - NE Australia	250
French Polynesia	1,100
Hawaii	2,200
Total	75,000

The estimated total longline catch in the Pacific is approximately 75,000 metric tonnes. The value of this harvest is difficult to estimate accurately since prices depend on the quality of the fish and the markets in which they are sold. Using a conservative estimate of US$20 per kg for sashimi grade tuna, the total value of Pacific longline bigeye harvest approaches US$1,500,000,000.

Less than 0.1% of this value is expended on research and management of this resource.

Recent Changes in Bigeye Tuna Harvesting

Increased targeting by surface fisheries

Purse seine operators in both the Eastern Tropical Pacific (ETP) and the Central and Western Pacific Ocean (WPO) have developed methods to harvest bigeye

[†] Estimates of total catch compiled from various sources cited in the References section of this document.

tuna in surface aggregations. These methods depend on the tendency of juvenile bigeye to aggregate around floating objects and consist of predominantly juvenile fish and. Scientists from the Inter American Tropical Tuna Commission (IATTC) estimate that the purse seine catch of bigeye in the ETP has grown from 5,000 mt in 1992 to over 50,000 mt in 1997. In the western Pacific, scientists for the South Pacific Commission (SPC) estimate the catch of bigeye tuna by the United States purse seine fleet in 1997 to be approximately 23,000 mt. Catches by purse seine fleets from other nations are likely to be similar, but the data are not yet complete.

Hawaii

During the late 1980s and 1990s, troll and handline fishermen developed a fishery for juvenile bigeye and yellowfin tuna around the offshore seamounts in the Hawaiian archipelago. The annual catch of bigeye at Cross Seamount is approximately 500 mt. In absolute terms, this fishery is not large, but a small number of vessels harvest a considerable tonnage of fish in a small area

Decline in ETP CPUE

The catch per unit of effort (CPUE) of bigeye by the longline fleets in the ETP increased throughout the 1980s, but has declined to previous low levels in recent years. These declines appear to be matched by declines in "indices of abundance", intended to "correct" CPUE for seasonal variability and changes in gear technology. Similar declines are not yet detectable in the WPO but are expected as the level of juvenile harvest of bigeye by surface fisheries increases.

Timing of Research

The decline in longline CPUE for bigeye in the ETP has caused considerable concern about possible effects of surface harvests on the bigeye population accessible to longline gear. Analyses by the IATTC demonstrate that the potential adverse consequences of purse seine harvest on longline yield could be significant. The Precautionary Approach requires conservation measures be imposed even if there is no hard scientific evidence that a problem exists. The Inter-American Tropical Tuna Commission is currently considering precautionary restrictions on purse seine harvests in the ETP.

Multilateral High-level Consultation on Management of western and central Pacific Ocean Highly Migratory Species (MHLC) has requested that the Standing Committee on Tuna and Billfish consider precautionary reference points appropriate for the management of highly migratory species in the WPO. A two day workshop on "Precautionary reference points and their relevance to Western and Central Pacific Ocean tuna fisheries", will take place in May 1998.

The MHLC process will almost certainly create a new arrangement for the management of fisheries for highly migratory species in the western and central Pacific ocean in 1999.

Nineteen-ninety-eight has been designated the Year of the Oceans by the United Nations.

These events argue strongly that *now* is the appropriate time to begin a large scale international effort to improve our scientific understanding of bigeye tuna.

Purpose of this Document

This prospectus presents an outline for a Pacific-wide international collaborative research program intended to address the information deficiencies surrounding bigeye tuna (*Thunnus obesus*). The document serves two purposes:

- to encourage collaboration of scientists from all interested regions and all pertinent disciplines, and
- as aid to potential collaborators for use in soliciting financial support.

Interested colleagues should feel free to offer changes to this prospectus that would both improve the research and enable their participation.

General Scientific Background and Issues

A recent genetic analysis of bigeye populations (Grewe and Hampton, 1998) was unable to detect major subdivision population the Pacific ocean. It is likely that the bigeye population in the Pacific ocean consists of a single genetic stock and that exchange rate of individuals between areas is sufficiently high to eliminate regional genetic differences.

Analysis of bigeye movement is therefore a critical subject. Few large-scale studies of bigeye movement have been undertaken. The South Pacific Commission tagged and released about 8,000 bigeye during 1990-92. These results (Hampton, *et al.* 1997) provide the most comprehensive data from which to deduce movement patterns and mortality rates for bigeye. Bigeye are clearly capable of long-distance movement; 25% of the observed displacements were greater than 200 Nmi and 5% greater than 1000 Nmi. Two fish tagged off the northeast coast of Australia in the Coral Sea were recaptured near 130°W. On the other hand, a considerable number of bigeye were recaptured at the release site after more than 5 years at liberty. See Figure 1. Site fidelity appears to be an important feature of bigeye life history. Indeed, preliminary results of a PFRP-sponsored tagging study at Cross Seamount (K. Holland, pers. com.) demonstrate clearly that bigeye show a much longer residence period at the seamount than do the yellowfin.

