Changing Oceans and Changing Fisheries: An Introduction to the Workshop

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"...it is my belief that in fishery oceanography the challenge and the opportunity lies in studying the changing sea rather than the equilibrium ocean, and in studying the biological consequences of the changes at various trophic levels. .....In the aggregate this implies the necessity of observation of physical and chemical properties of sea water, its motions and mixings, and the numbers, kinds, and perhaps stages of the biota inhabiting the waters, all with space and time continuity sufficient to describe the events that take place and to investigate their inter-relationships." **O.E. Sette** (1961)

Introduction

Marine fisheries have experienced dramatic growth in the 20th century, expanding into nearly all reaches of the world ocean. As greater demands are placed on living marine resources, the rate of increase in total catch has slowed significantly (FAO 1993; Garcia and Newton 1994). The need for management of marine fish stocks is thus greater than ever. Management, however, is greatly influenced by the behavior and dynamics of the fished stocks, specifically fluctuations in distribution and abundance, which in turn are affected not only by fisheries harvests but also by variations in the environment.

A plethora of meetings have addressed questions of environmental variability and fisheries, specifically examining the role of the environment in fish stock fluctuations. FAO Expert Consultations (Bakun et al. 1982; Sharp and Csirke 1983), specialized meetings on operational fisheries oceanography, regional meetings (e.g., Wooster 1983), and a variety of ICES meetings and symposia have all focused on this topic. This dialog exists in part due to the historical approach in fisheries science, in which research and management have concentrated specifically on how fishing alone impacts the stocks, without dealing with the underlying environmental variability (Sharp et al. 1983; Bakun 1996).

Impacts of ocean variability on fish distribution have been known to fishermen for centuries. Only recently has science uncovered the relationships, and we can now categorize them on spatial and temporal scales (Smith 1978). Short term movements may be keyed to small scale fluctuations in the environment (Mendelssohn and Cury 1987; Rose and Leggett 1988). Seasonal patterns of availability are often tied to migrations. Migrations are in turn dependent upon the physiological requirement for specific environmental conditions at different life history stages, invoking adaptive behaviors such as movement between spawning and feeding grounds (McCleave et al. 1984; Lynn 1984). On interannual time scales, fishing success may often be attributed to differential movement patterns of fish in response to environmental conditions (Sette 1960), simple habitat submergence or emergence (Sharp 1978) or even basin-scale food availability (Polovina 1996). At longer time scales, we must be concerned with not only climate changes (Beamish 1995; Everett et al. 1995) but also with decadal scale changes in the ocean which impact production throughout the ecosystem (Aebischer et al. 1990; Ebbesmeyer et al. 1991; Polovina et al. 1994).

Assessing how ocean variability affects the abundance of fish is somewhat more difficult. The importance of variability in the ocean environment was made clear after the realization that fish produced in a given year could make variable contributions to the fishery. Johann Hjort (1914, 1926) was first to develop hypotheses to explain variability in year class strength that incorporated the concept of ocean variability. Hjort's *Critical Period hypothesis* invoked two types of environmental variability; first, unusual patterns of advection could direct the young fish to regions inappropriate for further development and survival. Second, variability in the availability of food when the yolk sac was absorbed, presumably itself a function of a variable ocean, could result in varying larval mortality. The critical period hypothesis has been variously expanded and modernized as the "match-mismatch" hypothesis (Cushing 1975), the "stable ocean hypothesis" (Lasker 1975) or the "member-vagrant" hypothesis (Sinclair 1987). A common thread in these conceptual ideas remains the importance of variability in the physical environment.

Since the end of World War II, major integrated fisheries oceanography programs have been developed to address these issues on various scales. The efforts have included the 1949 to present California Cooperative Oceanic Fisheries Investigations (CalCOFI), the 1984 to present Fisheries Oceanography Coordinated Investigations (FOCI -- Schumacher, this volume), the 1989-1997 South Atlantic Bight Recruitment Experiment (SABRE), and more recently Georges Bank GLOBEC, to name just a few regional programs in the US. Such studies provide the complex data useful for ecosystem models (see Pauly and Christensen 1996).

Large programs in fisheries oceanography as well as smaller scientific investigations have advanced the potential to incorporate environmental data into the field of fisheries, but we are a long way from achieving a systematic application of environmental information to fisheries research and management (Sharp 1995). Although the CalCOFI program was organized around learning the causes of the demise of the California sardine population, most early efforts in fisheries oceanography were tied to *fisheries development* as opposed to management. The Pacific Oceanic Fisheries Investigation (POFI) provides a good example. Although POFI conducted a great deal of the basic oceanographic research in the central and South Pacific in the 1950s, the fundamental goals were for "...exploration, investigation, and development of high seas fisheries of the Territories and island possessions of the United States" (Sette 1949). Environmental determinants of fish abundance and movements can be used to predict successful fishing grounds, something of obvious importance to the fishing industry. As Japan expanded its fisheries to the far seas after World War II, it developed remarkable expertise in fisheries oceanography (see Uda 1961) and a strong partnership between government fisheries research and the fishing industry developed. This remains a strong, important economic alliance today.

As marine fisheries production is reaching its upper limits (Pauly and Christensen 1995), fisheries management for conservation and sustainability becomes of critical importance (Rosenberg et al. 1993; Pitcher 1996). Because environmental variability contributes a great deal to uncertainty in fisheries management advice (Rosenberg and Restrepo 1994), there is a compelling need to incorporate increasingly complex environmental data into fishery research and management (Beamish et al. 1989). There has been no shortage of calls for improving this effort. In addition to the meetings and volumes mentioned above, expert panels of the National Research Council have repeatedly identified the need for improving our understanding of the role of environmental variability in resource fluctuations for fisheries ecology in general (NRC 1980), for managing fisheries (NRC 1994b), for bluefin tuna (NRC 1994a), for salmon (NRC 1996b), and for the Bering Sea Ecosystem (NRC 1996a). It is thus timely to assess where we stand in the application of environmental information in marine fisheries research and management and to plan and implement strategies for improvement.

