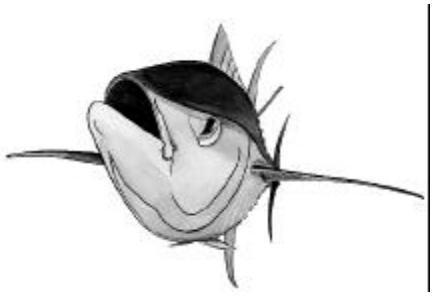

Bigeye Tuna:
Five-Year Research Plan

A Prospectus for Coordinated International Research

The prospectus was prepared by the Pelagic Fisheries Research Program at the University of Hawaii for the purpose of promoting international collaborative research on bigeye tuna. For further information, contact

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Bigeye Tuna:
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Executive Summary

The bigeye tuna population in the Pacific supports fisheries conservatively estimated to be worth between US $500,000,000 and $1,500,000,000. In comparison, the financial resources directed towards research and management of this critical resource is about 0.1% of this value. This Prospectus outlines an ambitious plan to address scientific uncertainties regarding bigeye tuna populations in the Pacific ocean. The research plan is based on presentations before a workshop attended by scientists from throughout the Pacific. A clear conclusion from the workshop is that there are many research projects in conceptual and planning phases, but implementation is contingent on future funding. Under the proposed plan, major research institutions in the Pacific would deploy research assets locally to achieve global goals.

Specific areas where additional financial assistance is required to support a coordinated international research effort are:

- Purchase and deployment of 2000 advanced electronic tags by 2000.
- Operation of a dedicated Pacific Ocean tuna tagging vessel

General Background

Importance of Bigeye

Bigeye tuna is the mainstay of longline fisheries throughout the Pacific basin. This species has been a primary target of the distant-water longline fleets since the introduction of the “deep” longline technique in the Japanese longline fleet in the 1960s. The importance of bigeye to Pacific longline fleets has grown in the 1990s as the number of locally-based longline vessels have increased in Hawaii, French Polynesia, Australia, and developing Pacific island states. Viability of these fisheries depend critically on the continued abundance of bigeye tuna. The nascent fleets in the developing Pacific island states are particularly vulnerable to declines in bigeye catch rates.

The total catch of bigeye in the Pacific is difficult to determine because there is no central record-keeping authority. Estimates of total landings of bigeye have hovered around 150,000 tonnes for the last 10 years; see Figure 1. The total 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 conservative estimates of the price of sashimi grade tuna in Japan, the total value of Pacific longline bigeye harvest is between US$500,000,000 and US$1,500,000,000.

