

LAGRANGIAN AND MODEL BASED STUDIES OF THE ARABIAN SEA

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LONG TERM GOALS

The aim of this research is to extend basic knowledge of the interactions between the physical circulation of the ocean and marine populations. The goal is to produce a truly interdisciplinary synthesis of the dynamics of marine populations in a variety of physical settings. The efforts involve a combination of field work and modeling with an emphasis on rigorously testing model formulations.

OBJECTIVES

The structure of population boundaries and the biological dynamics that control the edges of major biogeographic regimes are two fundamental questions in biological oceanography with profound consequences to questions ranging from local variations in the marine ecosystem to features in the optical and acoustic properties of the ocean environment. Facing these problems also provides a unique avenue for testing our methods for investigating marine populations both in the field and in models. The role of population models in this context is to first sketch out the problem in terms of concrete, testable hypotheses and then carry through by aiding in the design of field sampling, data analysis and ultimately in a comparison between field results and model predictions. Therefore modeling in close cooperation with field and laboratory work to attack the problem of what processes set the end of a populations extent in space is the immediate goal of this effort. This effort is funded by ONR Biological Oceanography.

APPROACH

Here the models to be used are a set of multiple population formulations set within physical models of varying complexity. The biological formulations developed as part of the ONR URIP on marine population modeling include interactions between competing species in the presence of variable resources and allows for different subpopulations and the explicit treatment of age and condition variations within populations. The latter in particular allows the models to ask questions concerning sampling issues to be faced in the field. Of particular interest to the problem of model development is the problem of specifying the mechanisms behind the population gradients. In the current context the interest is in the shifts in populations as one proceeds spatially from coastal upwelling

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zones into the open Arabian Sea and temporally from upwelling to downwelling in the monsoon cycle.

In order to judge the degree to which the model formulations actually reproduce the real ocean a set of field observations have been made. These consist of cruise data taken as part of the 1995 field program and drifter deployments. The drifter work done in cooperation with G. Hitchcock involves modification of WOCE drifters to carry bio-optical packages. The major focus on the shipboard work is an attempt to model the populations of *Calanoides carinatus* in cooperation with S. Smith.

The model effort involves implementation to two biological models in a WOCE funded a regional simulation of the Arabian Sea with the Miami Community Ocean Model (MICOM). The physical model has a highly resolved surface layer with a mixed layer code. The first biological model is a two food-chain code that includes both a microbial and macro-plankton loop. This is used to simulate the biomass fields. The second model is a age-stage, and metabolically structured copepod model. Due to the complicated nature of the latter model and its strong dependence on the life history of the copepod, it is run in a Lagrangian mode. This model is parameterized using laboratory work with *carinatus* in Germany and South Africa.

WORK COMPLETED

Model simulations with the two food-chain code have been completed. A broad set of sensitivity runs have been done as well as comparisons with different forcing fields. The Lagrangian code has been run in a set of preliminary cases to understand the dispersion of copepods in the surface layer during the SW monsoon and at depth during diapause. Since little is known about the latter process, a set of experiments with different clues to the onset and end of diapause are being set up.

The field data have been processed in cooperation with G. Hitchcock, S. Smith and A. Mariano. Satellite imagery for a multi-year period have been processed and used to validate the physical model. Analysis of the drifter data in the eddy field off Somalia and comparison to model results are currently underway.

Three manuscripts are currently in review. These involve model development aspects including the effects of behavior on the parameterization of models.

RESULTS

The food-chain results are interesting in that they suggest that the monsoons force a fluctuation between an ecosystem dominated by pico-plankton and micro-zooplankton during monsoon lulls and copepods during the monsoons. The copepods are restricted to the eddy field along the Somali coast during the monsoon lulls, but extend well into the interior in filaments and jets during the SW monsoon. The initial Lagrangian simulations suggest that the flows at one kilometer off Somalia and Oman are conducive for

maintaining *carinatus* in these regions during diapause. A significant population is also retained in the surface eddy field during the SW monsoon. The simulations imply, however, that the rate at which these animals encounter high food supplies is extremely variable due to the complex nature of the upwelling and eddies. The model also suggests high exchange of animals between the Somali and Oman coasts. Substantial loss to the interior and equatorial region are also suggested. It is interesting that neither the model simulations nor the observed drifter trajectories suggest transport to the Indian coast where *carinatus* has not been reported even though there is a well developed upwelling system there.

IMPACT

The biological modeling results have lead to five invited lecture trips over the past year and chance to co-conviene a workshop on fisheries oceanography. These included a presentation at the 25th anniversary symposium for the University of Sao Paulo's oceanography department. While the PI has done physical oceanography in the South Atlantic for more than a decade, the talk requested was on biological modeling. The model codes are being placed on a website and used are various places. The group also hosted a European Union funded pre-doctoral student for a month in August. She is working at University of Las Palmas on upwelling ecosystems. The interest from the fisheries community stems from earlier work on the Gulf Stream front and the Lagrangian model with behavior. Both of these were ONR funded as part of BIOSYNOP and the marine population biology URIP at WHOI.

TRANSITIONS

In addition to the use of codes developed as part of this work by various groups, there has been considerable interest in using the Lagrangian models for fisheries and sea-air rescue purposes. A recent review of bluefin tuna stock assessment suggests our model/observational techniques as a method. The U.S. Coast Guard has also billeted an officer to Miami to work with A. Mariano and the PI on sea-air rescue using the model.

RELATED PROJECTS

The physical model that is being used is supported as part of the U.S. WOCE program and NSF. Funding from JPL/NASA is allowing an extensive intercomparison of surface forcing products and their influence on both the physics and the biology. This is part of the NSCAT program. Finally, this effort would not have been possible without the ONR funding for the WHOI URIP effort.

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