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The Climate and Eastern Ocean Systems Project

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Abstract

A brief description of the NMFS/ORSTOM/ICLARM Climate and Eastern Ocean Systems (CEOS) project is given. CEOS will study the four major eastern boundary current regions (Peru/Chile, California, Northwest and Southwest Africa) and attempt to separate local short-term changes of their resources and/or dynamics from long-term, climatic global changes. Expected products range from a large, widely accessible oceanographic/atmospheric database to various documents that will present key results as well as improved contacts and stronger analytical capabilities in cooperating national institutions.

Introduction

The injection of millions of tonnes of greenhouse gases into the earth's atmosphere may be viewed as a gigantic experiment aimed at exploring the earth's reaction to such challenge. Unfortunately, this experiment is run without proper "controls", and hence the heated debates about the actual impact of those gases may last too long, beyond the time where the "experiment" should be called off. The international scientific community is forced, however, to address this problem in spite of the lack of scientific controls.

One way to address this is through the comparative method, a major tool in those disciplines in which experiments are hard to perform, e.g., evolutionary biology (Mayr 1982), and fisheries science (Parrish et al. 1983; Bakun 1985).

Given the importance of the four major upwelling systems off Peru/Chile, California, Northwest and Southwest Africa (Fig. 1) both as sources of fish and as CO_2 "pumps", scientists from the Pacific Fisheries Environmental Group (PFEG), the National Marine Fisheries Service (NMFS), Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM), and the International Center for Living Aquatic Resources Management (ICLARM), and partners from other institutions have teamed up to investigate these systems in the context of global changes, through a project called CEOS (Climate and Eastern Ocean Systems) funded by the National Oceanic and Atmospheric Administration (NOAA) and ORSTOM.

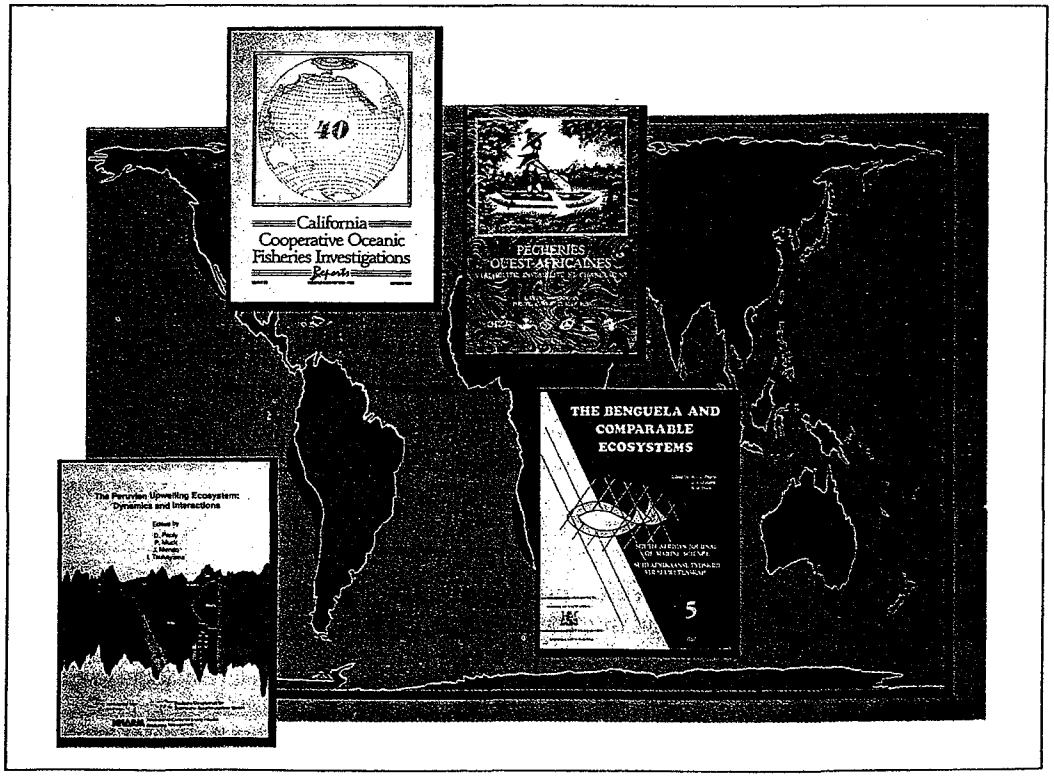

Fig. 1. *Location of the four major upwelling systems to be investigated by CEOS, with photos of some of the major sources of information on these systems.*

Objectives of CEOS

The CEOS project is an international collaborative study of potential effects of global climate change on the living resources of the highly productive eastern ocean upwelling ecosystems and on the ecological and economic issues directly associated with such effects. A major focus of the study are the clupeoid fishes (anchovies, sardines, etc.) that are heavily exploited in these large marine ecosystems and which have recently been exhibiting episodes of collapse, rebound, or switches in dominance.