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

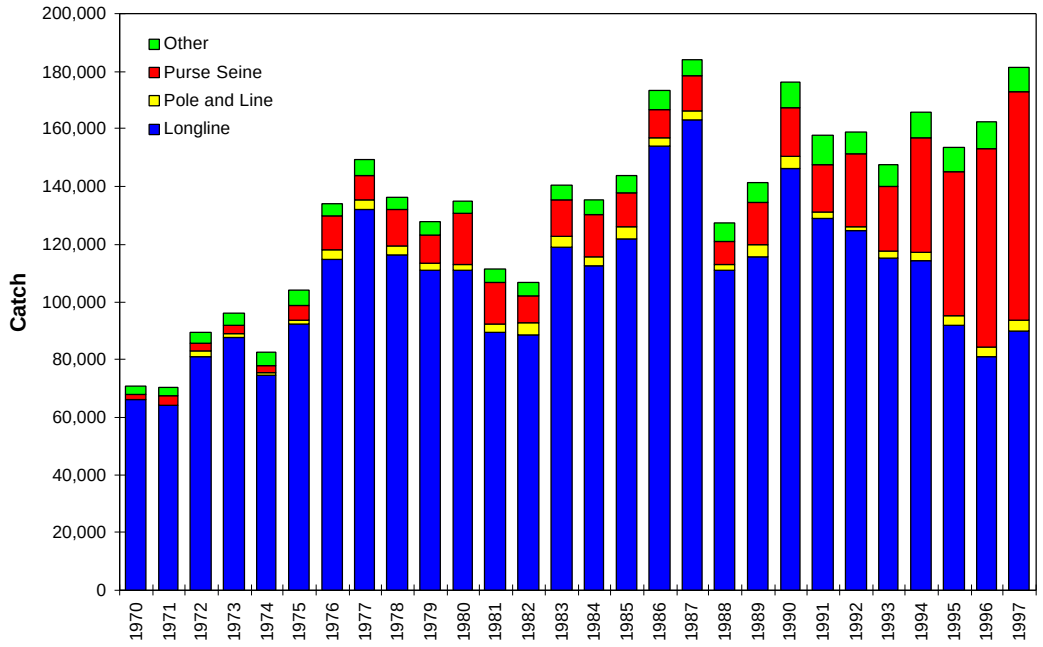

Figure 1. Total catch of bigeye tuna in the Pacific. Source: “Report of the eleventh meeting of the standing committee on tuna and billfish”, 28 May – 6 June 1998, Honolulu.

Recent Changes in Bigeye Tuna Harvesting

Increased targeting by surface fisheries

Purse seine operators in both the Eastern Pacific Ocean (EPO) and the Central and Western Pacific Ocean (WPO) have developed methods to harvest bigeye tuna in surface aggregations. Surface fishing methods primarily depend on the tendency of juvenile bigeye to aggregate around floating objects. In the EPO, scientists from the Inter-American Tropical Tuna Commission (IATTC) estimate that the purse seine catch of bigeye has grown from 5,000 mt in 1992 to over 50,000 mt in 1997. In the WPO, scientists from the Secretariat of the Pacific Community (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 available. These changes are reflected in the total catch statistics (Figure 1).

Decline in EPO CPUE

The catch per unit of effort (CPUE) of bigeye by the longline fleets in the EPO increased throughout the 1980s, but has declined 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.

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.

Timing of Research

Analyses by IATTC scientists on the potential consequences of purse seine harvests on longline yield in the EPO has caused concern about possible effects of surface harvests on the bigeye population accessible to longline gear. The IATTC results demonstrate that the potential adverse consequences of purse seine harvest on longline yield could be significant, although this conclusion is highly dependent on the natural mortality rate, which is uncertain. The Precautionary Approach, however, requires conservation measures be imposed even if there is no hard scientific evidence that a problem exists. The Inter-American Tropical Tuna Commission implemented precautionary restrictions on purse seine harvests in the EPO in 1998.

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", was convened in May 1998. The workshop concluded that information about bigeye tuna was not sufficient to support rigorous stock assessment or to determine scientifically defensible precautionary reference points. 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 2000.

These events convey urgency to international efforts to improve our scientific understanding of bigeye tuna.

Scientific Issues

A recent genetic analysis of bigeye populations (Grewe and Hampton, 1998) was unable to reject the hypothesis 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 indicating that there are no natural barriers to population movement in the Pacific. On the other hand, a considerable number of bigeye were recaptured in the general area of release after more than 5 years at liberty (see Figure 2). 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, *et al.* 1999) demonstrate clearly that bigeye show a much higher site fidelity to Cross Seamount than yellowfin.

The impact of large catches of juvenile fish on subsequent catches of mature fish depends strongly on mortality rates. Analyses of the limited amount of bigeye tagging data at the SPC (Hampton, *et al*. 1997) show order of magnitude discrepancies in estimates of both fishing mortality and natural mortality rates. Uncertainties in mortality rates plague attempts at age structured population analysis (IATTC, 1997). No reliable age-dependent estimates of natural mortality are available for Pacific bigeye.