The impact of large catches of juvenile fish on subsequent catches of mature fish depends strongly on mortality rates. Estimates of natural mortality based on the SPC bigeye tagging data (Hampton, *et al.* 1997) show order of magnitude differences in estimates of both fishing mortality and natural mortality rates. Similar uncertainties in mortality rates plague attempts at age structured population analysis in the ETP (IATTC, 1997). No age-dependent estimates of natural mortality are available.

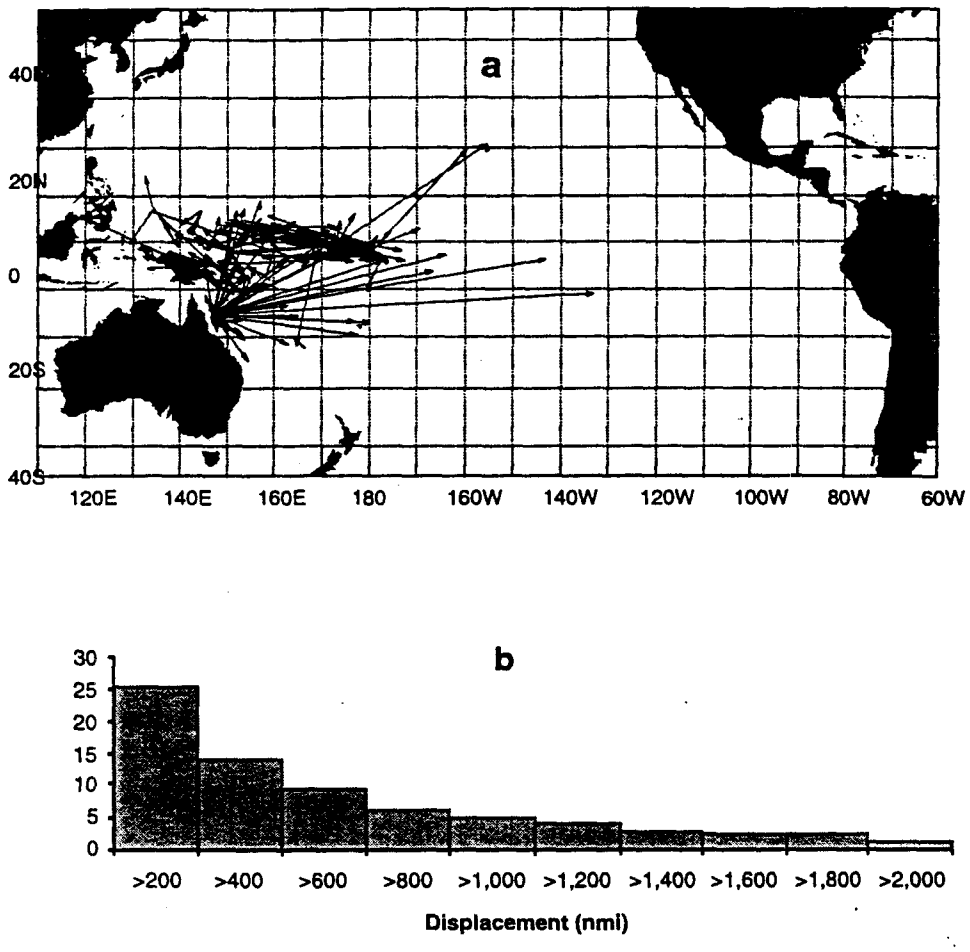

Figure 1. **a.** Long-distance displacements (>100 Nmi) of bigeye tuna tagged by the SPC Regional Tuna Tagging Project (RTTP) between 1990 and 1992. **b.** The cumulative distribution of all RTTP tagged bigeye displacements having accurate location data.

Mature bigeye occupy deeper water than most other tropical tunas. Preference for deeper water has provided the opportunity for longliners to target bigeye tuna by setting their hooks deeper and may be related to enhanced ability to extract oxygen from the colder water found at these depths (Brill, 1997). Juvenile bigeye, on the other hand, form aggregations near floating objects and seamounts. This behavior has provided the opportunity for purse seiners, armed with "deep" purse seines, improved electronics and techniques to "coax" bigeye into shallower depths, to target bigeye by setting their nets around floating objects. Variability in behavior thus makes bigeye vulnerable to different fishing methods at different phases of their life history.

