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Project Proposal Title: The Role of Oceanography in Aggregation and Vulnerability of Bigeye Tuna in the Hawaii Longline Fishery from Satellite, Moored, and Shipboard Time Series

Funding Agency: NOAA/NMFS/Pelagic Fisheries Research Program

1. Purpose of the project and indicative results.

Stock assessment of bigeye tuna (*Thunnus obesus*) is generally based on longline fishery catch-per-unit-effort (CPUE) as an index of abundance of the stock. Unfortunately, fishery-dependent CPUE does not necessarily reflect abundance of the stock, but rather the catchability of the stock. Catchability, in turn, is dependent to a considerable extent upon variable oceanographic conditions. Since the preferred foraging habitat of bigeye tunas appears to be the 8-15°C water at or near the base of thermocline, variability of thermocline depth could significantly affect aggregation of bigeye tunas. According to work by Boggs, Brill and others, bigeye tunas remain in the upper 10-90 m at night and repetitively migrate vertically between 350-500 m and 50-150 m during the day. This behavior suggests that at times when the thermal structure is depressed, bigeye tunas may be generally deeper and less aggregated due to their extended vertical migrations. Although the stock abundance may be unchanged, catchability and CPUE are reduced. Conversely, when the thermal structure is elevated, the habitat is generally shallower and bigeye tunas may be more aggregated, resulting in increased catchability and CPUE. Likewise, horizontal and vertical velocity shears have a profound effect on catchability and CPUE by modifying the depth of penetration and performance of longline gear.

Based on these considerations, the role of oceanography on the aggregation and vulnerability of bigeye tuna in the Hawaii longline fishery are being investigated: 1) to examine closely the relationships between bigeye tuna CPUE and oceanographic features observed using moored, shipboard, and satellite time series of the vertical and horizontal structure of the upper ocean, and 2) to utilize those relationships to develop methods to improve stock assessment estimates based on standardized logbook CPUE using remotely sensed observations of sea surface height, sea surface temperature, ocean color, and surface winds.


**BIGEYE Mooring**

The first major component of the Bigeye Oceanography Program involves the establishment of an oceanographic mooring to provide a high resolution time series of the vertical structure of temperature and currents in an area with moderately high and temporally varying values of CPUE. After a little more than one year in the water, the BIGEYE 1 mooring was successfully recovered at 20°36.0'N, 161°24.2'W on December 14, 2000 by the NOAA Ship
The BIGEYE 1 mooring was instrumented with 8 Seabird temperature recorders at the depths 25, 75, 125, 250, 300, 400, 500 and 700 m and 5 Aanderaa current meters at the depths 50, 100, 150, 200 and 350 m. Figure 1 shows the data return timeline. All but one of the Seabird temperature sensors recorded data for the entire year. All but one of the Seabird sensors recorded temperatures for the entire year. The battery for the sensor at 25 m appeared to have exploded resulting in loss of data from that sensor. Each of the five Aanderaa current meters recorded data for different periods of time ranging from 265 days at a depth of 350 m to only about 15 days at a depth of 100 m. Four of the Aanderaa instruments have been sent back to the manufacturer to determine the source of the problem which resulted in reduced data collection. Preliminary information suggests that there was a problem with the Aanderaa data storage units or with the power supplies.

The temperature, velocity, conductivity and dissolved oxygen data from BIGEYE 1 clearly show significant eddy variability at the mooring site. Similar fluctuations of each of these properties were observed with each significant eddy feature. It is noteworthy that the depth penetration of eddy features extends from the surface to as deep as 700 m (Figure 2). Temperature fluctuations at thermocline depths (125 m) ranged from 16 C to 25 C. These preliminary findings provide further optimism that algorithms can be developed to utilize satellite-sensed properties (sea surface height) to estimate surface fields of the upper ocean.
With assistance and technical expertise provided by the TAO Project Office at NOAA’s Pacific Marine Environmental Laboratory, the BIGEYE 2 mooring was deployed at
20°36.3’N, 161°34.4’W on December 12, 2000 by the NOAA Ship Ka’imimoana. Vertical resolution and the ability to compute vertical velocity shear were significantly improved for the BIGEYE 2 mooring by replacing the Aanderaa current meters with two Sontek acoustic Doppler current profilers (ADCP). These ADCPs were installed on the mooring to provide velocity measurements every 8 m from a depth of about 15 m to a depth of about 275 m. This improved vertical resolution will allow better determination of shear and estimates of the effects on longline gear performance. The BIGEYE 2 mooring and data are scheduled to be recovered in December 2001. The deployment of BIGEYE 3 has been postponed until Aanderaa Instruments has completed the evaluation of the problems encountered with RCM-9 current meters. In addition, the acoustic releases used for BIGEYE 1 and 2, which were provided by the University of Hawaii at no cost, will not be available for the BIGEYE 3 deployment. We are in the process of procuring acoustic releases to allow deployment of BIGEYE 3 when the current meter evaluation is completed.