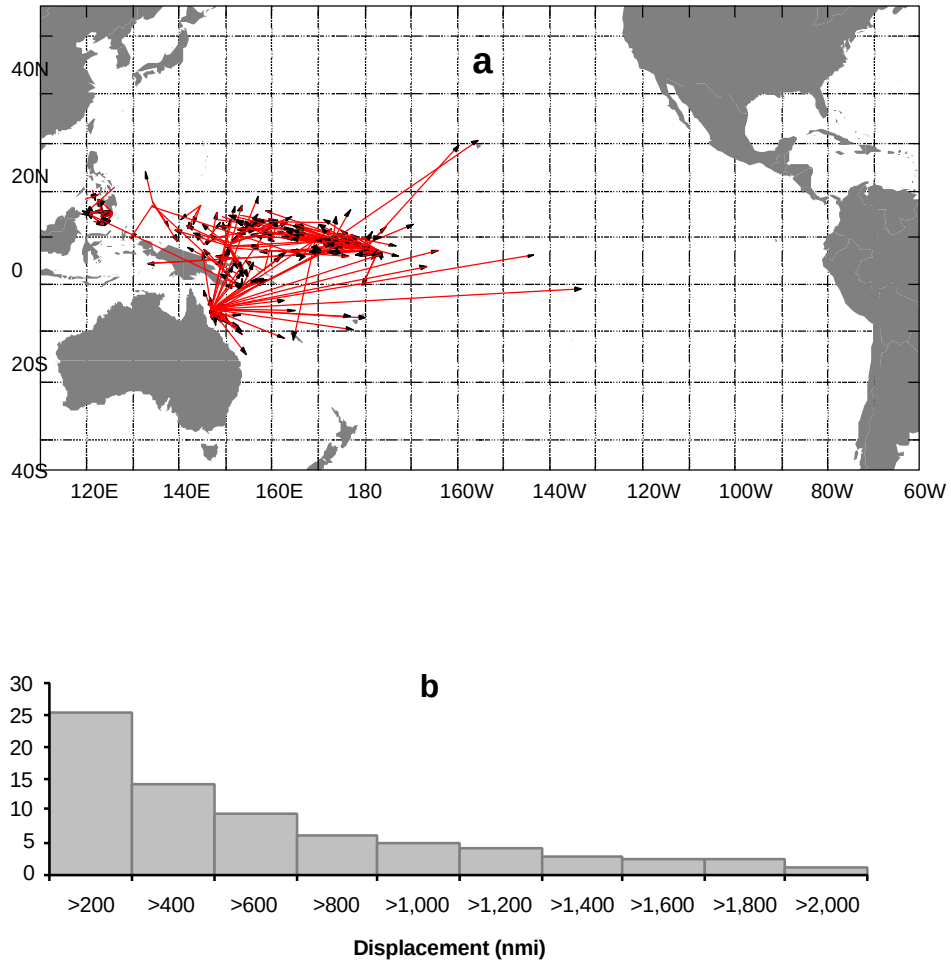

Figure 2. a. Long-distance displacements (>100 Nmi) of bigeye tuna tagged by the SPC Regional Tuna Tagging Project (RTTP) between 1990 and 1992. b. The cumulative distribution of all RTTP tagged bigeye displacements having accurate location data (Grewe and Hampton, 1998).

Mature bigeye occupy deeper water than most other tropical tunas, due perhaps to enhanced ability to extract oxygen from the colder water found at these depths (Brill, *et al*. 1998). Longliners target bigeye tuna at greater depths by using special gear that enables them to set their hooks deeper. Juvenile bigeye form relatively shallow aggregations near floating objects and seamounts. Purse seiners, armed with “deep” purse seines, improved electronics and techniques to “coax” bigeye into shallower depths, 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.

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 longline CPUE in the eastern Pacific had declined sharply during the 1990s whereas the longline CPUE in the western Pacific has been nearly constant over the same period of time.

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 and the impact of this behavior on population assessment procedures are unknown (as they are for most tunas).

Research Objectives and Approaches

Scientific objectives and approaches were generally discussed in November 1998 at a workshop attended by scientists from all regions of the Pacific Ocean. The contents of some of the presentations are summarized here. The full workshop report is in Appendix I.

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. Longlines select older fish; purse seines select younger fish. Both very young fish and very old fish appear to die of “natural” causes at higher rates than fish of “middle age”.