The tendency for bigeye tuna to form large and persistent aggregations has only recently come to the attention of fisheries researchers (although fishermen appear

to have been aware of it for years). The functions of these aggregations are unknown (as they are for most tunas).

Indices of abundance are often used to asses the condition of tuna stocks. These indices attempt to "correct" reported catches for variation in fishing intensity, seasonal variability, gear efficiency and other variables suspected to influence catch. The most common used index of abundance is catch per unit of effort or CPUE. Several more sophisticated indices are often applied. The bigeye abundance indices for the eastern and western Pacific show different trends. The CPUE in the eastern Pacific had declined sharply during the 1990s whereas the CPUE in the western Pacific has been nearly constant over the same period of time. It is not known whether any index of abundance is actually proportional to the population of fish.

General Scientific Objectives and Approaches

Determine Exchange rates within and between regions

Tunas move both between regions and between fishing grounds within regions. Tagging studies provide the most direct means of estimating these movements. Conventional tagging yields quantitative estimates of rates of population exchange within areas of a few hundred km in linear extent. Other tagging techniques, using more sophisticated electronic devices, may provide more detailed information as well as information about longer movements.

Estimate age-specific mortality rates

Mortality due to fishing and other causes is sharply age dependent. Very young fish and very old fish appear to die of "natural" causes at higher rates that fish of "middle age". Different gear types select fish of different sizes and ages. Conventional tagging experiments have proved to be very useful in estimating age-specific mortality rates in skipjack and yellowfin (SPC, 199?).

Uncertainty about mortality is exacerbated by uncertainty about age and growth. Recent tag recaptures from the SPC bigeye releases in the Coral Sea indicate that bigeye may live longer and grow more slowly than expected.

Analyze the role of aggregation in bigeye life history

Tunas form a variety of aggregations — feeding, spawning, "social" —, and the phenomenon appears particularly important for in bigeye. Furthermore their propensity to form aggregations makes them particularly vulnerable to various type of surface-fishing gear. Basic biological field sampling of gonads and stomach contents would provide valuable insights into importance of reproduction and feeding in the formation of aggregations. Such sampling should also tailored to determination of time, area, and frequency of spawning. Tracking studies of individual fish in aggregations could provide valuable information on the rate of at

which individual fish enter and leave the aggregations. Methods should be developed to enable automated tracking of individual tunas in aggregations.

Determine how oceanographic features mediate movement

Oceanographic features mediate tuna movement and abundance on many scales. The depth of the thermocline and oxygen content of the water constrain their vertical distribution. The El Niño phenomenon determines the eastward and westward extent of some populations (Lehodey, *et al.*, 1997). Although a great deal is known about bigeye physiology, how physiology translates into behavior is not known. Geolocating archival tags are a promising tool to explore this dependency.

General approaches

All of these issues can be addressed by suitably designed tagging experiments. Conventional tagging can be combined with a suite of advanced electronic tracking devices to provide a powerful tool to address issues of movement, mortality and behavior. Tagging data on bigeye at the South Pacific Commission can be used in computer simulation models of tuna populations to assist in designing the most appropriate experimental designs.

Projcet Structure

Organization

A research project on the entire Pacific-wide bigeye population is beyond the means of most research institutions to implement. Furthermore, specific scientific research goals will vary between regions. Under the proposed plan, research institutions in different regions would deploy research assets locally in a coordinated way to achieve global goals.

Activities of collaborating research groups will be loosely coordinated by scientists involved in research on Pacific bigeye tunas. Several existing groups could form the nucleus of a coordinating group. For example, the Standing Committee on Tuna and Billfish Bigeye Research Group and the *ad hoc* bigeye research group periodically convened by the Inter-American Tropical Tuna Commission include scientists from most areas of the Pacific. Research coordination would be ensured by convening regular, perhaps semi-annual, workshops of collaborating researchers to discuss progress, preliminary results, and research plans.

Role of Pelagic Fisheries Research Program

The PFRP is a research facilitator rather than a research organization with a staff of researchers. The PFRP facilitates research by providing funding to researchers through competitive awards and by fostering communication between researchers from different disciplines and different institutions. The Program has sponsored over

35 different research projects since 1992 on all topics pertinent to fisheries for highly migratory species. Although many of these projects have concerned fisheries in Hawaii and other parts of the United States Pacific Exclusive Economic, many others have addressed Pacific-wide scientific issues. In addition, the PFRP has sponsored two interdisciplinary conferences devoted to research on pelagic fish in the Pacific and implications of research results for fishery management policy. By drafting this prospects the PFRP is offering to continue its role as facilitator in a research program of Pacific-wide importance.

