# A PELAGIC HABITAT ANALYSIS MODULE FOR TUNA OF THE EASTERN TROPICAL PACIFIC

**Dale Kiefer, Daniel Harrison, Timothy Lam, Frank O'Brien[1], Michael Hinton[2], Ed Armstrong[3]**

*[1] System Science Applications, P.O. 1589, Pacific Palisades, CA 90272, (USA), Email: kiefer@runeasy.com*

*[2] Interamerica Tropical Tuna Commission, La Jolla, CA , (USA), Email: mhinton@iattc.org*

*[3] Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109-8099 (USA), Email:Edward.M.Armstrong@jpl.nasa.gov*

**ABSTRACT**

We have begun development of a pelagic habitat information system that is designed to map the habitat of marine pelagic species. This information system integrates commercial fisheries data and scientific surveys of species distribution with satellite imagery and circulation models to identify physical and biological parameters that determine a specie's distribution. We first applied this software to define the habitat of tuna of the Eastern Pacific Ocean. Our analyses clearly shows that the distribution of yellowfin, bigeye, and skipjack tuna are determined to a large extent by the distribution of sea surface temperature and chlorophyll concentration. In addition we found that ENSO plays a large role in determining both the distribution of the adult population and the rate of recruitment of juveniles to the adult population.

## 1. INTRODUCTION

Classical assessment of the sustainable exploitation of a commercial stock of fish is largely based upon data from the fleet. The total catch and catch per unit effort provide an estimate of the size and distribution of the adult population and measurements of the age structure of the catch provides estimates of the rates of recruitment of juveniles to the adult population. Recently, national and international agencies have requested a more ecological approach to managing fisheries and other marine resources. With support from NASA's Decision Support Program we have begun development of a "Pelagic Habitat Analysis Module". The goal of this work is to improve stock assessment by integrating classical fishery data with environmental information. Specifically, PHAM is an application of the EASy geographical information system by which one can merge fisheries data, satellite imagery, output from a global circulation model, and statistical algorithms to characterize and map the habitat of pelagic species. Such information along with supporting information on recruitment can then be introduced into existing stock assessment models.

Here we describe our first application, the mapping of the habitat and recruitment variability of the tuna of the Eastern Pacific Ocean.

## 2. OVERVIEW OF TUNA MAPPING IN THE EASTERN PACIFIC OCEAN

The Pelagic Pelagic Habitat Analysis Module (PHAM) is a development of the Environmental Analysis System (EASy), a geographic information system that has been specifically designed for marine applications (www.runeasy.com). EASy is a 4-dimensional (latitude, longitude, depth, and time) that runs on either Windows desktops or on servers, where the application can be run interactively over the Internet.

The PHAM-tuna application contains records of the distribution of fish catch and age structure of bigeye, *Thynnus obesus,* skipjack, *Katsuwonus pelamis*, and yellowfin, *Thunnus albacares* ,tuna from 1975 to present. This data was provided by the Interamerican Tropical Tuna Commission. The fishery deploys both long lines and purse seines. The fishery also supports it purse seining with fish aggregation devices of varying sophistication.

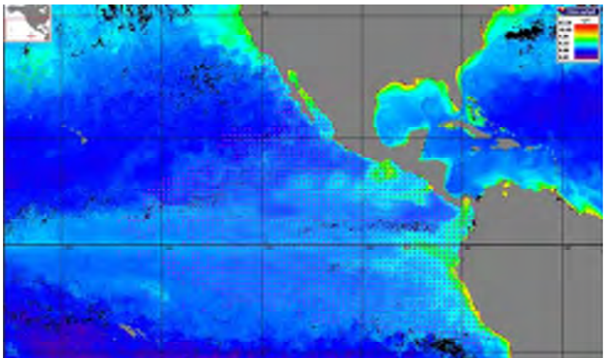

*Figure 1. PHAM screen of SeaWiFS image of surface chlorophyll and IATTC's tuna fishery stations. Overlap of chlorophyll and fishing grounds in noteworthy.*

Figure 1 shows the IATTC grid (1X1 degree) of sampling sites superimposed on an image of sea surface chlorophyll. The overlap between intermediate concentrations of chlorophyll and the grid of fishing effort is remarkable.