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.

Conventional tagging experiments have proved to be very useful in estimating age-specific mortality rates (SPC, 1996) and growth rates in skipjack and yellowfin.

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 bigeye. Furthermore, their propensity to form aggregations makes them particularly vulnerable to various types 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 be 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 the relationship between oceanography and movement.

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 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 appropriate tagging strategies.

Regional Research Plans

Participants in the November 1998 workshop presented the state of current research on bigeye in their respective regions. One clear conclusion from the workshop is that there are many research projects in conceptual and planning phases, but implementation is contingent on the availability of additional funding.

Eastern Pacific Ocean

The Inter-American Tropical Tuna Commission (IATTC) has an active research program on tuna fisheries in the EPO. The primary interest of IATTC in bigeye resources centers on interaction issues between EPO longline fisheries for large, high value fish and a recently developed FAD based purse seine fishery that takes significant quantities of juvenile bigeye. Estimation of age specific natural mortality

rates is a high priority since stock assessments and interaction estimates depend heavily upon these parameters.

The IATTC is planning a large-scale, ongoing bigeye tagging project for the EPO over the next several years but no specific plans are currently in place pending the identification of funding sources. This project would focus on conventional tagging of bigeye found in aggregations around floating objects. The objectives are to estimate movements, interaction between surface and sub-surface fisheries, and rates of natural mortality in bigeye. Simultaneous tagging of yellowfin would provide the opportunity to gain a better understanding of the relationship between southern (south of 5°N) and northern groups of yellowfin in the EPO. A pilot tagging project in early 1999 to tag bigeye, yellowfin and skipjack in the EPO purse seine fishing grounds is in the planning stage. Archival tags would be deployed in the southern region in conjunction with conventional tags.

The IATTC will begin life history research on EPO bigeye in 1999, which will include studies on the age, growth and reproductive biology. Otoliths and vertebrae will be sampled from bigeye in conjunction with chemical marking of tagged fish for age validation purposes. Size and age specific reproductive characteristics from surface and sub-surface fisheries will be determined using histological analyses of gonad material. Similar studies throughout the Pacific are critical to elucidate regional differences in reproductive biology and growth characteristics.

French Polynesia

Several research organizations, EVAAM (SMA), IFREMER, and ORSTOM, are pursuing a joint research program, ECOTAP, on pelagic resources of the French Polynesian Exclusive Economic. Two years of field work have been completed, involving pelagic longlining, echo sounding, sonic tracking of tuna and pelagic trawling. The project conducted research on bigeye behavior and habitat, and longline characteristics in relation to catch rates. The ECOTAP program will conclude in mid 1999. The ECOTAP results have proven to be very useful to local fishermen, and the legacy of ECOTAP is a willingness and interest of local commercial vessels to collaborate in future research.

Western Equatorial Pacific

The Secretariat of the Pacific Community (SPC) Offshore Fisheries Programme (OFP) has a long history of large-scale tagging projects in the WPO, including release of 6,800 tagged bigeye, but the SPC has no plans to undertake further conventional tagging of bigeye. The most recent tagging project concluded in the early 1990s. The SPC will participate actively in the upcoming Coral Sea archival tagging project (below). In addition, a proposal has been lodged with the United States Tuna Foundation (USTF) for the purchase of 300 archival tags to be deployed in as yet undetermined areas, but likely to include the WPO adjacent to the main longlining area in the central Pacific. The success of this proposal remains uncertain. It is possible that renewed funding from the European Union in 1999 could assist further archival tagging work.

The OFP plans to continue research on other subjects relevant to bigeye research, such as age and growth studies, environmental determinants of tuna production, observer and port sampling work, and stock assessment.