There is not a shortage of environmental information, only the ability and resolve to apply it. A great deal has changed since Sette (1961) stated

> "...there are only a few things we can measure. ...In oceanography we can only measure the temperature and salinity when we want to know which way the water is running, and how fast. ...For the most part we have to deduce what we want to know from something else that we can measure."

Platforms, both moored and drifting, remotely sensed information from aircraft and satellites, and output from meteorological and oceanographic numerical models have all contributed to a data explosion, and the means of accessing, processing, and visualizing these data are continually improving. Given some of the needs, as expressed above, this workshop was developed with the following objectives:

1. to assess the current and future needs for environmental data bases (oceanographic, atmospheric, remote sensing, geological) in fisheries and fisheries-related ecosystem research;
2. to identify data sources and formats; and
3. to recommend ways to facilitate access to the data.

It was obvious that scientists from a variety of disciplines would be necessary to address these objectives, and accordingly, the workshop participants (see Appendix 4) were chosen with expertise in fisheries research and management, oceanography (physical, biological, geological), remote sensing, numerical modeling, computer science, and data management. We sought to bring together the data "supply side" (computer scientists, data managers, physical scientists and modelers) with the "consumer side" (fisheries scientists and fisheries oceanographers). While the latter are often terminal users of the data, they are not always knowledgeable about, or skilled in using, available data and data distribution systems. Further, data accessibility is changing rapidly, as are the sheer quantities of environmental data currently available. NOAA and other agencies are working to make data accessible on the world wide web (see, for example, papers in this volume by Daddio & Brazille, Stein, and Holt & Digby).

In bringing varied expertise together, it must be realized that the disciplinary *cultures* differ in ways that often make communication difficult (Wooster 1986). In the introduction to a book dealing comprehensively with environmental variability and fisheries, Andy Bakun (1996) put this in a different way:

> **Won't somebody please talk to me!** I am a physical oceanographer who works on biological and fisheries problems. As such, I find myself straddling a gap between two distinctly separate disciplines, physical oceanography and fisheries biology, each growing out of different traditions and points of view. The communication problems go far beyond mere differences in terminology and jargon, involving completely different conceptual frameworks with which information is received and organized. What is "signal" to one group often seems to be "noise" to the other.

The measure of success for fishery biologists may be the accuracy of a stock assessment, for the numerical modeler it may be the accuracy of the model in simulating the behavior of the atmosphere or ocean, and for the database manager it may be the volume of data available. Therefore, a major goal of the workshop was to improve the communication among scientists dealing with data, with oceanography, and with fisheries, potentially developing partnerships to facilitate incorporation of environmental data into fisheries research and management. There is a need to improve the utility of products from one discipline to applications in another, and it is the responsibility of the recipient discipline to clearly specify the basis of its needs.

Participants for this workshop were brought together on 16-18 July, 1996 at the Pacific Fisheries Environmental Laboratory in Pacific Grove, California, to address the following questions:

- What are the current environmental data needs for research in fisheries and fisheries oceanography?
- What are the shortcomings of existing data and what are likely future data needs for research in fisheries and fisheries oceanography?
- What data sources are available, in what form, and how are they accessed?
- What are new advances in environmental data, including oceanographic model output and remote sensing products, that could be beneficially applied to fisheries?
- What environmental data products, tailored specifically for biological applications, may be appropriate and require further development?
- How have other agencies successfully applied environmental data sets to research problems?

The dwindling potential economic benefits of fisheries have made stewardship of marine resources a priority element of the NOAA Strategic Plan ("Build Sustainable Fisheries", "Sustain Healthy Coasts", and "Recover Protected Species" -- NOAA 1996). Fisheries resource management agencies no longer house all the expertise required to address the full range of questions that use of environmental data in fisheries research and management problems entail. Thus an attractive prospect for support from Congress and funding agencies is the implementation of partnerships in oceanography, broadly defined to include interagency cooperation as well as with academia and private industry. This may become the hallmark of scientific advances as well as growth in programmatic funding (NRC 1992). Efforts to this end have culminated in a new law (Title II, Subtitle E, Public Law 104-201), the National Oceanographic Partnership Program, which provides funding incentives to leverage the resources and expertise of government agencies, academia, and industry to address multidisciplinary problems. Understanding how environmental variability influences fisheries is clearly a subject area that could benefit from such support.

Organization of the workshop report

A common basis for the diverse expertise at the meeting was provided by a series of introductory papers, which also set the stage for the working groups. Five papers describe how environmental data are used in fisheries and give a perspective on what future needs might exist; eight others describe environmental data sources of different agencies and how they can be accessed. After a series of demonstrations of environmental data systems and ocean models (descriptive abstracts are included as Appendix 1), the remainder of the workshop was spent in the five working groups. Working groups were charged with specific questions and generated reports with recommendations, which were placed in priority order through voting by participants. Also included are abstracts of posters presented at the meeting (Appendix 2), contributed abstracts (pertinent studies on applications of environmental data to fisheries and data systems that were not presented at the meeting -- Appendix 3).

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CHANGING OCEANS AND CHANGING FISHERIES: ENVIRONMENTAL DATA FOR FISHERIES RESEARCH AND MANAGEMENT A WORKSHOP

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