The application also contains GHRSST and AVHRR imagery of SST, CZCS and SEAWiFS imagery of the concentration of chlorophyll within the surface mixed layer, and AVISO sea surface height. It also contains output from the ECCO-2 global circulation model, which can be displayed dynamically at any selected depth. The circulation field can be seeded with tracer particles at any location in order to track water movement from sources such as spawning sites. Finally, the application contains a number of graphical and statistical tools such as unbalanced ANOVA, polynomial regression analysis, histograms, and soon code for empirical orthogonal function analyses. These tools allow rapid integration and analysis of a specie's habitat. Our initial tests of the application are described below.

## 2. RESULTS

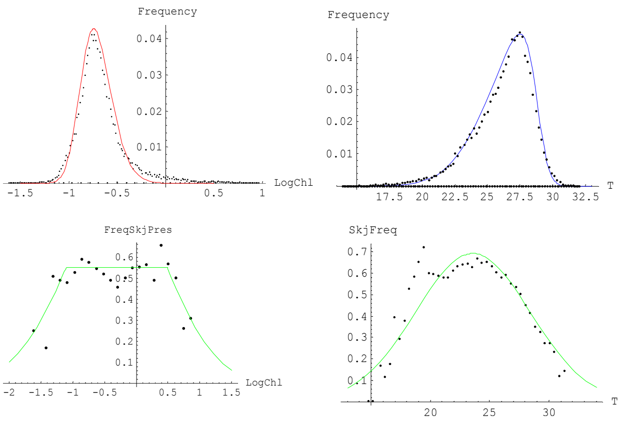


*Figure 2. Upper panel. The frequency distribution of CZCS and SEAWiFS log chlorophyll concentration and GHRSST temperature at tuna fishing sites, and our fits of skewed normal functions to the data. Lower panel. The frequency with which fisherman caught skipjack at fishing sites where remotely sensed chlorophyll (left) and temperature (right) were recorded.*

Figures 2 and 3 shows our approach to integrating sea surface temperature and chlorophyll imagery with data from the tuna fishery data. The upper panel of figure 1 shows the distribution of chlorophyll concentration (left) and the temperature at the sea surface at grid points where fishing occurred. The data points show the frequency that fishing occurred as a function of the value of log chlorophyll as recorded from CZCS or SEAWiFS imagery and temperature as recorded from AVHRR or GHRSST imagery. The curves are best fits to the data for a skewed normal distribution. We see from the figure that fishing occurred most frequently in waters where the concentration of chlorophyll within the mixed layer was 0.16 ug/l and the surface temperature was 27.6 $^{o}$C.

The lower panel shows the frequency with which the fisherman caught skipjack tuna at a grid point vs the log of the chlorophyll concentration (left) or temperature (right) at that grid point. The best fits to the skewed normal function are also shown. We see that the fisherman caught skipjack with a frequency of about 0.6 over a broad range of chlorophyll concentrations. In order to fit the skewed normal distribution to this relationship we set an upper threshold of 0.6 to the predicted frequency. Variations in the frequency of catch with temperature fit better the skewed normal distribution.

We then formulated a function to predict the frequency with which fisherman catch skipjack as a function of both temperature and chlorophyll. This function has the form of the product of the function for predicting the frequency of catch for temperature alone (left hand side of the lower panel in figure 2) and the function for predicting the frequency of catch for log chlorophyll alone (right hand side of the lower panel in figure 2). The values for the coefficients of this function were once again obtained by searching for values of the coefficients that provide the best fit to the data. A graph of this function is shown in the upper panel of figure 3, and a plot of the predicted frequencies of catch and the observed frequencies are shown in the lower panel (We expect much closer agreement when we complete the tuning.)

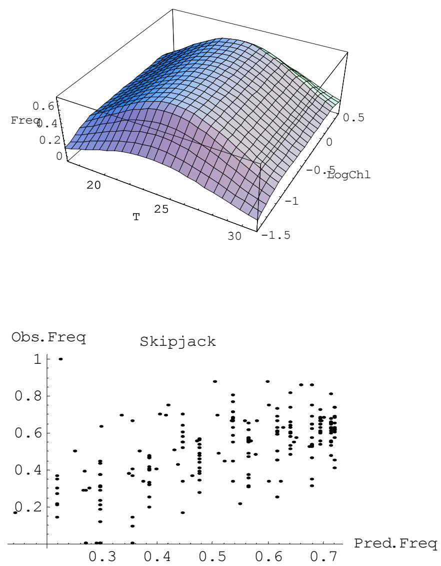


*Figure 3. Upper panel. 3-dimensional plot of the function describing the frequency with which skipjack are caught at a given temperature and log chlorophyll concentration. Lower panel. Plot of observed catch frequencies and predicted frequencies.*

