

Pelagic Fisheries Research Program

Integrative modeling in support of the Pelagic Fisheries Research Program: spatially disaggregated population dynamics models for pelagic fisheries

Progress Report

June 1997

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Background

The research reported here has two foci: (1) development of spatial models of pelagic fish population dynamics that explicitly include movement, mortality, and fisheries; (2) creation of an internally consistent conceptual framework for the research program of the Pelagic Fisheries Research Program (PFRP).

The pelagic fisheries operating within the various jurisdictions of the Western Pacific Regional Fishery Management Council (WPRFMC) are embedded in stocks of fish that extend over the entire Pacific Ocean basin. The dynamics of fish stocks inside of individual Extended Economic Zones (EEZs) are coupled to the dynamics of the larger stocks. Issues of how fisheries operating in one area influence fisheries operating in other areas, "interaction", depend on rates of movement, mortality and exploitation. Fisheries interaction questions are posed on all scales; interactions between fisheries operating on neighboring fishing grounds (as in the case of various components of the Hawaii tuna fleet) or between fisheries operating thousands of miles apart (as in the case of the impact of large-scale purse seine harvests of yellowfin tuna on the general availability of yellowfin in Hawaii). Methods to address these questions on the appropriate scale need to be developed. Conditions for international research and management of highly migratory species are evolving rapidly lending some urgency to the need to address ocean-basin scale questions.

The PFRP is a broadly multidisciplinary program. It supports many different research projects in the biology, social, and physical sciences. There is a risk that the PFRP will degenerate into a disconnected collection of individual research projects. The integrative modeling attempts to incorporate results from the suite of PFRP projects into a single conceptual framework.

Objectives

The general objective of the proposed research is to integrate the results of different PFRP components into spatially disaggregated models of pelagic fisheries which integrate knowledge of fish movement, the fishing process, economics and oceanography.

General Project Status

Dr. Peter Bills, assistant researcher with this project, left the UH last year. His report on the design of a tuna tagging experiment for the Hawaii EEZ is in press as a PFRP technical report. The results have been used in development of a tagging proposal. The departure of Dr. Bills and the preoccupation of the PI (Dr. Sibert) with PFRP program administration and related activities has slowed progress on project goals.

Progress on 1996-97 Goals:

1. Complete analysis of SPC tuna tagging data and apply results to the analysis population exchanges within the WPRFMC area.

Analysis of the 1978-82 (SSAP) skipjack tagging is complete. A manuscript describing the method and presenting an analysis of seasonal variability in movement pattern is in preparation for publication. Difficulties remain in analyzing both the skipjack and yellowfin data from the 1989-92 (RTTP) tagging experiment. Extension of the recapture period through 1995 seems to have improved the results. Analysis of the yellowfin and skipjack data sets with the longer time series is in progress. Software to analyze population exchanges within the WPRFMC area is complete.

2. Continue collaboration with Tohoku National Fisheries Research Institute (TNFRI, Japan) scientists on analysis of north Pacific skipjack migration.

Additional fishing effort data was obtained from the SPC to include the recapture entire period from 1988 through 1994. Dr. Ogura from the Tohoku laboratory is currently justifying reported tag recapture positions with reported fishing positions to ensure that tags were not returned from positions where no fishing was reported. This analysis will be completed in mid 1998.

3. Include additional variables, i.e. oxygen, topography, into the habitat parameterization of tuna movement. If feasible, output from oceanographic models to simulate "real time" observations of temperature and oxygen fields.

Dr. Michel Bertignac spent one month at UH to collaborate in development of a habitat-based tag movement estimation procedure. Dr. Bertignac and his colleagues at the SPC have created a habitat-based skipjack population model for the Pacific ocean that predicts fairly well the distribution of known fisheries. His model derives an index of habitat quality from sea surface temperature (SST) and an estimate of skipjack "forage" computed from advected ocean color.

The existing movement model, referred to as "regional", characterizes movement as a function of geographic region and season of the year. The model requires 60 movement parameters to be estimated for a two season, ten region model. In addition one parameter is estimated for natural mortality and one catchability coefficient is estimated for each fishing fleet. The estimation software was generalized to accommodate different

methods of computing movement parameters in such a way that the fits to the data can be compared between models.

The regional model converges to a solution with a negative log likelihood value of about 4,000. The lowest negative log likelihood value achieved with Bertignac's original model was over 10,000. Reformulation of the habitat model as a cubic polynomial of SST and "forage" produced better results. Even so, the lowest negative log likelihood value was over 5,000. In no case did the numerical function minimizer converge to a solution of the parameter estimation problem. Even if convergence had occurred, a negative log likelihood value of around 4200 would be required to produce a significantly improved fit to the data. In other words, the simple habitat based models tested do not fit the data as well as the regional model.

There are several possible causes for the lack of fit:

1. The SST data were taken from climatological means, and the "forage" proxy was computed from SEASAT data. Neither of these data sets pertains to the period during with the SSAP tags were at liberty.
2. The upwind difference approximation used in the solution of the PDE introduces "numerical dispersion" into the solution which depends on the advective field. These fields were radically different in the two models.
3. Ecological theory is not informative on how multiple factors interact to define an organism's habitat. It is not clear how, in the strictly operational terms required for a numerical model, to resolve the conflict between the Hutchinsonian niche and the simpler notion of a limiting factor. To put it more simply, will a hungry cold tuna move toward food or toward "warm"?
4. The variables selected to characterize skipjack habitat did not include other factors (oxygen, topography, "front density") that might be important.

Negative results are always the most informative because they clearly point to areas that are poorly understood such as items 3 and 4 above. An extremely important accomplishment of this work is the creation of a framework in which to test competing biological hypotheses about large scale movements of fish. In the long run this is a very powerful tool.

4. Continue work on the problem of estimating movement from catch and effort data (tag-independent movement analysis). Use results of YFT fecundity study to model recruitment.

No work was attempted on this activity.

5. Test alternative numerical approximations to the advection-diffusion PDE used to model fish movement, such as the "QUICKEST" 4-point approximation and single step implicit methods.

A one-step implicit method (using a biconjugate gradient solution method) is under evaluation. One alternative PDE approximation was evaluated, the quadratic upstream

interpolation for convective kinematics (or "QUICK") method. Although it appears to be somewhat more accurate than either the upwind or centered space approximation under certain circumstances, it still retains grid-scale oscillations in the solution field. This level of improvement does not support effort of implementation. Other methods are under investigation.

Goals for 1997-98:

Project goals for the next year will be substantially unchanged from the previous year. An assistant researcher will be recruited to collaborate in model development.

- 1. Continue development of habitat-based movement models. If feasible, output from oceanographic models to simulate "real time" observations of temperature and oxygen fields. Explore possibilities of including stock structure.**
- 2. Complete analysis of SPC tuna tagging data and apply results to the analysis population exchanges within the WPRFMC area.**
- 3. Continue collaboration with TNFRI scientists on analysis of north Pacific skipjack migration.**
- 4. Continue to improve numerical approximations to the partial differential equations used to model fish movement.**

Remarks on budget

The only significant change in the budget is the addition of an Assistant Research position to collaborate in the development of habitat-based movement models.