The major objectives of the CEOS project are thus to: 1) assemble, summarize, and analyze the data record of the past four decades regarding the four eastern ocean boundary upwelling ecosystems mentioned above along with data from other upwelling areas; 2) apply the comparative method to identify key physical processes and ecosystems responses; 3) resolve underlying global-scale trends in each individual regional system that may be obscured by local interyear and interdecadal variability; 4) investigate the relationship of these global trends to accumulating greenhouse effects; 5) construct scenarios for future consequences of global climate change on upwelling resources; and 6) analyze and project ecological and social impacts on associated human activities and values.

Eastern ocean upwelling ecosystems present certain advantages that may make the study of effects of climate change on marine ecosystems particularly tractable; thus the study may serve an even wider purpose as an illustration of the sorts of impact that could affect more complex marine ecosystems.

The most immediate response to greenhouse warming is expected to occur within the atmosphere rather than within the ocean, affecting the wind field over the ocean, and hence, patterns of upwelling. Bakun (1990) presents evidence of this already occurring over the past decades. Thus global climate change could substantially alter the factors that determine favorable reproductive habitat, long before ocean temperature changes brought on by greenhouse warming may be evident.

By analyzing time series data from similarly functioning regional ecosystems distributed over the globe, we hope to tease out the significant global trends from within the "noise level" of naturally occurring regional climatic variability. By these, trends can be mechanistically linked to accumulating greenhouse effects, and would constitute one basis for projection into the future.

A somewhat independent basis for projecting effects of climate change will be sought in the analysis of the large amplitude natural regional variability (i.e., the "noise") overlying the trends. That is, ecosystem responses to shorter-period interyear variations in large-scale atmospheric forcing that may be confined to a single region will also be analyzed. In this approach, greatly increased degrees of freedom for empirical model formulation and verification are obtained from the more numerous realizations of shorter period events in the data record and from the fact that the different regional sets of realizations may be independent from one another.

Some initial scenarios are already available. For example, Bakun (1990) has argued that one consequence of increased greenhouse effects that can be confidently expected is that temperature gradient between the ocean and the continents will increase during the spring-summer upwelling seasons in these systems. This would be reflected in increased alongshore wind and enhanced sea breeze circulation, which would impact recruitment (Mendelssohn and Mendo 1987). Evidence exists for an "optimal environmental window" with respect to wind effects (Fig. 2), such that changes in characteristic wind speed may disrupt finely tuned reproductive strategies of the small pelagic fishes which are essential trophic components of these ecosystems.

Another approach to identifying trends in ecosystem processes will be through the construction of sequences of trophic models of the ecosystems and by computing the values of indices expressing their emergent properties. Emphasis will be given to the theory of Ulanowicz (1986) and to the concepts of maturity, stability, and especially "ascendency", an emergent attribute of ecosystem models that encompasses their size as well as their structure. The ECOPATH II software of Christensen and Pauly (1992), a derivative of the ECOPATH program developed by J.J. Polovina and collaborators at the NMFS Honolulu Laboratory, will be used for construction of several models for each of the investigated systems.

Identification of trends attributable to (global) climate

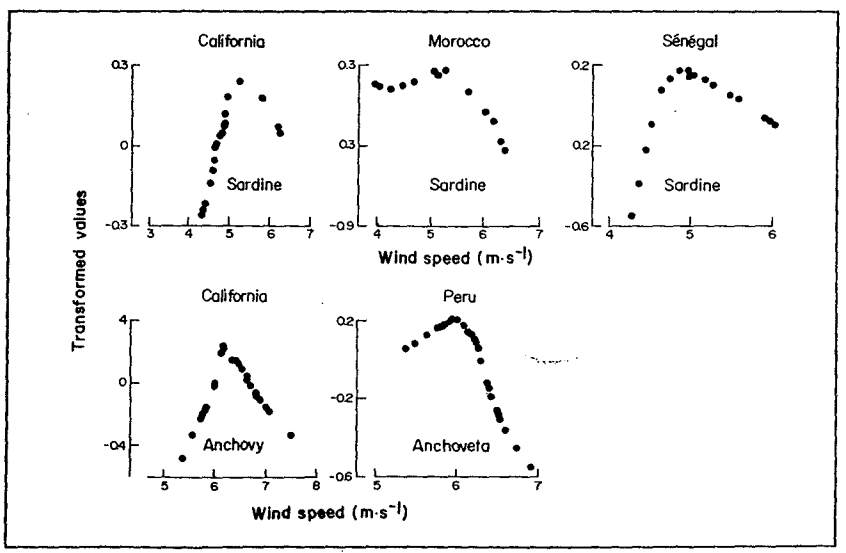

Fig. 2. ***Showing a general pattern extracted by comparative analysis of several upwelling systems: optimal recruitment occurs, in clupeoids, when wind speed is moderate (4-6 m.s⁻¹) and leads to moderate upwelling (adapted from Cury and Roy 1989, 1991, and unpublished data).***