Northwestern Coral Sea

CSIRO (Hobart, Australia) and SPCOFP are attempted to deploy eighty data logging archival tags in the Australia Coral Sea in December 1998, but were thwarted by poor fishing. Australian flag longline vessels will be used in 1999 to capture medium sized (80 – 100 cm) bigeye using both longline and handline gear. This projects exploits a unique aggregation of bigeye tuna found feeding on lanternfish (Myctophidae) in the northwestern Coral Sea during this time of year. The CSIRO plans to match the SPC-funded tagging with 100 additional archival tags to be released during the 1999 fishing season. A return rate of 10% can be expected from this archival tagging project based on over 200 recaptures from the 3800 medium sized bigeye tagged in this area during the early 1990s by the SPC.

Western North Pacific

The National Research Institute of Far Seas Fisheries (Japan) conducts field research on tropical tunas employing dedicated research cruises and observer trips on commercial tuna vessels. Field research on swordfish, albacore, bigeye and yellowfin research will begin in September 1999 in the Western Pacific on a chartered longline research vessel, providing opportunities to deploy both conventional and archival tags. Prefectural longline training vessels, operating near Hawaiian waters during late 1998 and 1999, are another possibility for collaborative research. A large and well equipped government research vessel (RV *Shoyo Maru*), currently working in the Indian Ocean, will become available for pelagic research in the Pacific during 1999. She will be capable of longline and gillnet operations, acoustic tagging of large fish and will be equipped with a full array of sophisticated marine electronics.

Hawaii

The Pelagic Fisheries Research Program (PFRP) funded a small scale tagging project for bigeye and yellowfin on the Cross Seamount, located within the Hawaii EEZ approximately 150 miles south of Oahu. This project, designed to address interaction and aggregation issues, was expanded to the Hawaii Tuna Tagging Project which will tag yellowfin and bigeye throughout the entire Hawaii EEZ for a two year period. Total releases to date for both projects exceed 11,000, of which 58% are bigeye. The overall recapture rate stands at about 11% by domestic handline, longline, pole and line and troll vessels. Most of the releases and recaptures have been made on the Cross Seamount and inshore FADs. A variety of commercial and sport vessels are being used as tagging platforms at the Cross Seamount, around the main Hawaiian Islands, the northwest Hawaiian Islands and near Midway Atoll. The project has been targeting aggregation points such as seamounts, isolated islands and anchored FADs to maximize bigeye releases. An ancillary project funded by the Hawaii State FAD program will begin in November 1988, targeting the tagging of small yellowfin and bigeye (20 - 35 cm) found in association with Hawaii State anchored FADs.

The PFRP has received several research proposals aimed at bigeye tunas. Scientific review of these proposals will be complete in early 1999, but implementation will depend on availability of funds. The proposed research projects are intended to elucidate how trophic interactions mediate aggregation, provide information on how oceanographic features influence longline catches of bigeye, and to create suitable assessment models for the Pacific-wide bigeye population.

The PFRP has provided funds to the Honolulu Laboratory of the National Marine Fisheries Service (NMFS) to deploy archival tags on bigeye tuna. As of November 1998, 24 tags have been deployed and one recaptured. Conventional tagging of longline caught bigeye continues on an opportunistic basis from the NMFS RV *Townsend Cromwell* which also conducts *in situ* fisheries oceanography in the Hawaii EEZ and adjacent seas.

The study of pelagic fish habitat and ecology in relation to offshore fisheries has been a major initiative of the Honolulu Lab in recent years, through direct field work, remote sensing and validation, bigeye habitat studies, large-scale ecosystem research and modeling, and physiological and biochemical analysis.

Project Structure

Organization

A research project on the entire Pacific-wide bigeye population is beyond the means of most research institutions to implement. Furthermore, specific fishery management and scientific research goals 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. Research coordination would be encouraged by convening regular, perhaps semi-annual, workshops of collaborating researchers to discuss research plans, report progress, and evaluate preliminary results. The first of these workshops was held in Honolulu on November 9-10. Scientists from all regions of the Pacific Ocean participated and provided much of the information contained in this document. The full workshop report is in Appendix I.

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 Zone, many others have addressed Pacific-wide scientific issues. In addition, the PFRP has sponsored interdisciplinary conferences devoted to research on pelagic fish in the Pacific and implications of research results for fishery management policy. By drafting this prospectus 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 co-sponsored 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 has deployed archival tags on bigeye tuna in feasibility tests. As of November 1998, one tag has been recovered.)