PFRP Bigeye Related Projects

The PFRP has already sponsored or cosponsored a number of projects concerning bigeye tuna. The following projects are either explicitly or implicitly directed to bigeye tuna.

1) Laboratory and field research to enhance understanding of tuna movements and distributions, and to improve stock assessment methods. Principal investigators: R. Brill, G. Grau, K. Holland.

2) An assessment of bigeye tuna (*Thunnus obesus*) population structure in the Pacific Ocean, based on mitochondrial and microsatellite DNA variation. Principal investigators: J. Hampton, P. Grewe.

3) Investigation of Pacific broadbill swordfish migration patterns and habitat characteristics using electronic archival tag technology. Principal investigators: C. Boggs, J. Gunn. (This project will deploy archival tags on bigeye tuna in feasibility tests.)

4) A tag and release program for the Hawaiian seamount yellowfin and bigeye tuna handline and troll fisheries. Principal investigator: K. Holland.

5) Hawaii regional tuna tagging project. Principal Investigators: K. Holland, D. Itano. (This project is an extends the scope of the seamount project and will emphasize bigeye throughout the main Hawaiian islands.)

New PFRP Initiatives

If there is sufficient interest in this Prospectus from the international research community, the PFRP will seek additional funding for specific purposes:

- To enlarge the geographical extent of the Hawaii regional tuna tagging project to include more of the central Pacific ocean. The expanded tagging area will include Midway, Wake, Johnston, and Palmyra Islands.

- To will establish a special fund to promote the development and eventual deployment of 1,000 advanced electronic tagging devices. These devices will be supplied to project collaborators for deployment in different regions. This initiative will be expanded below.

- To help finance participation in research coordination workshops.

Timing

1) Late 1998. First meeting of coordinating group. This meeting could be convened in Honolulu in conjunction with normal PFRP activities, in La Jolla with the *ad hoc* bigeye research group hosted by the IATTC, or at any other convenient venue. The goal of this meeting would be develop specific research plans on the part of all collaborators.

2) 1999 - 2000. Field work, including tagging. Biological sampling. Economic data collection.

3) 2001 - 2002. Completion of field work. Analysis of short-term tag recaptures. Preliminary estimates of within region mixing rates and age-specific mortality.

4) 2003. Final analysis of short-term recaptures. Preliminary analysis of archival tag data. Symposium to present results and conclusions.

References

Anon. 1997. Pelagic Fisheries of the Western Pacific Region, 1996 Annual Report. Western Pacific Regional Fishery Management Council, Honolulu, Hawaii.

Brill, R. ... 1997.

Grewe, P., and J. Hampton . 1998. An assessment of bigeye (*Thunnus obesus*) population structure in the Pacific ocean, based on mitochondrial DNA and DNA microsatellite analysis. Joint Institute of Marine and Atmospheric Research, Contribution 98-000, (in press).

Hampton, J., A. Lewis and P. Williams. 1997. Estimates of western and central Pacific ocean bigeye tuna catch and population parameters. Working Paper 17, Western Pacific Yellowfin Tuna Research Group, June 18-20, Nadi, Fiji.

IATTC. 1997. Assessment studies of bigeye tuna in the eastern Pacific ocean. Background Paper 5, June-3-5, 1997.

Klimley, A. P., E. D. Prince, R. W. Brill, and K. Holland. 1994. Archival tags 1994: present and future. NOAA Technical Memorandum NMFS-SWFSC-357

Lawson, T. (ed.) 1997. Tuna Fishery Yearbook. South Pacific Commission, Noumea, New Caledonia.

Lehodey, P., Bertignac, M., Hampton, J., Lewis, A., and Picaut, J. 1997. El Niño Southern Oscillation and tuna in the western Pacific. *Nature* 389:715-718.

Stein, Arsène, 1997. French Polynesia yellowfin and bigeye tuna fisheries. Working Paper 11, Western Pacific Yellowfin Tuna Research Group, June 18-20, Nadi, Fiji.

Ward, Peter. 1997. Tuna and billfish fisheries of the north-eastern Australian fishing zone. Background paper, Standing Committee on Tuna and Billfish, June 16-18, Nadi, Fiji.

Whitelaw, A. W. and V. K. Unnithan. 1997. Synopsis of the distribution, biology and fisheries of the bigeye tuna (*Thunnus obesus*, Lowe) with a bibliography. CSIRO Marine Laboratories, Report 228.

Advanced Electronic Tuna Tag Development Project

Current state of the art

A wide variety of electronic devices are currently in use or under development for monitoring the movements of large pelagic fish on different time scales.