change and of the mechanisms for change (or conversely, for homeostasis) will be attempted via detailed analysis of temporal changes in ascendency and related indices. The analysis will include comparisons among upwelling systems and also comparisons with models of other systems (coral reefs, estuaries, freshwater bodies, etc.) presently being accumulated at ICLARM within the framework of a project on "Global Comparisons of Aquatic Ecosystems" (Christensen and Pauly, in press).

Human activities facing local and global changes are also studied. The exploitation of marine renewable resources in the different upwelling areas appears to be a real challenge due to the fact that these resources are unstable. Comparative analyses of market response to local and global changes will be studied - building up on contributions in Cury and Roy (1991), and Durand et al. (1991) - in Peru, Morocco, and Sénégal. Also, detailed analysis of time series of fish meal exports and prices, i.e., of one of the main products from upwelling systems, will be performed.

This will give some new insights on how human activities are coping with economic and social change at different levels of organization, from which different new approaches on how to use unstable renewable resources may be derived.

Linkages of the CEOS Project

The CEOS project addresses most of the strategic and integrating priorities listed in the U.S. "Global Research Program Priority Framework", especially the "Ecological Systems and Dynamics" category, and addresses in some way most of the issues listed under that category: e.g., "(assembly and analysis of) Long-Term Measurements of Structure/Function", "Response to Climate and Other Stresses", "Interactions Between Physical and Biological Processes", "Models of Interactions, Feedbacks, and Responses", "Productivity/Resource Models", etc.

The project is designed within the general framework of the International Program of Ocean Science in Relation to Living Resources (OSLR), which is cosponsored by the Intergovernmental Oceanographic Commission and the Food and Agriculture Organization of the United Nations (Bakun et al. 1982). It can be considered an initial effort in the newly proposed subprogram of OSLR and Ecosystem Dynamics and Living Resources (EDLR). Elements of CEOS directly related with "recruitment" constitute contributions to the Sardine-Anchovy Recruitment Project (SARP), a major component of the International Recruitment Program (IREP) of OSLR.

Brainstorming Workshop on Simulation Modelling of the Peruvian Upwelling Ecosystem

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Fig. 1. ***Pelicans off the Peruvian coast—their much reduced populations reflect the much reduced populations of anchoveta, their main prey.*** (Photo by A. Jarre-Teichmann)

Faithful readers of *Naga* will note that Fig. 1 is a reproduction of the cover photo of the April 1990 issue, which also included a brief remark on ICLARM's collaborative research with the Instituto del Mar del Peru (IMARPE) at Callao, Peru, on the Peruvian upwelling ecosystem. This cooperation, aimed ultimately at a model for managing the large pelagic fisheries of Peru, resulted to date in the construction, (partial) analysis and publication of a considerable database, including 30 years' worth of oceanographic and biological time series (see contributions in Pauly et al. 1989). Recent progress included the construction of a set of 17 trophic (ECOPATH II) models (Jarre-Teichmann 1992), including models of three periods characterized by different species dominance and fishing patterns systems, "monthly" models capturing seasonal changes and models typifying warm and cold temperature anomalies (El Niño/La Niña).

An informal workshop on "Simulation modelling of the Peruvian upwelling ecosystem" has recently been conducted with ICLARM support, in the context of the CEOS Project (see p. 26). Five scientists of the informal Danish "Copenhagen Modelling Group" (CMG), i.e., the last author, as well as Henning Mejer, Henrik Maler, Søren Nielsen and Jørgen Salomonsen met with AJT and WH at

Several national research laboratories working on similar systems are associated with this project through a cooperative agreement with ORSTOM. This project presently includes: the Institut Scientifique des Pêches Maritimes, Morocco; the Centre de Recherches Océanographiques d'Abidjan, Côte d'Ivoire; the Fisheries Research Utilization Branch, Ghana; and the Centre de Recherches Océanographiques de Dakar-Thiaroye, Sénégal, which will focus on regional case studies of climatic variability, coastal ecosystem dynamic and associated human responses. The collaboration of scientists from these institutes with the CEOS project is funded by the Scientific Committee on Dynamics and Use of Renewable Resources (DURR) of ORSTOM. Other national institutions are linked directly with the project, and/or through their own linkages with ICLARM.