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 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 participate in the research activities by

- enlarging the geographical extent of the Hawaii regional tuna tagging project to include more of the central Pacific ocean. The expanded tagging area will include Wake, Johnston, and Palmyra Islands.
- Continuing to help finance participation in research coordination workshops.

Additionally the PFRP will seek funding for specific purposes to establish a special fund to promote the development and eventual deployment of 2,000 advanced electronic tagging devices. These devices will be supplied to project collaborators for deployment in different regions. This initiative will be expanded below.

Timing

1) November 9 -10, 1998. First meeting of coordinating group in Honolulu.

2) June, 1999. Second meeting of the coordinating group in French Polynesia. The goal of this meeting would be develop specific research plans on the part of all collaborators.

3) 1999 - 2000. Field work, including tagging and biological sampling.

4) 2001 - 2002. Completion of field work. Analysis of short-term tag recaptures. Preliminary estimates of within region mixing rates and age-specific mortality.

5) 2003. Final analysis of short-term recaptures. Preliminary analysis of archival tag data. Symposium to present results and conclusions.

Deployment of advanced Electronic Tuna Tags

Purpose

To promote international cooperation in large-scale tagging of bigeye tuna by

- supplying 2000 advanced electronic tags to collaborating scientists to be deployed on bigeye tuna by December 31, 2000.
- improving computational methods for interpretation of data derived from electronic tags.

Current state of the art in electronic tags

A wide variety of electronic devices are currently in use or under development for monitoring the movements of large pelagic fish and other animals at different time and space scales (Stone, *et al.* 1998).

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 bluefin tuna in both the Pacific and the Atlantic and on bigeye tuna near Hawaii. One archival tag has been recovered from a bluefin tuna after a trans-Pacific migration (Tsuji, *et al*. 1999), and one archival tag has been recovered from a bigeye after spending tree months near the island of Hawaii.

The main problem with archival tags is the necessity to physically recover the device. Research by several groups is underway 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 PSTATs were deployed in 1998 on Atlantic bluefin tunas. Further deployments of PSTATs are planed for 1999 on Pacific swordfish.

A variant of a **pop-up tag** has been tested successfully on Atlantic bluefin tuna. 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. These devices have the advantage that “recovery” is independent of the fishery. Therefore it is more feasible to employ principles of experimental design to create tag reporting strategies that address specific scientific hypotheses.

A variety of acoustic devices are frequently used in tracking fish. **Acoustic transmitters** broadcast information about the swimming depth of the fish and its

body temperate. Researchers track the acoustic signal from a vessel and record the information enabling them to obtain very detailed information for a freely swimming fish. The necessity to actually track the fish *in situ* increases the cost and inconvenience of these devices. **Acoustic monitors** can be moored in fixed positions to receive information transmitted by acoustic transmitters. 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 show that these devices can be very useful in obtaining information relative to the aggregation behavior (Klimley and Hollway, 1999). 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 of archival devices. Manufacturers of archival tags have generally absorbed the research and development costs without subsidies. The current high cost, nearly $1200 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.

A 1994 report (Klimley, *et al.* 1994) reviewing the state of archival tag technology concluded that potential errors in latitude estimation by these devices precluded their use in some applications. The results from the single bigeye archival tag recapture in Hawaii indicates that geolocation errors for bigeye are of the order of 2° in both longitude and latitude. An important conclusion from the November 1998 bigeye research coordination workshop (Appendix I) is that depth information from currently available archival tags is highly accurate and that the position estimates are sufficiently accurate to deduce large scale bigeye movements. The workshop also concluded that further development of geolocation algorithms would likely improve the accuracy of position estimates from archival tags.

Proposed activities

Electronic Tag Purchase and Deployment

A central procurement facility will be established by the PRFP at the University of Hawaii to purchase the devices required by the experimental design. This facility will enable economies of scale in tag purchase, calibration and distribution to collaborators. All tags will be tested and calibrated 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.