**Research Cruises**

The second major component of the Bigeye Oceanography Program is a series of shipboard surveys to expand the spatial representativeness of the mooring observations and to closely examine the vertical water column structure associated with oceanic variability; e.g., fronts, eddies and frontal meanders. Over the course of the project thus far, five research cruises (April 1999-2001 and November 1999-2000) aboard the NOAA ship Townsend Cromwell have been conducted and have focused on obtaining measurements of dynamic oceanographic variability and its influence on the biology. During these cruises, closely-spaced conductively-temperature-depth (CTD) casts were conducted to observe water properties at very high vertical resolution. In addition to temperature and salinity, dissolved oxygen, nutrients, chlorophyll, and other accessory pigments were sampled. The initial April 1999 research cruise was also used to conduct bathymetric surveys of the proposed mooring site and to provide baseline descriptions of the oceanographic structure around this location. During the November 1999-2000 research cruises, distinct cyclonic eddies were traversed and studied in detail with regards to the physical and biological responses to mesoscale physical forcing. These features were also continually monitored using satellite observations of sea surface temperature, sea surface height, and ocean color by the Hawaii CoastWatch program. Observations suggest that the cyclonic eddies induce localized upwelling and upward nutrient flux which enhances primary productivity however, there were marked differences in the magnitude of the vertical displacement of isopleths within each eddy. Typical ocean currents around these eddies were observed to be very strong, with velocities as high as 80-100 cms⁻¹ (~2 knots).

Most recently, the April 2001 survey occupied a 900 nmi long transect from 22°N to 7°N latitudes allowing an extension of the assessment of the BIGEYE mooring spatial representation and to enable characterization of the dynamic region influenced by the North Equatorial Current (NEC) and North Equatorial Counter-Current (NECC). In recent years, considerable fishing effort by Hawaii-based longline fishing vessels has been focused in this region. During this time of year, this region has now been closed to longline fishing.
**Satellite Remote Sensing and CPUE**

The final major component of the Bigeye Oceanography Program involves examining relationships between surface features observed using satellite remote sensing and both the vertical structure of the upper ocean temperatures and currents and fishery-dependent CPUE of bigeye tunas. Observations suggest that the cyclonic eddies induce localized upwelling and upward nutrient flux which enhances primary productivity however, there were marked differences in the magnitude of the vertical displacement of isopleths within each eddy. Typical ocean currents around these eddies were observed to be very strong, with velocities as high as 80-100 cm$^{-1}$ (~2 knots). Our recent findings of the impacts of cold core eddies on enhanced phytoplankton density has suggested that these features may also provide forage habitat for higher trophic levels including bigeye tunas. An examination of the Hawaii longline fishery found three cold core eddies all located southeast of the Hawaiian Archipelago which provided productive longline catch of bigeye tunas. Preliminary results from a depletion analysis of one of these features found bigeye catch/1,000 hooks over a two month period dropped from 5.6 to 4.1 with the removal of 4,433 bigeye from the feature resulting in an estimate of the bigeye population at the eddy of 13,811 fish.

3. **Plans for the next fiscal year.**

During FY2002, the Bigeye Oceanography Program will continue all data collection and analysis activities as originally proposed, except that the BIGEYE 3 mooring deployment will be delayed to determine the source of problems with the Aanderaa current meters. The BIGEYE 2 mooring will be recovered in December 2001. Due to the failures of some of the Aanderaa current meters during BIGEYE 1, it was decided not to backfill a vacated oceanographer position until near the retrieval of the BIGEYE 2 mooring. A physical oceanographer will be recruited to process and analyze the combined results of the BIGEYE 1 and 2 moorings and to begin examining differences between dynamic height and velocities from the moorings and those computed from TOPEX/Poseidon altimeter measurements. Two acoustic releases will be procured to prepare for the BIGEYE 3 mooring deployment and those to follow. The Sontek ADCP data will be quickly processed and analyzed prior to deployment of BIGEYE 3. If the data return and quality are high, the ADCPs will be serviced and prepared for redeployment on BIGEYE 3. Two research cruises are planned for FY2002 to continue characterizing the spatial representativeness of the BIGEYE mooring and examining the physical and biological water column responses to dynamic mesoscale oceanographic variability. Further work will be done to evaluate the role of cold core eddies and other physical features as habitat for bigeye tunas using remove sensing and bigeye CPUE.

4. **List of papers published in refereed journals during FY 2001.**


5. **Other papers, technical reports, meeting presentations, etc.**

Brainard, R.E., M.P. Seki, J.J. Polovina, and D.G. Foley. 2000. The role of oceanography in aggregation and vulnerability of bigeye tuna in the Hawaii longline fishery from satellite,
moored, and shipboard time series, Proceedings of the 51st Annual Tuna Conference, Lake Arrowhead, CA.


   At present, there are no students involved in this research activity.