Expected Products and Results of the CEOS Project

The project is expected to produce new insights - but these we cannot plan. We have planned some of the products, however, in which these insights will be presented. These will be:

- a multiauthored book, tentatively titled "Global versus Local Changes in Marine Pelagic Systems", which will contain most of the research results;
- one synopsis for each of the four anchovy species making up the bulk of the biomass in each of the abovementioned ecosystems (*Engraulis ringens*, *E. mordax*, *E. encrasicolus* and *E. capensis*);
- a report presenting ECOPATH II models of the four systems, and the data upon which they are based;
- various scientific papers in the primary literature.

Also, the project will support the entry into FISHBASE, a computerized encyclopedia of fish (Pauly and Froese 1991), of the biological data on the major fish species in each of the abovecited four upwelling systems. Further, the CEOS project will make available, most probably on CD-ROM (laser) disk, the time series of oceanographic

Kollekolle Seminar Center near Copenhagen during 19-20 August, 1992, for a brainstorming session on the conceptualization and construction of a spatially structured simulation model of the system. The participants agreed that the model should be aimed at predicting sustainable anchoveta catch for a few months in the future, given coastal wind, temperature observations and a fishing pattern. The model should consider the biological interactions among the key fish species anchoveta, sardine, mackerel, hake, and bonito, as well as the impact of the fishery on these groups. The model should also consider the pinnipeds and guano birds as additional top predator groups.

After construction of a conceptual diagram of the model inspired by earlier work of Dr. Peter Muck of the GTZ/IMARPE PROCOPA Project (Jarre et al. 1991), the participants agreed to proceed as follows:

(i) Construction of single-species model of Peruvian anchoveta in an artificial environment, disregarding spatial resolution;
(ii) Stepwise inclusion of the other four major fish groups into this model;
(iii) Inclusion of spatial resolution, as required for fisheries management, with alongshore, offshore, and depth components.

The group also listed the required state variables, forcing functions and parameters, as well as the set of nonlinear differential equations that will be used for the construction of the anchoveta model, which is now being parameterized by WH and will be programmed and evaluated in direct cooperation with Jørgen Salomonsen within the next few months.

The model will include a user-friendly output interface based on the GEOMARPE software developed at ICLARM, thus enabling Peruvian scientists and fisheries managers to assess immediately the results of different model runs and, e.g., evaluate the consequence of alternative fishing patterns under given meterological oceanographic conditions.

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The CEOS project, as one of its contributions, will make the Comprehensive Ocean-Atmosphere Data Set (COADS) available for use on MS DOS and Mac II Personal Computers at two different levels of resolution.

Worldwide data on air temperature, sea-surface temperature, surface winds, sea-level pressure and number of observations were extracted for 1946-90 from the Word Weather Disk (CD ROM) and from original COADS files, then implemented into microcomputer files.

A program called CODE2 was then written which can be used at the first level of resolution to retrieve monthly means by 2° squares, pertaining to a single box or a complex staircase of 2° boxes along a coastline. Output from the CODE2 program consists of annual and monthly output files, and a binary file of the selected data. The annual output file shows on a single line the 12 monthly means of a single parameter for a year, by parameter. The monthly output file shows all five parameters for a year, by month. The data are comma delimited in each output file, allowing for easy import into spreadsheet and/or graphics software.

The second level of resolution will create programs for retrieving the raw data (rather than 2° monthly means) from the COADS data set. This involves more than 2.5 gigabytes of data, starting from 1870. Before this reorganization, access to the COADS data set was available only on a mainframe computer and was a slow and tedious process. Contact the CEOS Project, c/o PFEG for details.

and other data upon which trend analyses will be based. This applies particularly to the COADS data set, which will be made available for use on MS DOS (and MacIntosh) personal computers (box).

Timing and Additional Linkages

The PFEG and ORSTOM component of the CEOS project began mid-1991 when Claude Roy and Philippe Cury, both from ORSTOM, began what will be a two-year stay at PFEG, in Monterey, California, USA, while the two-year ICLARM component (D. Pauly and V. Christensen) began in September 1992.

Thus, the project will last until mid-1994 at least, and this offers numerous possibilities for interested colleagues in developing or developed countries to team up with us. If you are interested, please write to the CEOS project at PFEG, P.O. Box 831, Monterey, California, 93942, USA, or fax us at (408) 646-3319.

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ICLARM Contribution No. 900.
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