Survival of tagged fish and recovery of tags and information depend on careful application of tags, whether externally placed conventional tags and pop-of devices or internally applied archival devices. The centralized facility will also

provide training in tagging procedures to ensure that tagging projects in different regions of the Pacific are conducted consistently. Preliminary work is currently underway at the University of Hawaii to produce materials for training tuna taggers.

A second meeting of the bigeye research coordination group will be convened in June 1999 to determine strategies for electronic tag deployment. This group will discuss the types of tag, times and places of release, numbers to be deployed, and appropriate sizes of fish on which to deploy them in order to contribute to the achievement of the research goals outlined in the Prospectus.

Computational Methods Development

Two types of computational methods are required for electronic tags to effectively contribute to the resolution of the scientific problems outlined in the Prospectus, *geolocation* and *population movement models*.

Existing geolocation algorithms use information on times of sunrise and sunset to estimate geographic position. The attenuation of light intensity with depth and the foraging behavior (diving at dawn and surfacing at dusk) of bigeye combine to confound estimation of times of sunrise and sunset. Further, there appears to be very little scope for improvement of light sensors on the archival tags. Therefore improvement of geolocation estimates will require use of ancillary information and more sophisticated use of existing position estimates. Sea-surface temperature and known positions of release and recovery could be incorporated into methods which combine position information with probable displacement rates into statistical models of behavior.

Electronic tags provide detailed and accurate information about individual animals. Conventional tags provide information of variable accuracy about a large number of individuals. Statistical methods to estimate movement and mortality parameters from conventional tagging data are well developed (Kleiber *et al.* 1987; Kleiber and Hampton 1994; Sibert *et al.* 1999; Holland *et al.* 1999). However, very little work has been conducted on estimation of movement and mortality from data derived from a combination of conventional tags, pop-up tags, and archival tags. A consistent analytical framework and suitable statistical procedures to apply to such a combined data set are an absolute requirement.

Indicative Budget

Item	Cost
Equipment	
Electronic tag purchase	$2,000,000
Computers and equipment	20,000
Staff	
Coordinator (3 years)	$250,000
Analyst/modeller (3 years)	$250,000
Travel	$50,000
TOTAL	**$2,570,000**

Timetable

Initial planning workshop	November 1998	
Deployment strategy workshop	June 1999	
Solicit bids for tags	July 1999	
Tag procurement	November 1999	
Testing & calibration	November 1999	January 2000
Model & algorithm development	November 1999	December 2001
Tag deployment	January 2000	December 2001
Tag Recovery and Analysis	January 2000	December 2004

Dedicated tagging vessel

A large fraction of current knowledge of distribution, movement and morality of tropical tunas in the Pacific is based on large-scale conventional tagging projects conducted since the 1960s. These tagging projects typically release 100,000 to 200,000 tagged fish over a 2-3 year period and can be viewed as “snapshots” of the population taken at the times and places at which the tagging was conducted. As conditions in the fisheries change, and, entering the Twenty-first Century, as the climate changes as well, the distribution and dynamics of the fish populations will also change. The field work of the most recent large-scale tuna tagging project in the Pacific concluded in 1992 and was confined to the western Pacific (OFP, 1998).

It is essential to update this critical information base and extend it to include the entire Pacific basin. The time required to conduct the field work within a region is about 1-2 years, and the time required to recover the tags from the fishery is 2-5 years. These times suggest that tagging regional projects could be effectively be repeated on a 5 to 10 year cycle within the Pacific basin.

Ocean-going research vessels are expensive to procure and operate. Costs of a dedicated tagging vessel would depend on the type of vessel, how it is procured and how it is operated. Some participants in the November workshop felt that an existing tuna fishing vessel could be procured for minimal costs. If so, the principal costs would be operational.

The level of funding required to operate a full-time dedicated tuna tagging vessel would be approximately $2,000,000 per year.

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Appendix I.
Pacific Bigeye Tuna Research Coordination Workshop

Final Report