The geolocating **archival tag** (Klimley, *et al.* 1994) is the most widely promoted of these devices. Archival tags measure features of the fish and its environment and record the information for later retrieval. The recorded data usually include time, ambient light intensity, water temperature, and body temperature. Once retrieved the information can be used to reconstruct the movements of the fish during the time it was carrying the tag. Archival tags have been successfully used on southern bluefin tuna where they have recorded migrations from Australia to the western Indian Ocean and back. Archival tags have also been recently deployed on Atlantic bluefin tuna.

The main problem with archival tags is the necessity to physically recover the device. The PFRP is cosponsoring work with the National Marine Fisheries Service and the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia to develop archival tags that will detach themselves from the fish and transmit the archived information to a satellite, a pop-up satellite transmitting archival tag or **PSTAT**. The first PSTAT will deployed on swordfish in 1998.

A variant of a **pop-up tag** was tested successfully on Atlantic bluefin tuna in 1997. The devices detach from the fish at preset times and transmit their current geographic position and a limited amount of environmental data to a satellite.

A variety of acoustic devices are frequently used in tracking fish. **Acoustic monitors** can be deployed to receive information transmitted bye the tag. At their present stage of development the tags transmit a simple identity code and the monitors must be physically retrieved to obtain the data. The feasibility of acoustic monitors has been established for yellowfin tuna in Hawaii by a PFRP sponsored project. Results summarized in the January 1998 PFRP Newsletter show that these devices can be very useful in obtaining in information relative to the aggregation behavior. Future development would be the capacity for the tags to transmit archival information to the monitors.

Although these advanced electronic devices have great promise for applications to the study of large pelagic fish, they have not been widely used.

High cost and unproved capability in real applications are the most cited reasons for the limited number of applications to date. Manufacturers of archival tags have generally absorbed the research and development costs without subsidies. The current high cost, nearly $1000 per tag, reflect the R&D costs. Larger orders for the current state of the art tags would almost certainly result in decreased prices and further R&D. Manufacturers have indicated that the size of the devices could be

substantially decreased and their capacity substantially increased if there were some assurance that R&D costs would be rewarded by increased orders.

Researchers attempting to deploy currently produced archival tags have reported a variety of technical and logistical problems. Some devices malfunctioned due to faulty manufacture. Others exhibit a unacceptable degree of variability in the recorded data (e. g. variability in estimated geographic position when placed on a window sill for several weeks.) Not all vendors have been able to meet purchasing deadlines.

Attachment of the devices is always problematic. Some of the pop-up devices are very large and must be attached externally; these devices therefore are only applicable to larger fish. Smaller devices can be implanted in either the body cavity or dorsal musculature of the fish, again restricting the minimum size of fish on which they can be deployed.

A 1994 report reviewing the state of archival tag technology concluded that potential errors in latitude estimation by these devices precluded their use in some applications. Few field trials have been conducted, and in 1998, the real positional errors of these devices is still unknown.

Proposed activities

The primary goal of this proposal is to establish the means to **deploy 1000 advanced electronic tags on bigeye tuna by January 1, 2001.** A program will be established to purchase, test, and calibrate devices which will then be supplied to researchers collaborating in the **Bigeye Five-Year Plan.** The secondary goal is to encourage further research and development in advanced electronic tags towards the following ends:

- decreased size
- increased accuracy
- decreased cost
- capacity for remote interrogation

Archival Tag Selection and Purchase

In the first year of the project, a representative sample of archival tags will be purchased from vendors capable of delivering tags by a specified deadline. These samples will be subjected to a series of standard tests to evaluate the reliability, accuracy, and general serviceability of the tags. On the basis of these tests, 1000 archival tags will be purchased during the second year from the most suitable vendor or vendors.

The tests will be specified and test results will be evaluated at workshops to be held in Honolulu. Workshop participants will be consist of researchers with practical experience in using electronic tagging devices.

Testing and calibration

These devices are expensive, and in spite of the selection procedure, each device should be thoroughly tested and calibrated prior to deployment. All tags will be tested prior to distribution to collaborators and records of the performance of each tag will be maintained to aid in interpretation of the data when the tag is retrieved.

Distribution of tags to collaborators

Archival tag deployment strategies will be determined by workshop of consisting of the collaborators in the Bigeye Five-Year Plan to be convened in early 2000. This group will determine the time, place, and number of tags to be deployed as well as the appropriate sizes fish on which to deploy them in order to contribute to the achievement of the Bigeye Five-Year Plan goals.

R&D Contracts

Costs

Timetable