Figures 4 and 5 show a second analysis using the PHAM-tuna application- the impact of ENSO variations on the recruitment of tuna of the Eastern Pacific Ocean. Here we subjected the time series from 1985 to 2007 of GHRSST imagery of the region to an EOF analysis and then compared the times series of variability in the temporal expansion coefficients of the modes with both the time series for the Southern Oscillation Index (SOI) and the time series of recruitment for our 3 species of tuna. This comparison clearly revealed that:

- The temporal expansion coefficients of both GHRSST modes 2 and 3 closely track the SOI.
- The time series of recruitment calculated from IAATC's stock assessment model for all 3 species track each other well.
- Large variations in the time series of recruitment calculated from IAATC's stock assessment model for all 3 species appear to be driven by large variations in the temporal expansion coefficient of GHRSST modes 2 and 3.

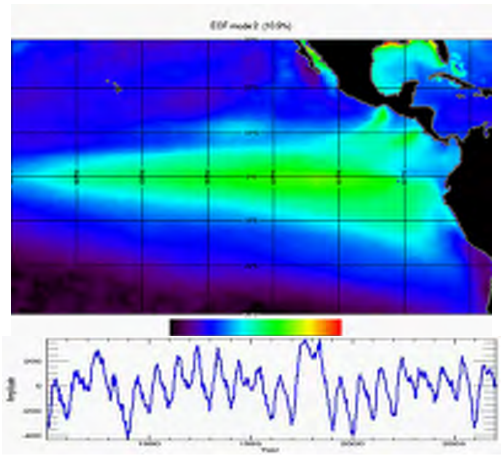

*Figure 4. The 2nd EOF mode (upper) and it temporal expansion coefficient (lower) for the GHRSST time series for eastern Pacific. The mode "catches" temperature shifts caused by El NINO and La NINA events.*

Figure 4 displays both the 2nd EOF mode of weekly GHRSST imagery and its temporal expansion coefficient. The El Nino of 1987,1992-93, and 1997-98 are expressed as maxima in the expansion coefficient, and the La Nina of 1989, 1999, and 2000 are expressed as minima.

The upper panel in Figure 5 displays the time series for the Southern Oscillation Index and the temporal expansion coefficient for the 3rd EOF mode of weekly GHRSST imagery. The co-variation between the time series is excellent as is the co-variation between the 3rd EOF expansion coefficient and SOI series. Obviously, the coupling between the ocean and atmosphere is tight and without significant lag.

The lower panel of figure 5 displays the time series of skipjack recruitment and the expansion coefficient of EOF mode 2. Although the co-variation between the two time series is not strong, it is clear that large swings in ENSO elicit a response in recruitment. Thus, the large swings in the temporal expansion coefficient that occurred between 1986 and 1989 and between 1997 and 99 drove large swings in recruitment.

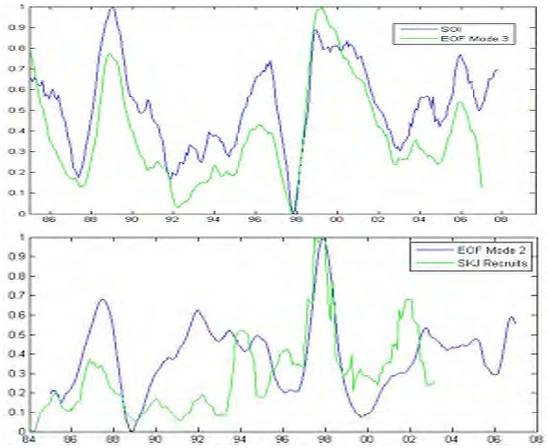


*Figure 5. Upper Panel. The temporal expansion coefficient for mode 2 closely tracks the Southern Oscillation Index. Lower Panel. The temporal expansion coefficients for mode 2 track the recruitment of skipjack as well as the bigeye and yellowfin tuna.*

## 3. CONCLUSION

Although our work on the Pelagic Habitat Analysis has just begun, we feel that the results so far indicate that the software will likely become a useful tool for ecosystem-based management of pelagic fisheries.